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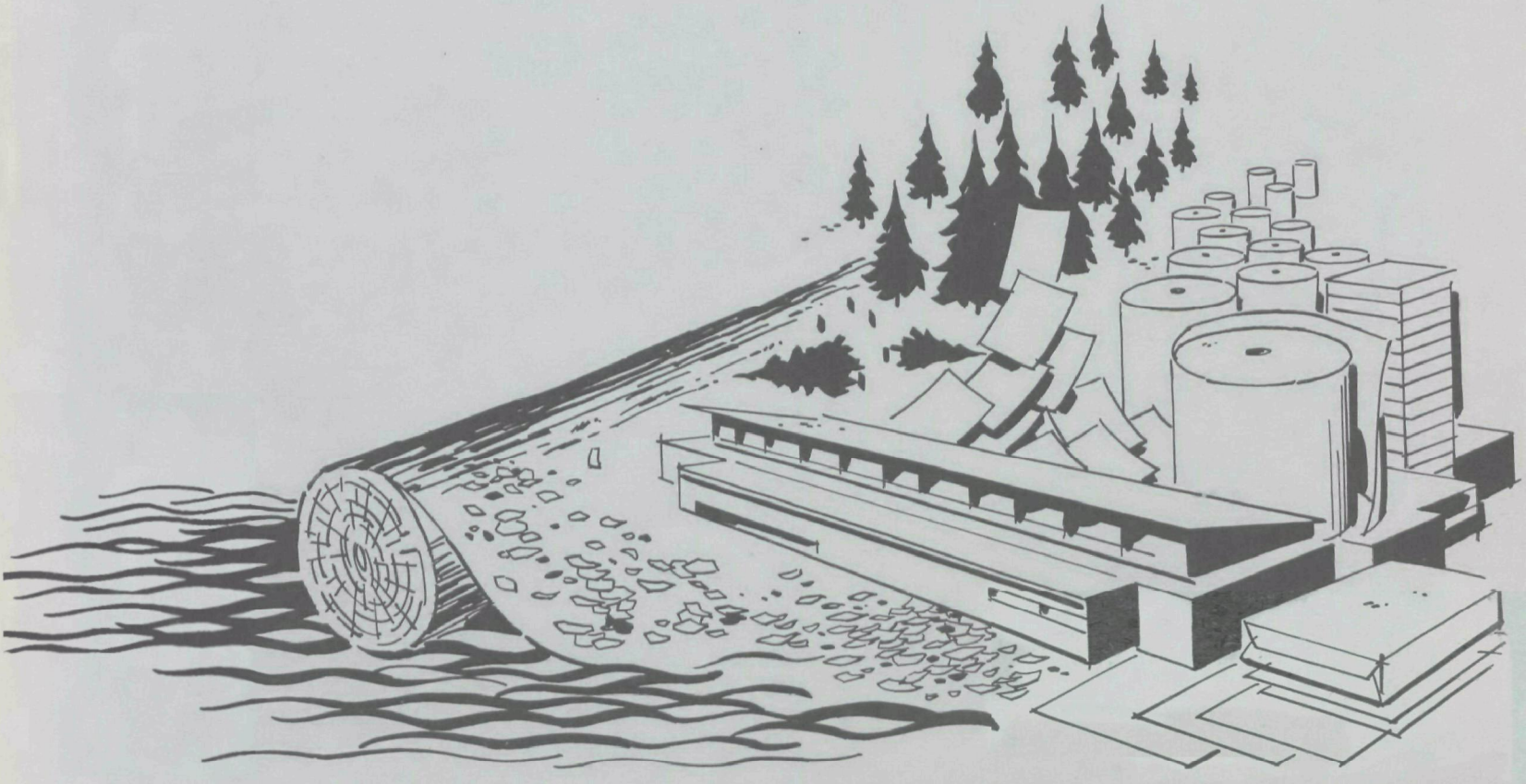
Aerated Lagoon Treatment of Sulfite Pulping Effluents



U. S. ENVIRONMENTAL PROTECTION AGENCY

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AERATED LAGOON TREATMENT OF SULFITE PULPING EFFLUENTS

By

Crown Zellerbach Corporation

Lebanon Division

Lebanon, Oregon

for the

Environmental Protection Agency

Program Number 12040 ELW

Project Number WPRD 69-01-68

December, 1970

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 - Price $1.25

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ABSTRACT

Secondary treatment of sulfite pulp and paper mill effluents in aerated stabilization basins was tested on a full-scale basis over a 17 month period of continuous operation. The secondary treatment plant consisted of two aeration basins. One basin was equipped with two 75-h.p. surface aerators and the other basin of equal volume was equipped with six 25-h.p. aeration units. Piping was designed to permit series and parallel operation of the two basins and provisions were made to recycle treated waste. The waste treated was a mixture of weak wash water from the pulp mill, evaporator condensate from the spent liquor recovery system and paper machine white water.

Experimentation conducted over the 17 month period showed that series operation was more efficient than parallel operation and that the 75-h.p. surface aerators were much more efficient mixing and aeration devices than equivalent capacity of 25-h.p. units. An 80% BOD reduction in the combined secondary system could be achieved at a BOD load of 3.53 lbs./1,000 cu. ft. of aeration capacity or 2.2 lbs./h.p.-hr. This was equivalent to a daily BOD load of 16,000 lbs. Biological treatment of the mill waste to a BOD reduction of 80 to 85% produced a waste which did not readily support slime growth when added to simulated experimental streams. Although slime growth was closely related to the amount of BOD added to the simulated streams, two to three times as

much slime was produced from untreated waste than for equivalent BOD additions of treated waste.

Total operating cost including interest on investment and depreciation was $169,500 per year or $4.79/ton of production. Total operating cost per pound of BOD destroyed was 3.48 cents.

This report was submitted in fulfillment of Grant Number WPRD 69-01-68, Program Number 12040 ELW under the sponsorship of the Federal Water Quality Administration.

KEY WORDS : Aeration basin, BOD removal, Pulping wastes, Sulfite wastes, Slime growth, Sphaerotilus natans, Surface aerators, Treatment costs.

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SUMMARY AND CONCLUSIONS

Secondary treatment of sulfite pulp and paper mill effluent in aerated stabilization basins was tested on a full-scale basis over a 17 month period of continuous operation. The secondary treatment plant consisted of two aeration basins each having a surface area of 5.42 acres or a liquid volume of 17 million gals. At a total waste flow of 4 mgd from the mill, the combined secondary system provided a detention of about eight days. The ponds were constructed to permit series or parallel operation and provisions were made to recycle treated waste. One basin was equipped with two 75-h.p. surface aerators and the other basin of equal volume was equipped with six 25-h.p. aeration units. One of the 75-h.p. aerators was a direct drive, high speed unit whereas the other was a low speed gear driven unit. The 25-h.p. surface aerators were direct drive, high speed units.

The treatment works were designed and constructed to achieve economy, efficiency and effectiveness in the prevention or abatement of pollution. Furthermore, the design of the process piping, equipment arrangement and structures in the facility provided for a maximum flexibility of operation and convenience in operation and maintenance. The waste treated was a mixture of weak wash water from the pulp mill, evaporator condensate from the spent liquor recovery system and paper machine white water.

The results from 17 months of experimentation warrant the following conclusions:

1. Series operation was considerably more efficient in BOD destruction than parallel operation. At a BOD load of 22,000 lbs./day or 4.85 lbs./1,000 cu. ft. of aeration capacity, parallel operation resulted in the destruction of 14,300 lbs. of BOD/day (3.15 lbs./1,000 cu. ft.) compared to 16,200 lbs./day (3.57 lbs./1,000 cu. ft.) for series operation.
2. To achieve an 80% BOD reduction in the secondary system, the pond with the six 25-h.p. surface aerators was loaded at 1.9 lbs. of BOD/h.p.-hr. or 6,600 lbs./day (2.91 lbs./1,000 cu. ft.) and the pond with the two 75-h.p. surface aerators received a load of 2.8 lbs./h.p.-hr. or 9,740 lbs./day (4.29 lbs./1,000 cu. ft.). The BOD load to the combined system should not exceed 16,000 lbs./day (3.53 lbs./1,000 cu. ft.) or 2.2 lbs./h.p.-hr. to maintain the desired 80% BOD reduction in the secondary system. An 80% reduction at a load of 20,000 lbs./day or 4.41 lbs./1,000 cu. ft. could be achieved by increasing the total aeration capacity from 300 h.p. to 375 h.p.
3. The 75-h.p. surface aerators were much more efficient mixing and aeration devices than equivalent capacity of 25-h.p. units. Nine 25-h.p. surface aerators would be required to achieve the

same BOD reduction as the two 75-h.p. units. Good mixing characteristics for the 75-h.p. surface aerators were obtained at a spacing of about 2.1 ft./h.p. The installed cost of the 75-h.p. Welles surface aerator was $285/h.p. compared to $375/h.p. for the 25-h.p. Welles units. On the basis of equivalent BOD reductions, the installed aeration capacity of 75-h.p. Welles units would have a total cost of $85,500 compared to $140,500 for the 25-h.p. Welles units.

4. No conclusive data were collected which demonstrated any difference in mixing characteristics and aeration capacity between the direct drive, high speed, Welles aerator and the low speed, gear driven Mixco unit.
5. D.O., temperature and BOD profiles conducted in the two ponds showed the pond with the two 75-h.p. surface aerators was completely mixed, i.e., BOD concentration and temperature gradients were not noted from waste inlet to outlet. There was a definite BOD concentration gradient from inlet to outlet of the pond with the six 25-h.p. surface aerators. The velocity profiles also confirmed that the large surface aerators were much more effective mixing devices than the small units.
6. Operational labor requirements for the secondary system were very low because of the ease of operation. Wide variation in

the incoming waste strength had only minimal effects upon treatment efficiency.

7. Although slime growth was closely related to the amount of BOD added to the simulated experimental streams, two to three times as much slime was produced from untreated waste than for equivalent BOD additions of treated waste. Biological treatment of the combined mill waste to a BOD reduction of 80% resulted in slime growth reductions in excess of 80% as measured in the simulated streams.
8. Optimum pH ranged from 6.5 to 7.5. Ammonia usage for neutralization varied from 198 lbs./day to 2,500 lbs./day and phosphorous addition rates of less than 40 lbs./day were sufficient to maintain optimum efficiency. Sodium hydroxide and ammonium hydroxide were interchangeable as neutralization chemicals but sodium hydroxide was considerably costlier.
9. Retention periods in excess of 7 days did not show a significant improvement in operating efficiency.
10. Aeration temperatures within the range of 16° C. to 26° C. (61° to 79° F.) did not have a significant effect upon BOD reduction.
11. The average heat loss from the secondary system during the summer period was 534,000 BTU/day when the incoming waste

temperature averaged 33° C. (91° F.). During the winter season, the heat losses averaged 793,000,000 BTU/day. During the winter, a drop in pond temperature of 11.7° C. (21° F.) can be expected and during the summer the temperature drop will average 8.3° C. (15° F.).

12. Recirculation of treated waste resulted in a drop of efficiency which was attributed to an overall reduction in waste retention.

13. The effluent discharged from the treatment plant contained about 62 ppm of suspended solids and had an average turbidity of 214 JTU. The turbidity consisted of dispersed bacteria which were not removed by sedimentation. Suspended biological solids buildup was calculated at 0.16 lbs./lb. of BOD destroyed.

14. The final treated effluent contained about 155 ppm of total Kjeldahl-nitrogen and 0.6 ppm of soluble phosphorous. Elimination of ammonia for neutralization reduced the Kjeldahl-nitrogen concentration in the treated effluent to about 98 ppm.

15. The capital cost of the Lebanon secondary treatment plant was $665,000. Total annual operating costs including interest on investment and depreciation was $169,500 or $4.79/ton of production. Total operating cost per pound of BOD destroyed was 3.48 cents or $111.20 per million gallons of waste treated.

INTRODUCTION

The Crown Zellerbach pulp and paper mill at Lebanon, Oregon has been in operation since 1890. Straw was first used as a raw material and major changes were made in the basic pulping equipment in 1906 when the mill was converted to the use of hemlock logs. Changes and modifications have been made since and the plant now has a rated capacity of 100 tons/day of unbleached sulfite pulp which is converted on two paper machines.

Late in 1949 the mill was converted to ammonia base pulping and a pilot plant recovery unit was installed to study the possibility of evaporating and burning the digester strength cooking liquor. The recovery phase of the operation is described in detail by Palmrose and Hull (1). Based upon the successful pilot plant work, a full scale by-product recovery unit was placed on stream in 1952. A detailed description of the by-product operation has been presented by Amberg (2).

The Lebanon mill is located on the South Santiam River which supports a sizeable anadromous fish run. Upstream impoundments now provide for a minimum drought flow of about 500 to 600 cfs. The discharge of untreated waste to the South Santiam River created two problems, both of which could have adverse effects upon the fishery resource. Heavy bacterial slime infestations generally extended to about six miles below the introduction of the untreated waste and a significant depression in

the dissolved oxygen concentration of the stream occurred during the summer drought period.

The effects of waste effluents upon the aquatic environment and particularly on the microbiological population of streams have been studied by many investigators. Cawley (3) has called attention to the biological imbalance in a stream receiving the effluents from a pulp mill producing dissolving grade pulp by the kraft process. Lincoln and Foster (4) have reported in detail the problem of slime infestations below the outfalls of sulphite pulp mills on the lower Columbia River. The factors affecting slime growth and an evaluation of several control methods were discussed by Amberg and Cormack (5).

Amberg and Cormack (5) found that one of the most effective processes for controlling slime growths from ammonia base spent sulfite liquor was an aerobic bacterial treatment employing a mixed culture of bacteria capable of reducing 80% to 95% of the applied BOD load. These experiments were in agreement with experimentation reported by Wuhrmann (6). Because of the small size of the Lebanon mill and the marginal economics of the operation, a treatment system to be successful must meet the following basic requirements: (1) ease of operation, (2) high BOD reduction, (3) low capital investment, and (4) low operating and maintenance costs. These requirements could be expected to apply equally to many small sulfite mills throughout the country which face

similar problems. The ultimate treatment plant design selected for the Lebanon mill met all of these requirements and since sufficient land was available on the mill property, the construction of the aerated stabilization basins presented no serious problems. A comparison of capital and operating costs for several types of treatment has been presented by Amberg (7) which shows the economic benefits of aerated stabilization basin treatment over the activated sludge process.

Aerated stabilization basins are quite widely used throughout the pulp and paper industry in the United States and Canada. Early laboratory studies (8) showed that paper machine white water could readily be treated by aeration in the presence of dispersed bacterial growths and that relatively high BOD reductions could be achieved in 5 to 6 days. Gellman (9) has discussed the application of this method for the treatment of pulp and paper mill effluents.

Although laboratory and field investigations have demonstrated the potential of secondary treatment by the aerated stabilization basin process, a number of factors which could have a decided effect upon operational performance and economics have not been thoroughly studied and evaluated by means of a full scale field study. Some of these factors such as series versus parallel operation, waste recycle, aerator configuration, aerator size, nutrient levels, etc. have not been studied in detail because of lack of adequate funds to conduct a study of this nature.

With the anticipated demands on the nation's water resources, it is essential that treatment works be designed and constructed to achieve economy, efficiency and effectiveness in the prevention and abatement of pollution. The aerated basin design for the Lebanon mill was selected to be economically attractive to small pulp and paper mills or other industrial operations which operate at rather small margins of profit.

An application was made to the Federal Water Quality Administration for funding of a research and demonstration facility which would meet all of the foregoing requirements. The results of this work and conclusions evolved from these results are the subject of this final report for the project.

GRANT PROGRAM PLAN

The experimental program described in this report may be divided into two phases. The first and major phase of the project was a large scale evaluation of aeration lagoon treatment of unbleached sulfite pulp and paper mill effluents and the second phase involved a study of the effects of varying levels of organic enrichment when added to simulated streams. The specific program objectives were as follows:

1. Evaluation of the factors affecting aeration lagoon efficiency to pinpoint those factors influencing treatment efficiency and to optimize treatment.
2. Optimization of treatment plant operation to achieve maximum improvement in stream conditions at the lowest possible cost.
3. Develop operating cost data for aeration basin treatment which will be useful to the industry.
4. Determine the degree of treatment necessary to eliminate slime growths in the receiving stream.
5. Compare the effectiveness of different size surface aerators as mixing and aeration devices in aerated stabilization basins.

PROCESS DESCRIPTION AND WASTE TREATMENT FACILITIES

The pulp mill at Lebanon, Oregon shown in Figure 1 is an ammonia-base sulfite mill using batch digesters and blow pit pulp washing. Liquor from the washing operation is separated by temperature sensing into three fractions, "Strong" liquor, "Weak" liquor and "Dilute" spent liquor.

From collecting tanks the strong liquor is processed by evaporation and spray drying to produce commercial lignin sulfonate products. When product sales are not adequate, the strong liquor is disposed of by burning in a steam generating furnace. Weak liquor is recycled to the pulp mill where it is used for cooking liquor dilution and blow pit padding. The weak spent liquor from the collecting system enters the waste treatment process just prior to the effluent collecting sump S-2 shown in Figure 2.

Excess white water from the paper machines, general non-chemical mill effluent and fresh water are combined in evaporator sump S-1. Water from here is used in the evaporator system for direct condensation of the vapors produced by strong liquor concentration. These combined effluents overflow the hotwell and into collecting sump S-2.

Total mill effluent is pumped over side-hill screens and into a primary treatment pond. Fiber recovered on the screens is returned to

the paper mill. Suspended solids settle to the bottom of the primary pond and areperiodically removed for disposal by land fill. Clarified effluent flows into waste sump WS-1 for pumping to secondary treatment at an average rate of four million gallons per day.

Chemicals such as ammonia, caustic soda and phosphoric acid are added for pH regulation and biological nutrition. The effluent is next distributed to one or both of two stabilization lagoons. Pond No. I contains six 25-h.p. surface aerators. These are direct drive Welles units with two-bladed 13-3/4-inch diameter propellers turning at 1,200 rpm. Two 75-h.p. aerators are installed in Pond No. II. One is a gear driven Mixco unit with a four-bladed turbine impeller, 116 inches in diameter operating at 37 rpm. The other is a direct drive Welles aerator with a three blade propeller, 23-3/4 inches in diameter running at 900 rpm.

Up to 8-1/2 days retention of the effluent is provided by either parallel or series operation of the ponds. These are diked basins constructed by cut-and-fill excavation, lined with a four-inch layer of sand and sealed with 14-mil black polyvinyl chloride film. Dimensional details are presented in Table 1.

Each pond overflows into separate sumps (WS-4 and 5) from where the effluent can be recycled or discharged into a slough leading to the South Santiam River.

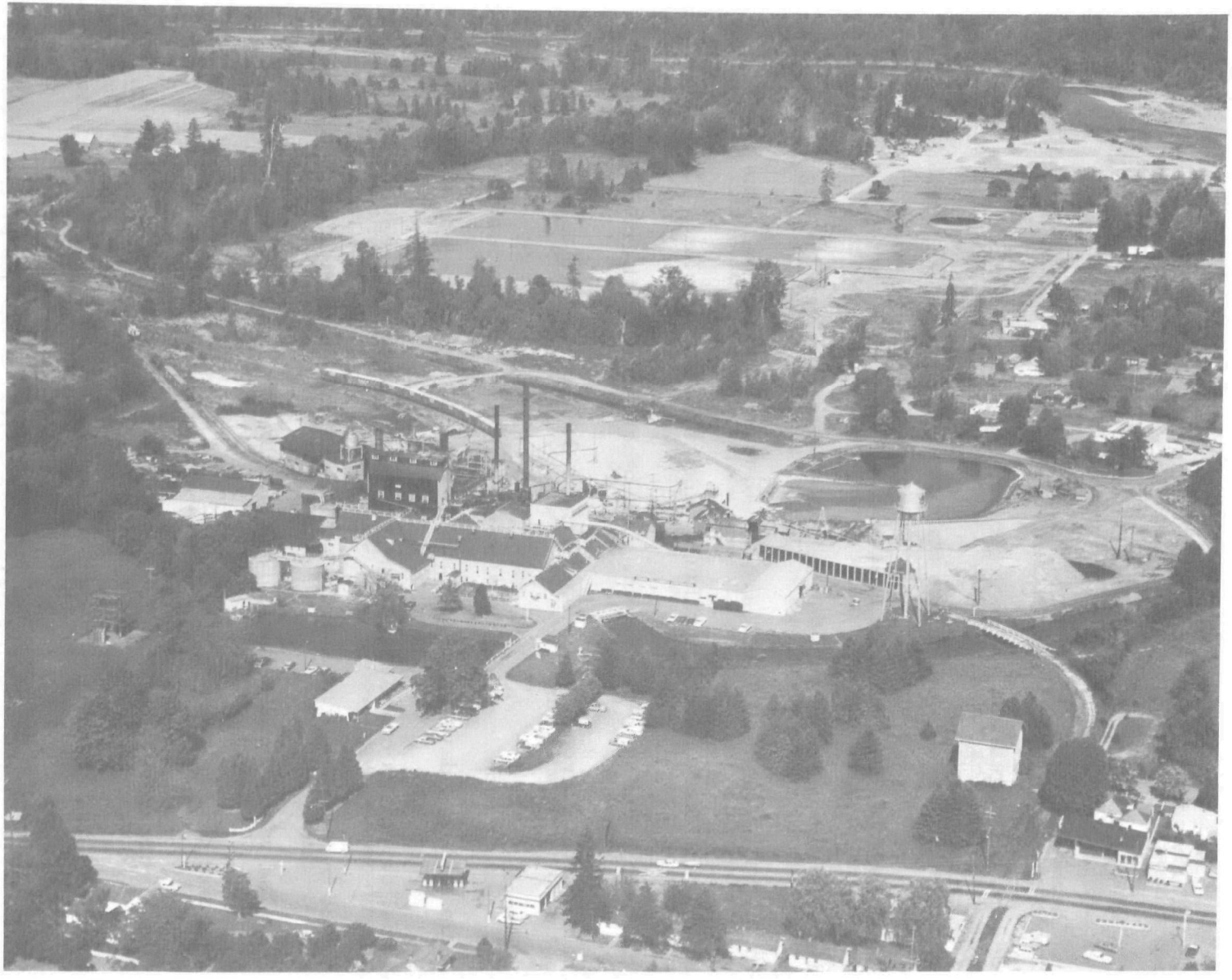
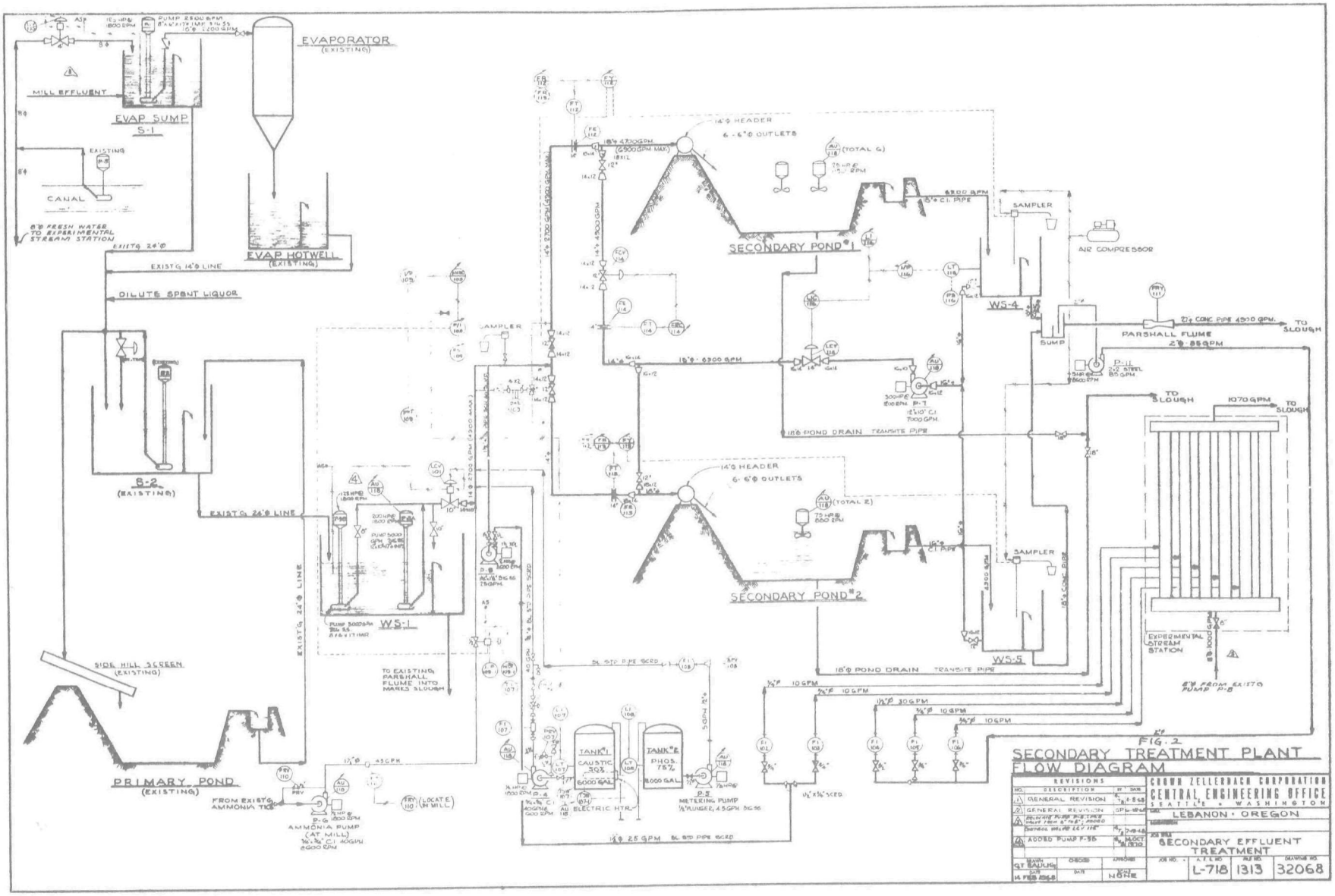


Figure 1. An Aerial Photograph of Lebanon Division of Crown Zellerbach Corporation Showing Aeration Basins in Background


EVAPORATOR
(EXISTING)
EVAP SUMP
S-1
MILL EFFLUENT
CANAL
EVAP HOTWELL
(EXISTING)
DILUTE SPENT LIQUOR
B-2
(EXISTING)
EXIST'G 24'Ø LINE
EXIST'G 14'Ø LINE
SECONDARY POND #1
SECONDARY POND #2
14'Ø HEADER
6 - 6'Ø OUTLETS
SAMPLER
AIR COMPRESSOR
WS-4
WS-5
WS-1
SUMP
PARSHALL FLUME
2'Ø 85 GPM
2'Ø CONC PIPE 4500 GPM.
TO SLOUGH
1070 GPM
18'Ø POND DRAIN TRANSITE PIPE
SIDE HILL SCREEN
(EXISTING)
PRIMARY POND
(EXISTING)
TO EXISTING PARSHALL FLUME INTO MARES SLOUGH
EXPERIMENTAL STREAM STATION
8'Ø FRESH WATER TO EXPERIMENTAL STREAM STATION
8'Ø FROM EXIST'G PUMP P-8
TANK #1
CAUSTIC 30%
6000 GAL
TANK #2
PHOS. 75%
1000 GAL
AMMONIA PUMP (AT MILL)
FROM EXIST'G AMMONIA TK.
ELECTRIC HTR.
METERING PUMP
SECONDARY TREATMENT PLANT
FLOW DIAGRAM
FIG. 2
CROWN ZELLERBACH CORPORATION
CENTRAL ENGINEERING OFFICE
SEATTLE • WASHINGTON
LEBANON • OREGON
SECONDARY EFFLUENT TREATMENT
L-718
1313
32068

An experimental streams station is included containing six flumes for simulating the effects of mill discharge into the river. Pumps and flow metering are provided for two concentration levels of non-treated and three levels of treated effluent in fresh stream water.

TABLE 1

AERATION POND DIMENSIONAL DETAILS

	Pond No. I	Pond No. II
Wall Slope, Horiz. /Vert.	3/1	3/1
Width @ Bottom, ft.	218	279
Width @ Top, ft.	296	357
Length @ Bottom, ft.	785	625
Length @ Top, ft.	863	703
Overall Depth, ft.	13	13
Operating Liquid Depth, ft.	9.9	9.9
Area @ Liquid Surface, sq. ft.	236,000	236,000
Liquid Vol., Million gal.	17.0	17.0
Area of Pond Liner sq. ft.	260,000	260,000

A variety of construction materials are used throughout the treatment plant. Piping to the primary pond and to WS-1 is fabricated from 304 stainless steel. Fiberglass reinforced polyester pipe is used to distribute and recycle effluent to the secondary lagoons. Both cast iron

and concrete pipe are used to handle treated effluent. The Welles aerators have 304 stainless steel propellers with 17-4PH stainless steel shafts and are supported by fiberglass reinforced plastic floats housing polyurethane foam. The Mixco aerator has a 304 stainless steel shaft and impeller. The floats on this unit consist of polystyrene foam shrouded by galvanized steel. The latter is showing substantial signs of corrosion after almost two years of operation. Stainless steel cable is used to moor the aerators to anchor posts on the shoreline.

An aerial photograph of the aeration basins is shown in Figure 3 and a simplified flow diagram of the system is presented in Figure 4. The secondary system was designed to permit either parallel or series operation. Recycle of treated waste from the outlet of either pond to the inlet is also possible.

Figure 3. Aerial Photograph of Secondary Treatment Plant at Lebanon Division.

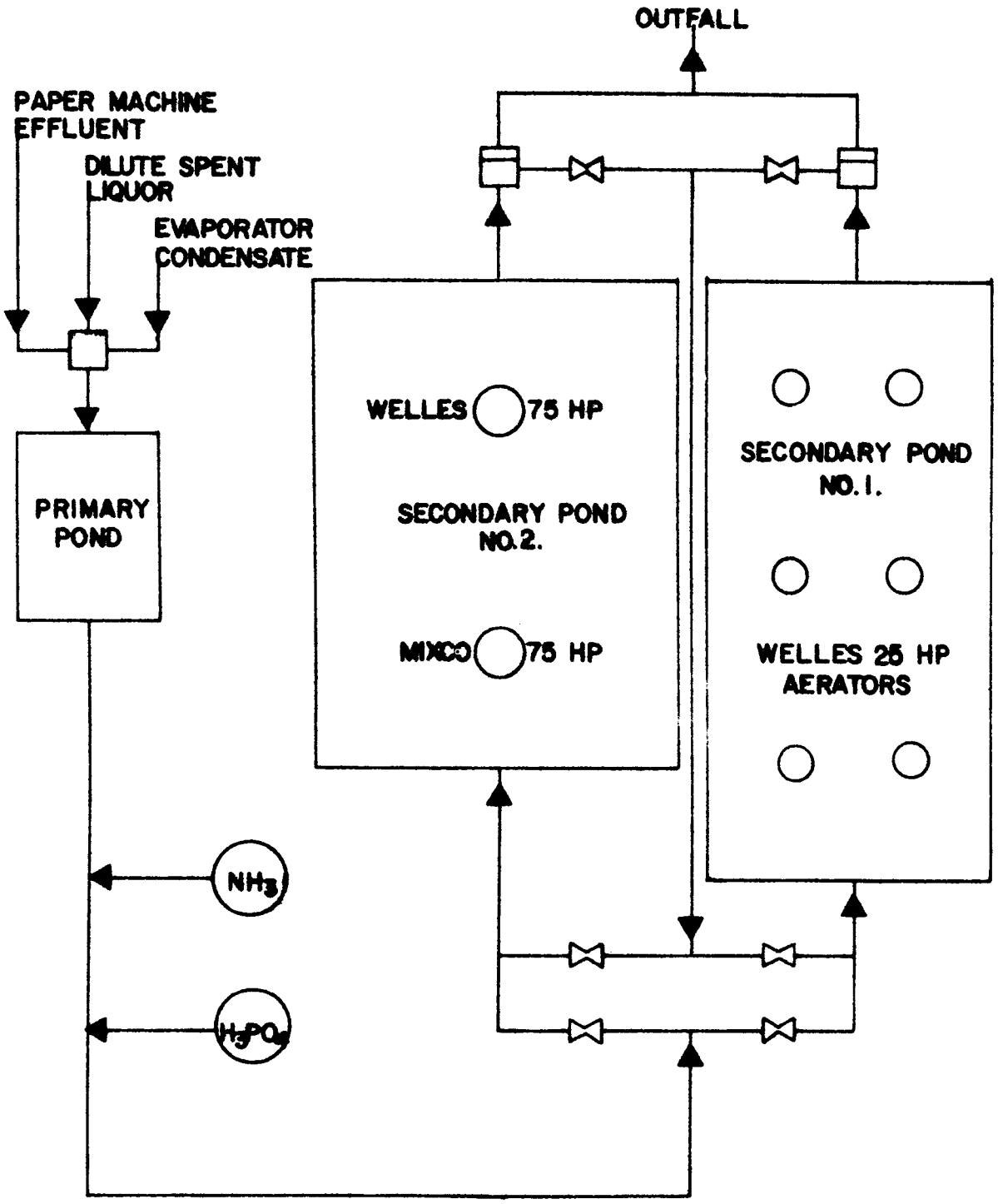


FIGURE 4.—FLOW DIAGRAM OF THE LEBANON MILL TREATMENT PLANT.

METHODS AND PROCEDURES

Sampling

Daily 24-hour composite samples were taken from the influent to the aeration basins, the effluents from Pond I and Pond II and the combined effluent. The daily 24-hour composites were split and shipped by mill personnel to the Pacific Northwest Water Laboratory of the FWQA at Corvallis, Oregon and to the Central Research Division of Crown Zellerbach Corporation at Camas, Washington. The Pacific Northwest Water Laboratory conducted the following tests: BOD, total suspended solids, volatile suspended solids, chemical oxygen demand and total organic carbon. Since there was an unavoidable delay between collection of samples and analyses, the following procedure was used by the FWQA laboratory for sample preservation:

1. BOD - refrigeration at 4^{o} C. for up to 24 hours.
2. Total suspended and volatile suspended solids - refrigeration at 4^{o} C. up to 24 hours.
3. Chemical oxygen demand (COD) and total organic carbon (TOC) - acidification with 2 ml/liter of concentrated sulfuric acid plus refrigeration at 4^{o} C.

Weekly composite samples were taken by the FWQA laboratory for the following analyses: Kjeldahl-nitrogen, ammonia, nitrate, nitrite, total phosphorous and ortho-phosphate. These samples were preserved

by the addition of 40 mg of $HgCl_2$/liter and refrigeration at 4° C.

Samples were shipped from the Lebanon mill to the Central Research Division laboratory at Camas, a distance of 120 miles, by truck. A shipment period of two days was involved which necessitated preservation of the samples. The daily 24 hour composite samples shipped were preserved by adjusting the pH to 2.0 with concentrated sulfuric acid. Prior to conducting the BOD test and turbidity measurement, pH was readjusted to 7.0 by the addition of sodium hydroxide.

The following data were recorded at the site by the personnel from the mill technical department: pH, flow, ammonia and phosphoric acid addition rates, power consumption and pond temperatures.

Extensive sample preservation studies were conducted which showed that acidification of samples with concentrated sulfuric acid did not affect the determinations and protected the samples for more than a week. However, whenever possible, samples were analyzed as soon as received in the laboratory.

Analytical Methods

Biochemical oxygen demand was conducted as outlined in Standard Methods for the Examination of Waste Water and Sewage (10) with the exception of the seed preparation stage. Seed was prepared by centrifuging 400 ml of biologically treated effluent at 10,000 rpm. The inoculum or seed was washed with cold water and resuspended in 150 ml

of dilution water. Microscopic examinations were made on the effluent before centrifuging to ensure that active motile bacteria were present. The bacterial suspension was again examined microscopically to determine whether the bacteria were concentrated and not adversely affected by the separation step.

The chemical oxygen demand was determined in accordance with Standard Methods (10). Total organic carbon was measured using a Carbon Analyzer. A micro sample was injected into a catalytic combustion tube which was enclosed by an electric furnace thermostatically controlled at 950° C. The water is vaporized and the carbonaceous material is oxidized to carbon dioxide which is measured by an infrared analyzer.

Total solids (TS) were determined by pipetting a 100 ml sample into a tared crucible and drying at 110° C. for 24 hours. Total suspended solids (TSS) were determined by vacuum filtering 500 ml of waste through a tared 12.5 cm No. 40 Whatman filter paper. The residue was dried to constant weight at 105° C. The dried residue was fired at 600° C. for two hours for the volatile suspended solids determination. This procedure has been outlined in detail in another publication (11).

The Azide modification of the Winkler method as outlined in Standard Methods (10) was used to determine dissolved oxygen. A D. O. probe designed and manufactured by Precision Scientific Company was used to conduct the D. O. profiles in the ponds.

A Beckman Model N pH meter was used and turbidities were measured with a standard Jackson candle in accordance with the procedure outlined in Standard Methods (10).

Kjeldahl-nitrogen was run in accordance with Standard Methods. A Technicon AutoAnalyzer was used to determine ammonia-nitrogen, nitrate-nitrogen and nitrite-nitrogen. The ammonia determination was based upon the formation of an indophenol blue color by reaction of ammonia with alkaline phenol hypochlorite. Sodium nitroprusside was used to intensify the blue color. The cadmium reduction of nitrates to nitrites in the presence of a cadmium-copper catalyst was used to determine nitrate and nitrite. The nitrites originally present plus the reduced nitrates were then reacted with sulfanilamide to form the diazo compound which was then coupled in an acid solution at pH 2.0 to 2.5 with N-1 napthylethylenediamine hydrochloride to form an azo dye. The azo dye intensity which is proportional to the nitrate concentration is then measured. Separate rather than combined nitrate and nitrite values were readily obtainable by carrying out the procedure with and without the cadmium-copper reduction step.

The ammonium molybdate and potassium antimonyl tartrate method (12, 13) was used to determine total and ortho-phosphate. These compounds reacted in an acid medium with dilute solutions of phosphorous to form an antimony-phosphate-molybdate complex. The complex was reduced to an

intensely blue-colored complex by ascorbic acid. The color developed was proportional to the phosphorous concentration.

Because of the tremendous volume of data collected over the 17 month period, the daily analyses were averaged for each run. The rough data will be filed at the Central Research Division of Crown Zellerbach for reference. The average values have been prepared in table form and are presented in the Appendix of this report.

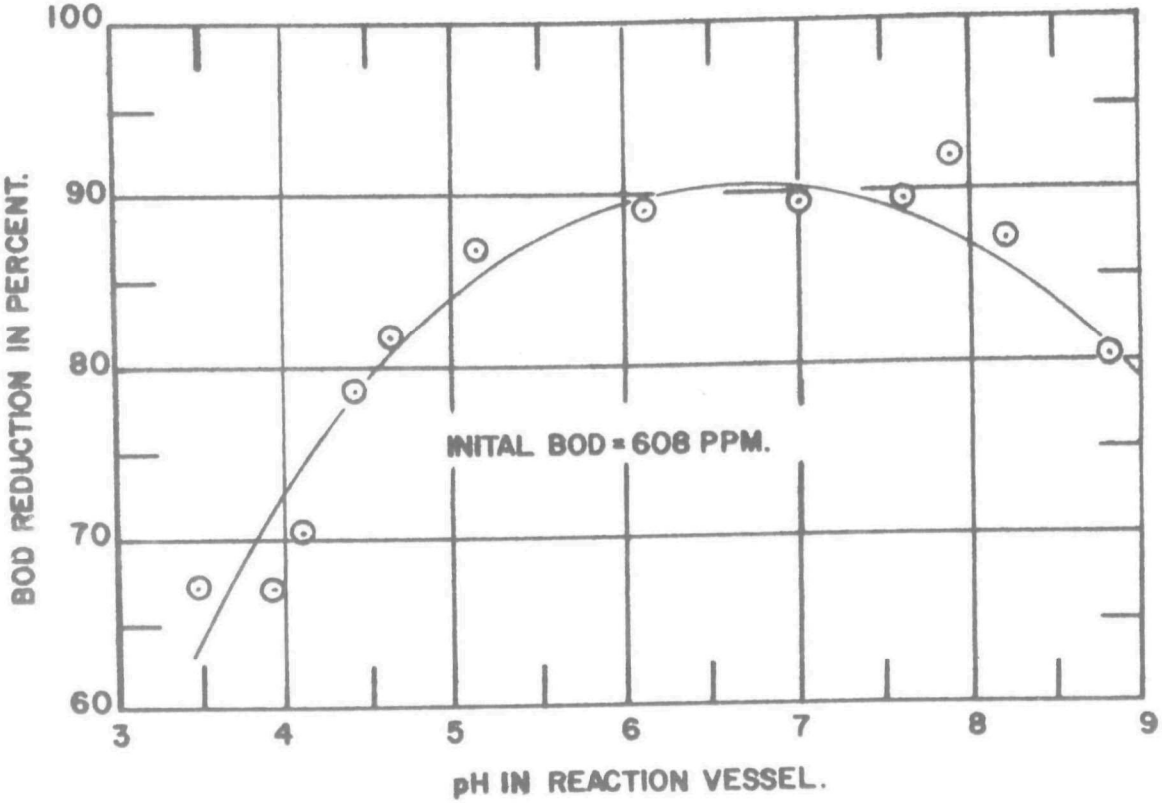
OPERATIONAL RESULTS AND DISCUSSION

Nutrient and Chemical Requirements

To approximate nutrient and neutralization requirements, laboratory shaker flask studies were conducted. Inoculum for this study was obtained by centrifuging treated effluent from several shake flasks. The cells were then added to 12 flasks, each containing 100 ml aliquots of raw spent sulfite liquor. The pH of the raw waste was adjusted to a range from 4.0 to 9.5 in 0.5 pH unit increments. Each day 20 ml were removed and replaced with 20 ml of untreated waste. BOD determinations were conducted after 15 days of continuous operation. The data are shown in Figure 5. The initial BOD of the untreated waste was 608 ppm. Optimum pH appears to be in a range of 6.0 to 7.5. The BOD reduction within this range was close to 90%. Microscopic examination of the samples showed that the predominant microorganisms at the low pH levels were yeast. At the higher pH values there were considerable numbers of long rods. Yeast, however, were present over the entire pH range studied. On the basis of the laboratory studies it appeared that the aeration basins could be operated at quite low neutralization chemical requirements.

Phosphorous requirements were also determined in the laboratory using the laboratory shaker flasks. In these experiments the raw waste pH was adjusted to pH 8.0 with ammonium hydroxide and/or sodium

FIGURE 5:—EFFECT OF pH ON BOD REDUCTION AFTER FIVE DAY RETENTION.



hydroxide. The BOD to phosphorous ratios studied were 160:1, 80:1, and 40:1. The results of the laboratory trial are shown in Figure 6. The effects of increasing phosphorous additions were not too dramatic and very little difference was noted between the "control" which received no supplemental phosphorous and the maximum phosphorous level.

To evaluate the effect of pH upon treatment efficiency, three large scale trials were chosen which varied in pH from 5.7 to 7.0. Pond temperatures during the three trials averaged 24° C. A summary of the average operating results is presented in Table 2.

The neutralization chemical requirements for the three runs were:

pH 5.7 - 198 lbs. of ammonia-nitrogen/day

pH 6.4 - 2,623 lbs. of sodium hydroxide/day

pH 7.0 - 2,512 lbs. of ammonia-nitrogen/day

In referring to Table 2 it can be seen there was an increase in BOD removal as the pH approached neutrality. The difference in efficiency, however, was small. No difference in operating efficiency could be attributed to the substitution of sodium hydroxide for ammonia as a neutralization chemical. Because of the difference in molecular weight between the two chemicals, cost of neutralization to the same pH would be substantially higher for sodium hydroxide than for ammonium hydroxide. All of the runs conducted during the experimental 17 month period except the July 1970 run utilized ammonia for reaction control.

FIGURE 6.—EFFECT OF PHOSPHOROUS ON BOD

REDUCTION AFTER 5 DAY RETENTION.

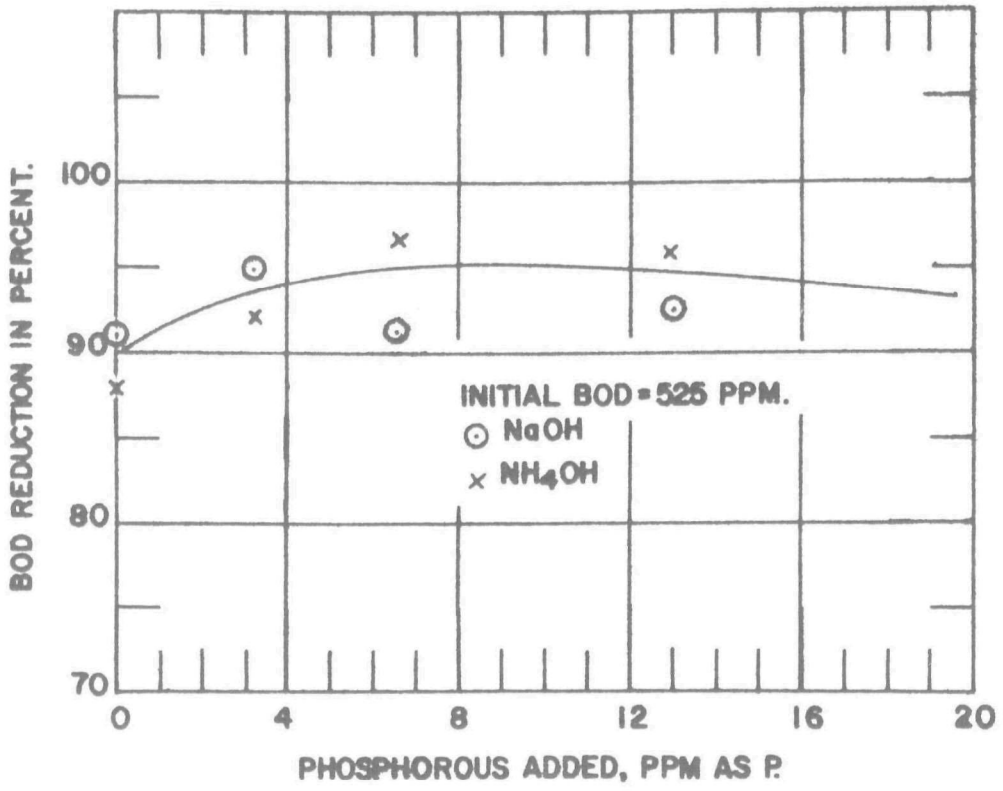


TABLE 2

THE EFFECT OF pH ON BOD REDUCTION IN COMBINED TREATMENT SYSTEM

Run No.*	pH in Pond	Waste Volume mgd	Waste Retention, Days	Pond Temp., °C.	BOD, Lbs./Day			BOD Red. %	BOD, Lbs./hp.hr.	
					In	Out	Red.		Added	Reduced
1	5.7	4.16	8.2	24	17,445	4,821	12,624	72.4	2.42	1.75
2	6.4	4.17	8.2	26	17,908	4,590	13,318	74.4	2.49	1.85
3	7.0	4.42	7.7	23	17,489	3,903	13,586	77.6	2.43	1.89

*Run 1 - May 6-June 9, 1970

Run 2 - June 27-July 13, 1970

Run 3 - Sept. 1-Sept. 19, 1969

Several large scale field trials at varying phosphorous addition rates were conducted during the summer of 1969 and the average results are presented in Table 3. The four tests were conducted under quite similar conditions of BOD loading and temperature. To ensure equilibrium between each run, about 14 days were allowed prior to the collection of samples.

The pounds of BOD removed per day were fairly uniform under all phosphorous addition rates. It appears that the ponds can be operated without supplemental phosphorous or at very low phosphorous addition rates of less than 40 lbs./day. The total and soluble phosphorous concentrations in the treated effluent were 1.74 and 0.53 ppm, respectively, when operating at the low phosphorous addition rates.

The laboratory and field trials have shown that neutralization and phosphorous requirements are quite low. For example, during the May 6 to June 9, 1970 run, ammonia neutralization requirements were 198 lbs./day and satisfactory operation was maintained without phosphorous supplements.

Series Versus Parallel Operation

Because of the ease of operation and the lower power costs, most of the trials during the 17 month experimental period were conducted by operating the ponds in parallel. However, from January 16 to February 18, 1970 the aeration ponds were operated in series. The untreated

TABLE 3

THE EFFECT OF PHOSPHOROUS ON BOD REDUCTION (COMBINED TREATMENT SYSTEM)

Run No.*	Phosphorous Added Lbs./Day	Soluble Phosphorous, ppm		Temp., °C.	BOD, Lbs./Day			% BOD Red.	BOD, Lbs./hp.hr.	
		Influent	Effluent		In	Out	Red.		Added	Reduced
1	100	----	--	24	16,180	3,385	12,795	79.1	2.25	1.78
2	106	2.30	1.40	25	14,620	2,484	12,140	84.1	2.03	1.69
3	0	0.19	0.21	26	14,833	1,964	12,869	86.8	2.06	1.79
4	0	0.46	0.50	23	17,489	3,903	13,586	77.6	2.43	1.89

*Run 1 - June 12-June 26, 1969

Run 2 - July 7-July 21, 1969

Run 3 - Aug. 1-Sept. 1, 1969

Run 4 - Sept. 1-Sept. 19, 1969

waste entered Pond II which contained the two 75-h.p. aerators and was then pumped by means of the 75-h.p. recirculation pump back to the inlet of Pond I which contained the six 25-h.p. aerators. To compare series and parallel operation, the results from a parallel run conducted from November 20, 1969 to January 16, 1970 were used.

The neutralization, nutrient and power usage for the two runs were as follows:

	Series	Parallel
Ammonia addition rate, lbs./day	1,810	1,703
Phosphorous addition rate, lbs./day	29	33
Power usage, kw-hr./day	11,030	8,351

There was a considerable increase in daily power usage when operating the ponds in series because of the use of the recycle pump. If the ponds had originally been designed for series operation, the flow would have been by gravity thereby eliminating the need for the pump. The characteristics of the influent and effluent from the two runs are shown in Table 4.

Under parallel operation both ponds assumed an equilibrium temperature of 16° C. Although the final waste temperatures were about the same for parallel and series operation, it was possible to maintain Pond II at a substantially higher temperature during series operation. The suspended solids concentration of the final effluent during the series operation was considerably higher than during parallel operation. This

TABLE 4

CHARACTERISTICS OF INFLUENT AND EFFLUENT DURING PARALLEL AND SERIES OPERATION, RATED HORSEPOWER - 150/BASIN

Operation	Waste	Waste Vol., mgd	pH	Temp., °C.	BOD ppm	COD ppm	Susp. Sol. ppm	Vol. Susp. Sol. ppm	Tot. Sol. ppm	JTU
Series	Influent	4.49	7.1	29	593	1864	117	92	1580	112
Series	Pond II	--	6.9	19	258	1547	90	72	1679	276
Series	Pond I	--	6.8	15	161	1431	114	96	1639	229
Parallel	Influent	4.31	7.3	28	604	2211	88	76	2661	116
Parallel	Pond II	2.18	7.2	16	188	1813	77	66	1919	299
Parallel	Pond I	2.13	7.0	16	235	1845	72	66	1939	248
Parallel	Composite	4.31	6.9	16	207	--	--	--	1873	274

may result from the somewhat higher velocity attained under series operation since the waste volume to each pond is doubled.

A comparison of the operating efficiencies for the two runs is presented in Table 5.

TABLE 5

COMPARISON OF PERFORMANCE - SERIES VERSUS PARALLEL OPERATION RATED HORSEPOWER - 150 PER BASIN

Operation	Waste	Waste Flow, mgd	BOD, Lbs./Day In	Out	Red.	BOD Red. %	BOD Lbs./hp.hr. Added	Red.
Series	Pond II	4.49	22,000	9,667	12,533	56.5	6.17	3.48
	Pond I	4.49	9,667	6,033	3,634	37.6	2.69	1.01
	Composite	4.49	22,000	6,033	16,167	72.8	3.06	2.25
Parallel	Pond II	2.18	10,988	3,420	7,809	71.1	3.05	2.17
	Pond I	2.13	10,741	4,129	6,562	61.1	2.98	1.82
	Composite	4.31	21,729	7,447	14,282	65.7	3.01	1.98

Under series operation the major portion of the BOD reduction was accomplished in the first pond (Pond II) which received the untreated waste. The readily available organic material was rapidly destroyed in the first of the series operated ponds and the more resistant organic material was left for the second pond. A total of 16,167 lbs. of BOD/day was destroyed or 72.8% of the applied load. The BOD reduction under

parallel operation averaged 14,282 lbs./day or 65%. There was a definite improvement in efficiency when the two ponds were operated in series.

A summation of the average performance under series and parallel operation is presented in Table 6. It can be seen that series operation

TABLE 6

SUMMARY OF PERFORMANCE UNDER SERIES AND PARALLEL OPERATION

	Parallel	Series
Volumetric Load, mgd	4.31	4.49
BOD Load, lbs./day	21,729	22,200
BOD Discharged, lbs./day	7,447	6,033
BOD Reduction, lbs./day	14,282	16,167
BOD Reduction, %	65.7	72.8
Suspended Solids Discharged, lbs./day	4,568	4,272
Suspended Volatile Solids Discharged, lbs./day	4,280	3,597
Ammonia-nitrogen Discharged, lbs./day	5,684	5,433
Soluble Phosphorous Discharged, lbs./day	30	16

resulted in an additional 1,414 lbs./day BOD reduction. About 78% of the total BOD reduction occurred in the first of the series operated ponds and 22% occurred in the second pond. It appears that the major portion of the BOD is easily destroyed in about 3.8 days, the retention in Pond

II during the series operation.

The D. O. profiles shown in Figure 7 clearly show that BOD reduction could probably have been improved by increasing the aeration capacity of Pond II during the series operation since the D. O. in most of the pond was zero during the run. The D. O. content in Pond I was uniformly high during the run.

It is of interest to compare the D. O. profiles under series and parallel operation. Profiles conducted on February 23, 1970, when operating in parallel, are shown in Figure 8. It will be noted that when the ponds are equally loaded under parallel operation, the large aeration units were able to supply substantially greater amounts of D. O. than the small 25-h. p. units.

Effect of BOD Load on BOD Reduction

The average operating data for the individual ponds and the combined treatment system are presented in Tables I, II and III of the Appendix. Since aeration capacity appears to be the limiting factor affecting BOD removal, plots of the BOD reduction/h. p. -hr. versus BOD loading have been prepared and are shown in Figure 9 for the two ponds. BOD reduction appears to be a straight line function of BOD load over a rather wide range of loadings. The BOD reductions in the two ponds over a loading range from 1. 5 lbs. to 5. 5 lbs. /h. p. -hr. are presented in Table 7.

FIGURE 7.—DISSOLVED OXYGEN PROFILES FOR PONDS IN SERIES OPERATION, FLOW FROM POND II TO POND, I, ON FEBRUARY 16, 1970.

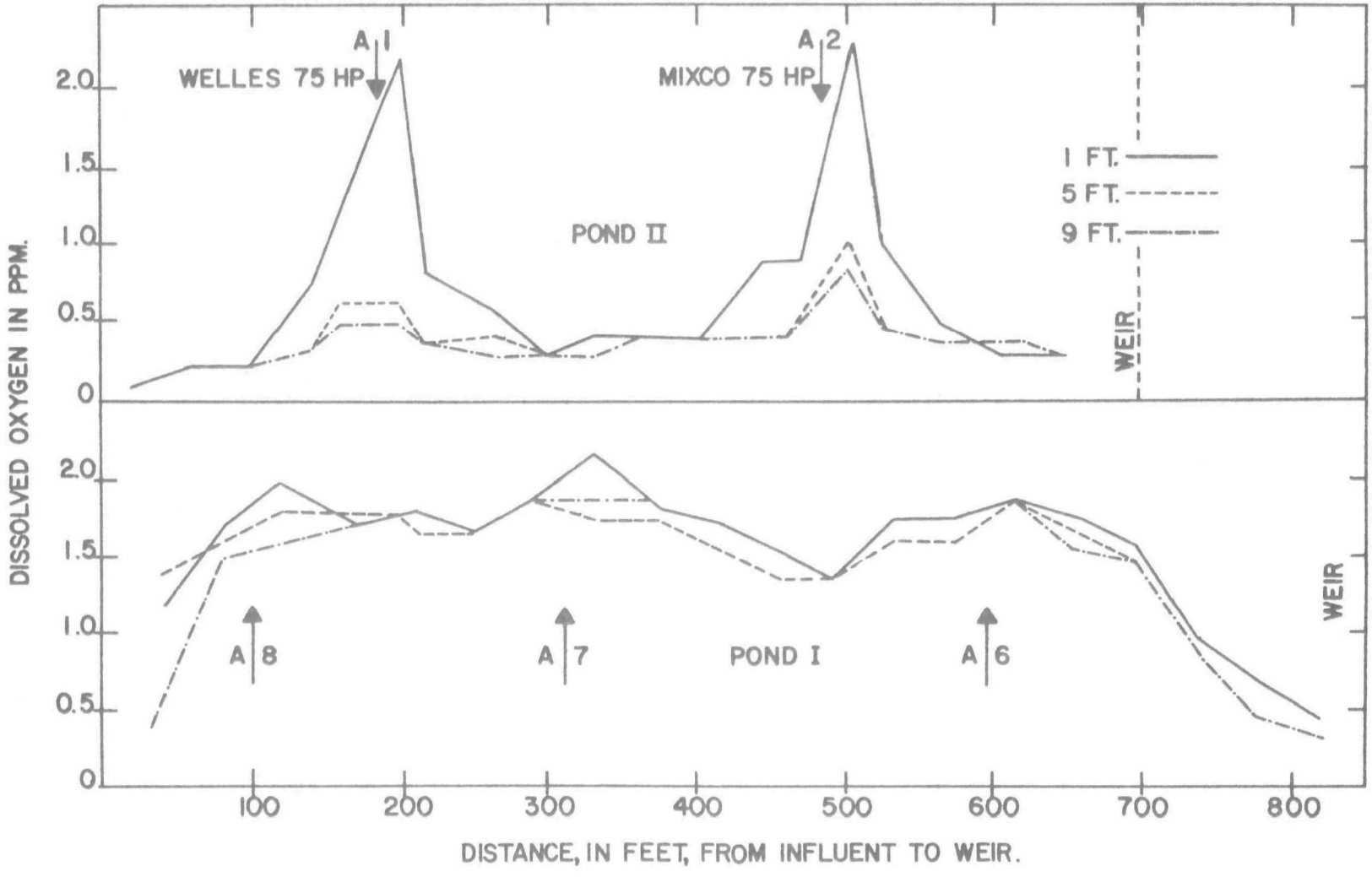
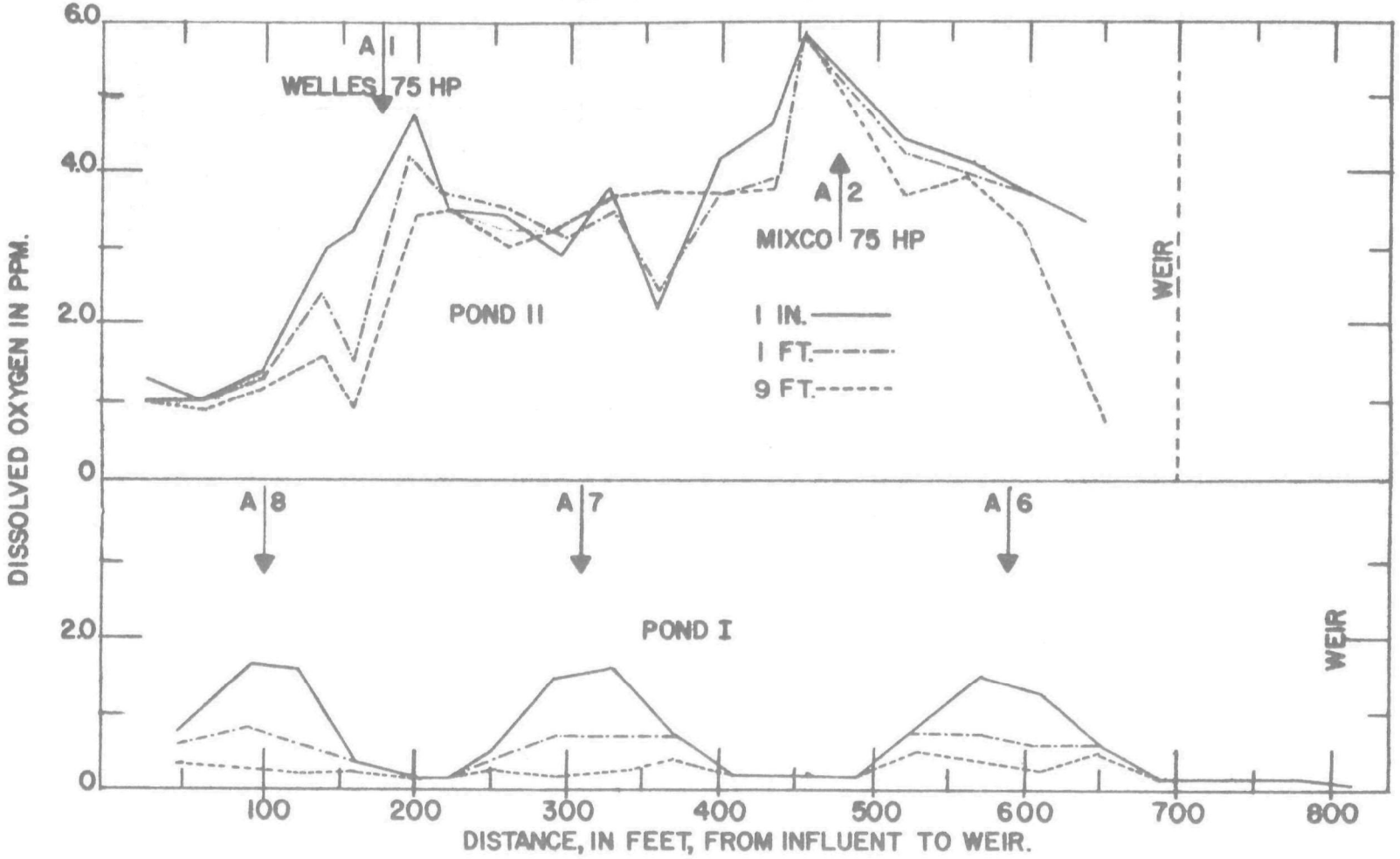


FIGURE 8.—DISSOLVED OXYGEN PROFILES FOR PONDS IN PARALLEL OPERATION ON FEBRUARY 23, 1970.



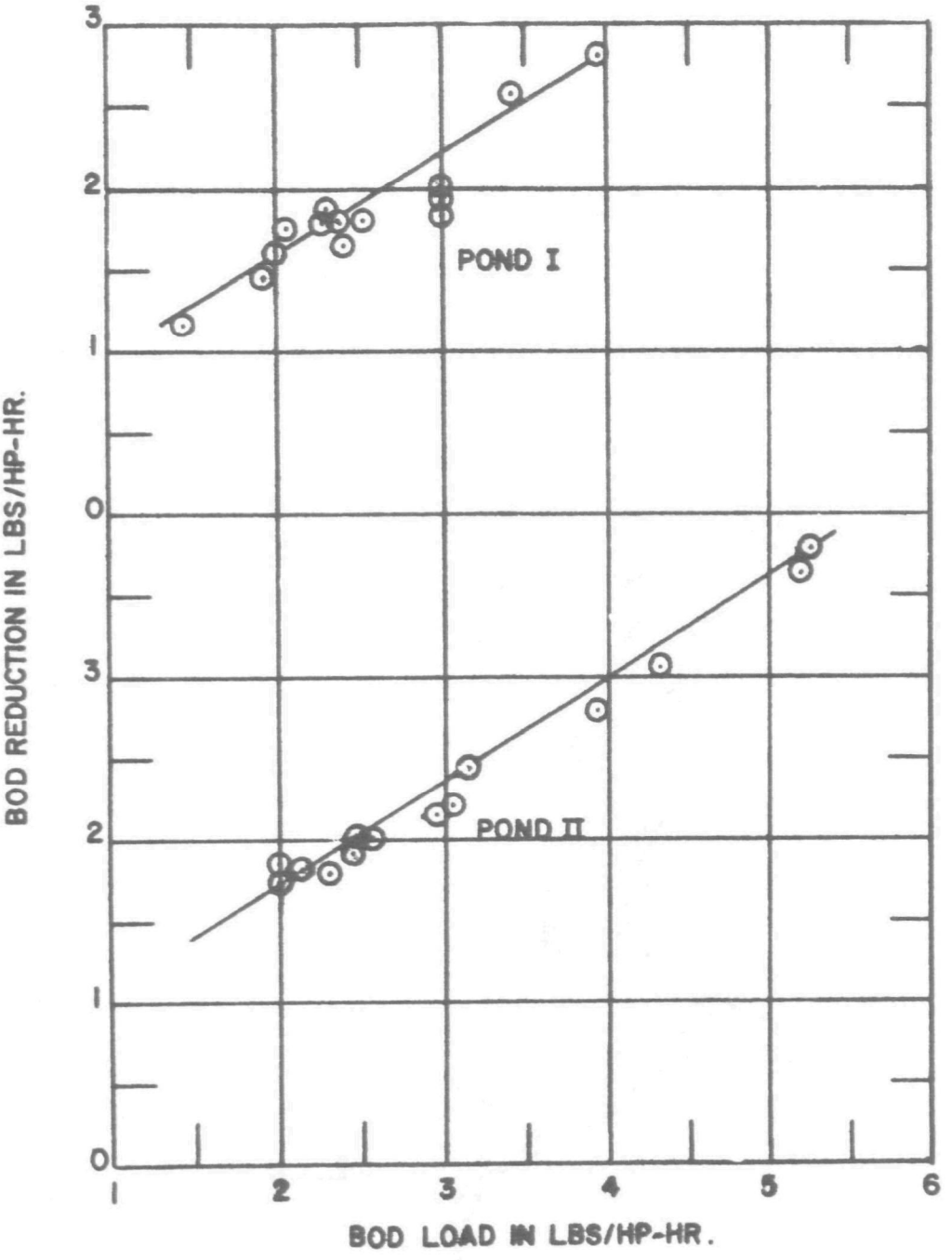


FIGURE 9.—EFFECT OF BOD LOAD ON BOD REDUCTION.

TABLE 7

BOD REDUCTIONS IN THE TWO AERATION BASINS

BOD Load, Lbs. /h. p. -hr.	BOD Reduction Lbs. /h. p. -hr.		BOD Reduction, %	
	Pond I	Pond II	Pond I	Pond II
1.5	1.25	1.40	83.4	93.3
2.0	1.58	1.75	79.0	87.7
2.5	1.88	2.05	75.3	82.0
3.0	2.20	2.37	73.3	79.0
3.5	2.50	2.67	71.4	76.3
4.0	2.80	3.00	70.0	75.0

To achieve an 80% BOD reduction, Pond I would have to be loaded at 1. 9 lbs. of BOD/h. p. -hr. or 6, 840 lbs. /day and Pond II could receive a load of about 2. 8 lbs. /h. p. -hr. or 10, 000 lbs. /day. It becomes apparent that Pond II which is equipped with the two 75-h. p. surface aerators is much more efficient than Pond I with the six 25-h. p. units. An additional three 25-h. p. surface aerators would be needed in Pond I to bring it up to the efficiency of Pond II. On the basis of the work conducted, the two 75-h. p. units were equivalent to nine of the small 25-h. p. aerators.

The performance of the combined aeration systems is presented in Figure 10 and summarized in Table 8.

FIGURE 10.—RELATIONSHIP BETWEEN BOD LOADING AND REDUCTION FOR COMBINED SECONDARY SYSTEM (300 HP AERATION CAPACITY).

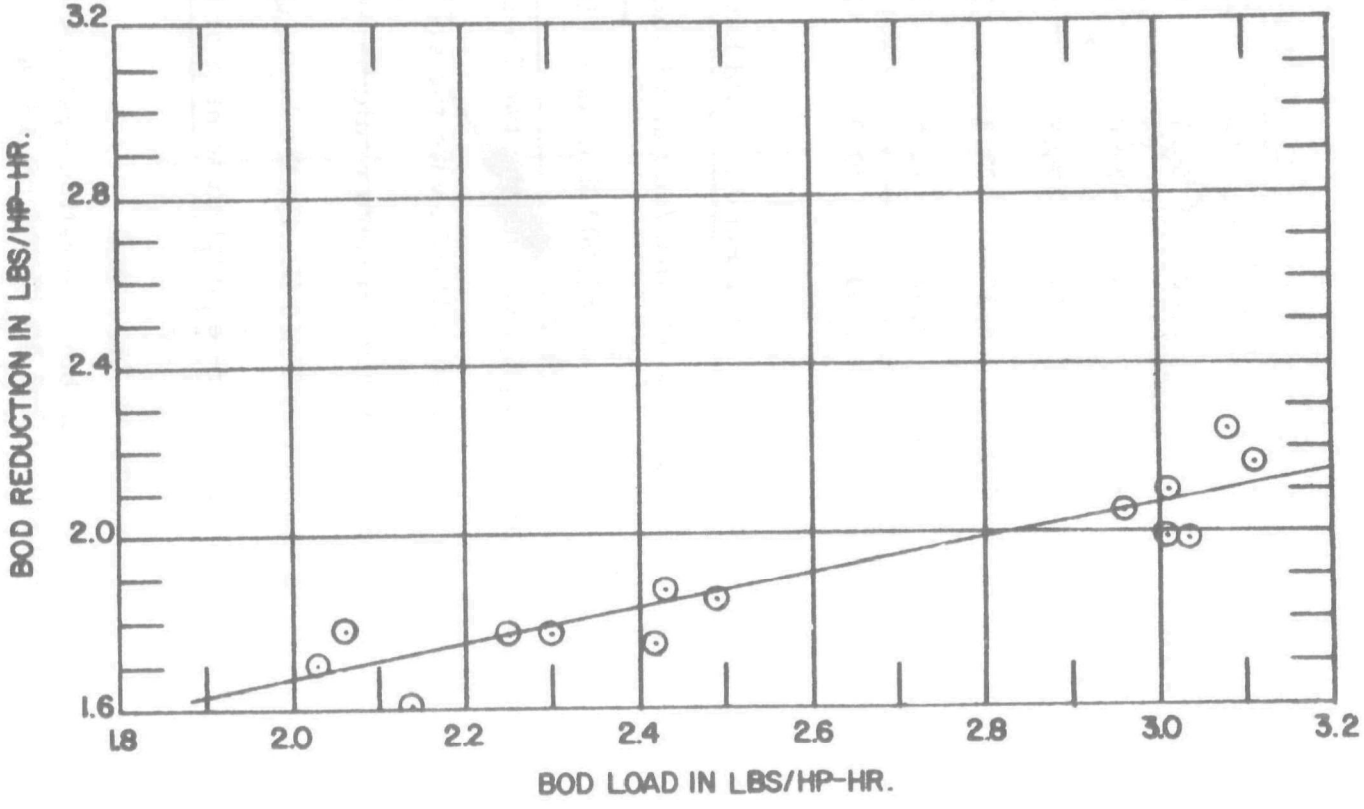


TABLE 8

PERFORMANCE OF COMBINED TREATMENT SYSTEM

BOD Load Lbs. /h.p.-hr.	BOD Load Lbs. /Day	BOD Reduction Lbs. /h.p.-hr.	BOD Reduction Lbs. /Day	BOD Reduction %
2.00	14,400	1.68	12,100	84.0
2.30	16,550	1.80	12,970	78.3
2.60	18,700	1.92	13,820	73.9
2.90	20,900	2.05	14,770	70.7
3.10	22,400	2.13	15,320	68.7

If the overall requirement for primary and secondary treatment is considered to be 85% and if 5% is allotted to primary treatment, an 80% reduction must be reached in the combined secondary system. To permit selection of the allowable BOD load, Figure 11 has been prepared which presents the percent BOD reduction as a function of BOD loading. To achieve an 80% BOD reduction in the secondary system the BOD load must be limited to about 15,800 lbs. /day or 2.2 lbs. /h.p.-hr. At a daily load of 20,000 lbs. /day the BOD reduction can be expected to be 72%. An 80% BOD reduction at a load of 20,000 lbs. /day could be achieved by the addition of another 75-h.p. surface aerator which would bring the total aeration capacity for the two ponds to 375 h.p.

During the 17 month experimental period, the incoming BOD load to the aeration ponds varied quite widely from day to day. It was noted,

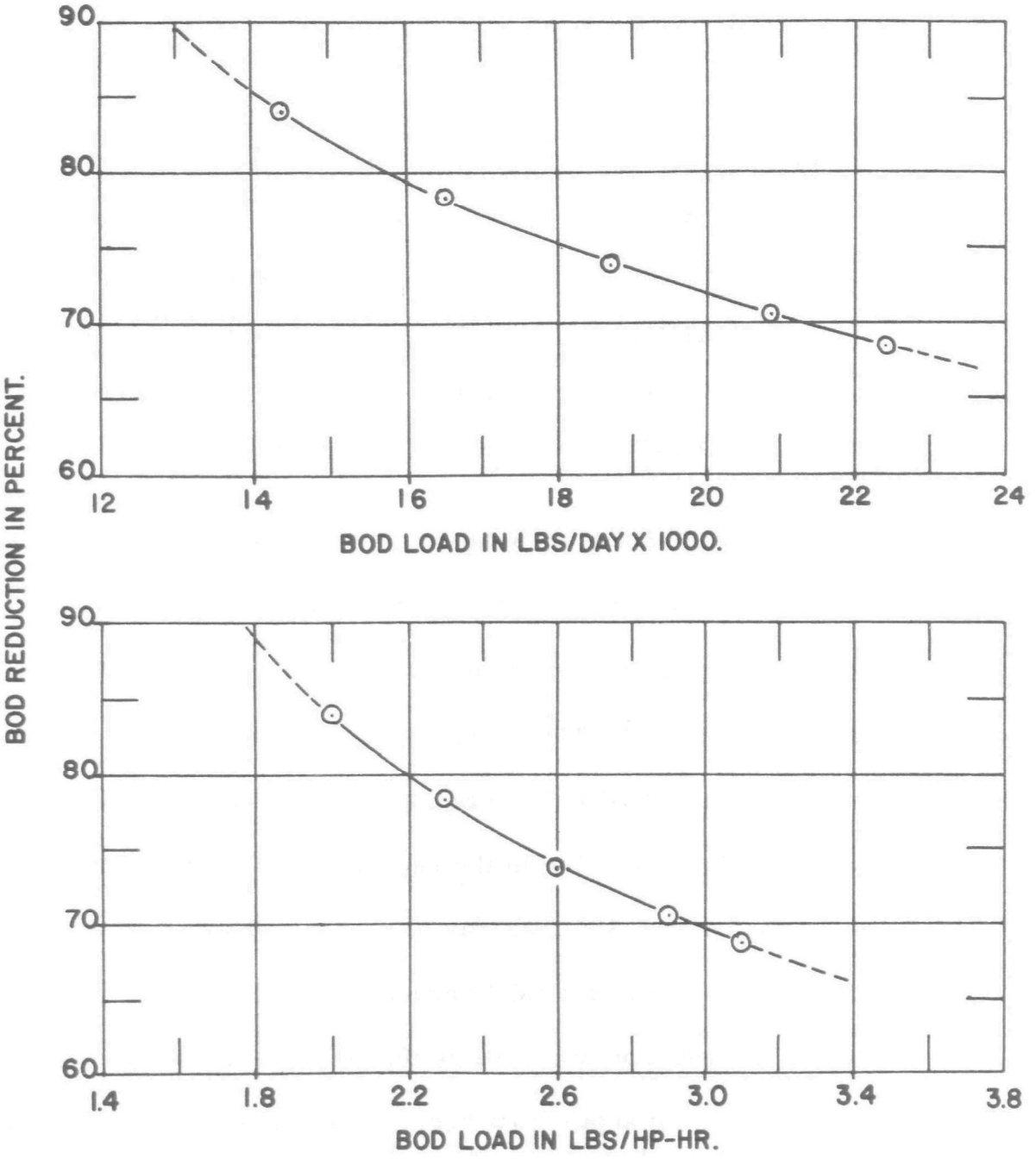


FIGURE 11.—EFFECT OF BOD LOADING ON BOD REDUCTION FOR COMBINED SECONDARY SYSTEM (300 HP AERATION CAPACITY).

however, that these fluctuations had very little effect upon the final effluent which had a fairly uniform BOD concentration. Very high shock loadings were readily absorbed without drastically affecting the final BOD. This can readily be seen by referring to Figure 12 which shows the daily BOD concentrations into and out of the secondary system. The effects of shock loadings are minimized because of the mixing characteristics of the system and the long retention available for equilization.

Effect of Retention on BOD Reduction

Although various retention periods were studied, it was impossible to provide a constant BOD load at the various retentions, i.e., there were generally two variables. Under these conditions, the low retentions showed better BOD reductions than would have been achieved if the BOD load had remained the same for all runs. Three runs from Pond II and one from Pond I were selected and a summation is presented in Table 9.

In referring to Table 9, it appears that considerable nitrification may be occurring during the 16.7 day retention and at the low BOD load used during this run. This would account for the relatively low BOD reduction. Unfortunately, nitrate and nitrite determinations were not available for the run. Weekly checks for nitrite and nitrate during runs conducted from April 14 through July 10, 1970 at fairly heavy BOD loads

FIGURE 12.—DAILY OPERATING DATA CONCERNING BOD OF INFLUENT AND EFFLUENTS FROM PONDS I AND II.

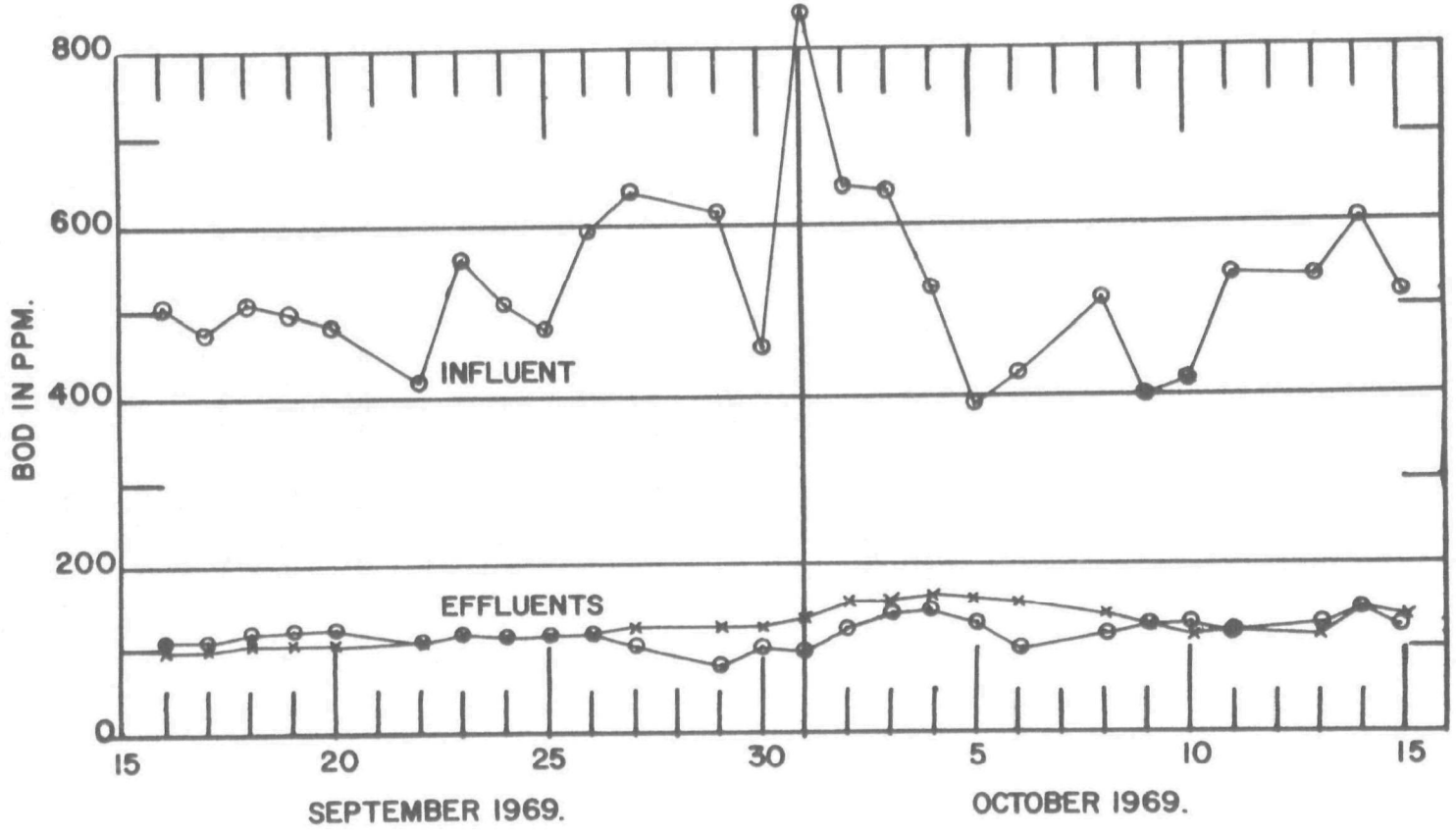


TABLE 9

THE EFFECT OF RETENTION ON BOD REDUCTION

Run No.*	Retention Days	BOD, Lbs./Day In	Out	Red.	BOD Red. %	BOD, Lbs./ h.p.-hr. In	Red.
1**	16.7	5,329	1,200	4,129	77.5	1.48	1.15
2	7.2	11,364	2,610	8,754	77.0	3.16	2.43
3	5.3	16,779	6,621	10,158	60.5	4.66	2.82
4	3.8	22,200	9,667	12,533	56.5	6.17	3.48

*Run 1 - Mar. 23-Apr. 7, 1970

Run 2 - Apr. 7-May 6, 1970

Run 3 - Mar. 23-Apr. 7, 1970

Run 4 - Jan. 16-Feb. 16, 1970

**Run from Pond 1

showed only traces. The average nitrite and nitrate concentrations from 14 weekly samples taken of the influent, effluent from both ponds, and composite were as follows:

	NO_2-N, ppm	NO_3-N, ppm
Influent	0.18	0.54
Effluent Pond I	0.17	0.52
Effluent Pond II	0.19	0.49
Composite Effluent	0.19	0.51

No significant differences in nitrite or nitrate were detected between the influent and effluent. It is of interest to note that the D. O. concentration in the ponds during these runs was close to zero except close to the aerators which would explain the absence of nitrifying bacteria.

The results from the three trials conducted on Pond II are presented in Figure 13. Based upon the results obtained, it is doubtful whether significant improvements in efficiency can be gained by exceeding the design retention of 7 to 8 days. Additional aeration capacity would be expected to have more pronounced effects upon efficiency than increases in waste retention. For example, Pond I was generally devoid of D. O. which resulted in facultative operation instead of the desired aerobic operation.

Temperature Effects

During the experimental period, the feed temperature to the secondary treatment system varied from 28° to 35° C. (82° to 95° F.) whereas the composite outlet temperature varied from 16° to 26° C. (61° to 79° F.). There was a substantial temperature drop at all times of the year. The summer temperature drop was caused by heavy evaporation rates whereas the winter drop was attributable to low ambient temperatures and dilution by cold rain water. Typical ambient monthly average temperatures and evaporation rates for the Lebanon area are presented in Table 10. The average evaporation rate from May 1

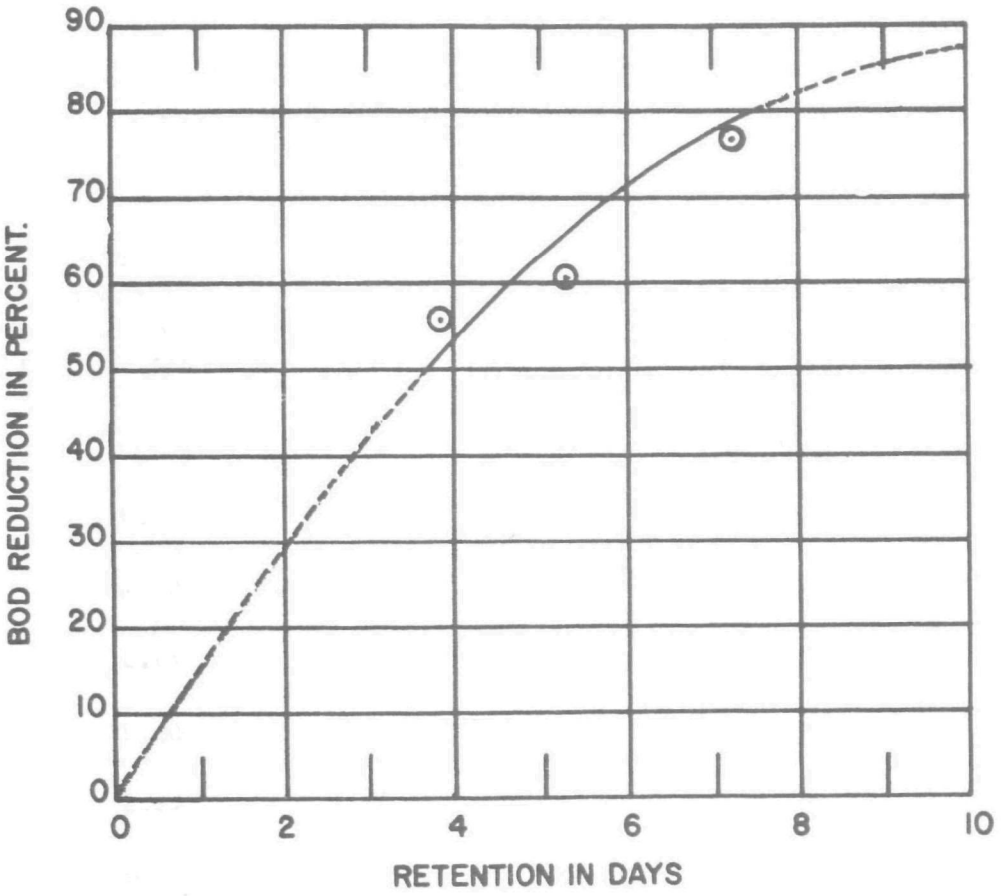


FIGURE 13.—EFFECT OF RETENTION ON BOD REDUCTION UNDER VARIABLE BOD LOAD IN POND II.

through September 30, 1969 was about 6.8 inches per month, whereas the average ambient temperature was 62.5°.

TABLE 10

AVERAGE MONTHLY AMBIENT TEMPERATURES AND EVAPORATION RATES AT CORVALLIS - ALBANY STATIONS

Month	Average Monthly Temp., °F.	Evaporation Rate Inches/Mon.	Month	Average Monthly Temp., °F.	Evaporation Rate Inches/Mon.
Jan., 1969	35.4	--	Nov.	46.2	--
Feb.	40.0	--	Dec.	41.9	--
March	46.6	--	Jan., 1970	41.1	--
April	49.1	3.25	Feb.	45.3	0.92
May	58.2	6.06	March	46.3	2.02
June	64.4	6.31	April	46.8	3.48
July	64.6	7.62	May	55.0	5.44
Aug.	63.6	8.51	June	63.8	7.01
Sept.	61.6	5.34	July	66.3	9.45
Oct.	51.2	2.16			

The average temperature data for each run were used to calculate the heat losses. The results of these calculations are shown in Table 11. The average heat loss from May through September of 1969 was 534,000,000 BTU/day when the incoming waste temperature averaged

33° C. (91.4° F.). During the winter period from November through April, heat losses averaged 793,000,000 BTU/day. Heat losses were found to be greater for series operation than for parallel operation.

TABLE 11

SECONDARY TREATMENT SYSTEM TEMPERATURE DATA AND CALCULATED HEAT LOSSES

Run No.*	Av. Vol. mgd	Temp., ° C. In	Out	Temp. Diff. °C.	°F.	Heat Loss/ Day BTU X 10^6
1	4.22	33.4	24.9	3.5	15.3	539
2	4.08	33.7	25.6	8.1	14.6	495
3	4.42	31.5	23.5	8.0	14.4	531
4	3.75	32.5	21.0	11.5	20.6	645
5	4.31	28.0	16.0	12.0	21.6	777
6	4.54	29.2	17.3	11.9	21.4	811
7	4.53	30.1	18.5	11.6	20.9	790
8	4.16	32.0	24.0	8.0	14.4	500
9	4.17	35.0	26.0	9.0	16.2	563
10	4.21	34.4	25.3	9.1	16.4	575
**11	4.49	29.0	15.0	14.0	25.2	945

*Run 1 - July 7-July 21, 1969
Run 2 - Aug. 1-Sept. 1, 1969
Run 3 - Sept. 1-Sept. 19, 1969
Run 4 - Sept. 19-Oct. 22, 1969
Run 5 - Nov. 20-Jan. 16, 1970
Run 6 - Mar. 1-Mar. 12, 1970
Run 7 - April 12-May 6, 1970
Run 8 - May 6-June 9, 1970
Run 9 - June 17-July 13, 1970
Run 10 - July 25-Sept. 5, 1970
Run 11 - Jan. 16-Feb. 18, 1970

** Series Operation, Pond II to Pond I.

The relationship between monthly ambient air temperatures and average heat losses is shown in Figure 14. At an average ambient summer temperature of 65° F., heat losses will average 500,000,000 BTU/day and at an average winter temperature of 40° F. heat losses can be expected to average 815,000,000 BTU/day. These calculations are based on an average inlet waste temperature of 32° C. (89.5° F.). The actual waste temperature drop that can be expected at various ambient temperatures is also shown in Figure 14. During the winter season a drop of pond temperatures as great as 11.7° C. (21° F.) can be expected and summer operation can be expected to result in a drop of 8.3° C. (15° F.).

Since temperature in the ponds could not be controlled, temperature was in equilibrium with the ambient temperature. Pond temperatures varied from 16° C. (61° F.) during the winter to 27° C. (80° F.) in the summer. Since biological activity increases with increasing temperature, it would be expected that BOD reductions would be substantially greater in the summer than the winter. However, a careful analysis of the data indicated that temperature had no significant effect upon the secondary system. This can be shown by referring to Figures 9 and 10 which include all of the BOD data regardless of temperature. The data used to develop these figures covered an 11° C. spread in temperature, yet no significant effect upon treatment efficiency could

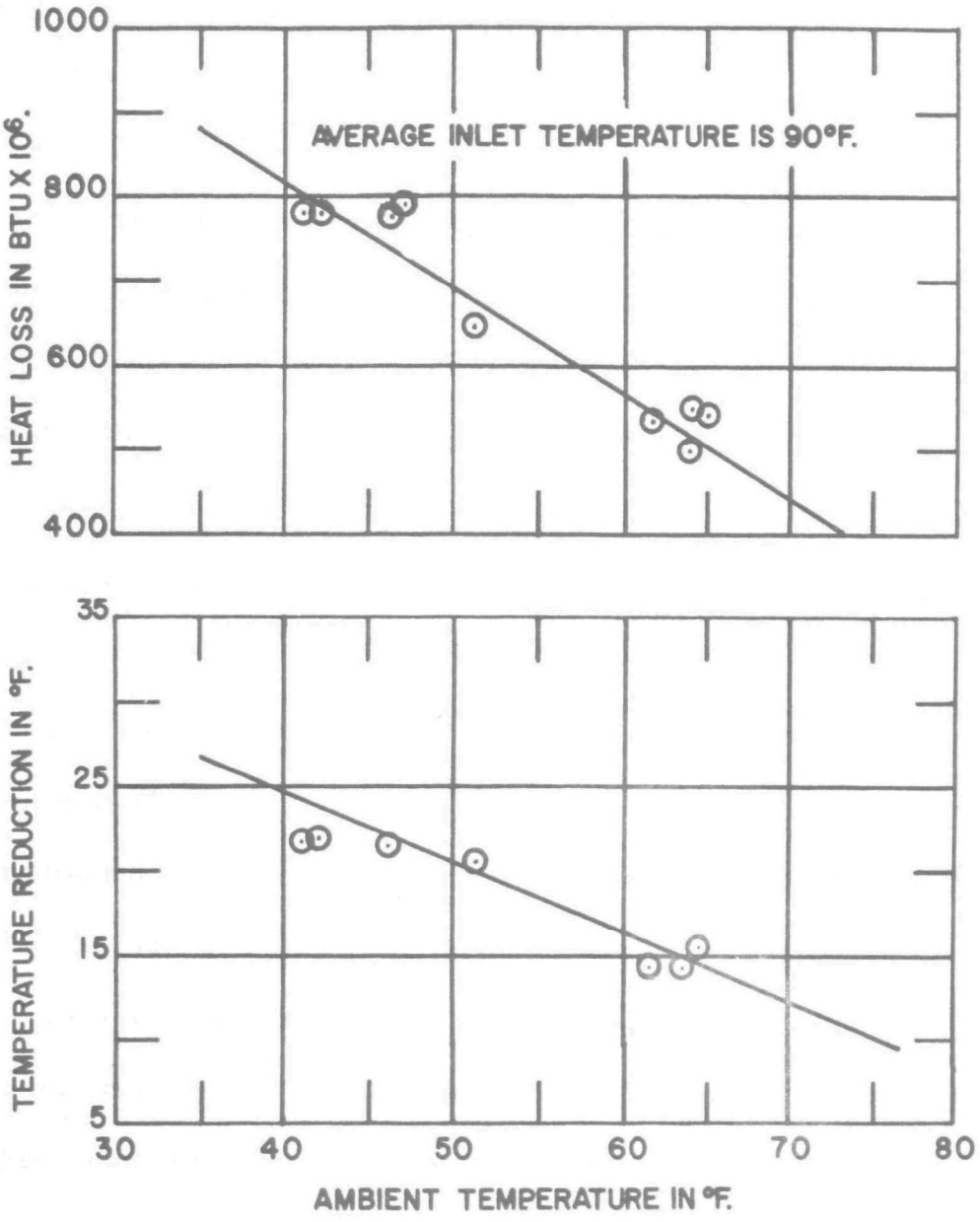


FIGURE 14.—EFFECT OF AMBIENT TEMPRATURE ON HEAT LOSSES FROM SECONDARY TREATMENT AND ON TEMPERATURE REDUCTION IN THE PONDS.

be attributed to temperature effects. If temperature was critical, a much greater spread in the individual points would be expected and BOD reduction would not plot as a linear function of BOD load.

In evaluating the data, it appears that other factors have a more pronounced effect upon BOD removal than temperature for this particular system. For example, if aeration capacity or nutrient concentrations were limiting factors, increases in temperature would not necessarily result in an increase in efficiency. Since nutrients have been found to be adequate, aeration rate may be the limiting factor, thereby masking the temperature effect. If aeration capacity were sufficient to maintain a 2 ppm D.O. residual in the ponds, a more pronounced temperature effect would undoubtedly have been experienced. During most of the runs, the D.O. in Pond I, which contained the 25-h.p. aerators, was close to zero. It has already been shown that additional aeration capacity in Pond I would improve efficiency. Furthermore, laboratory shaker flask studies have shown that BOD reductions of 90% can readily be attained in five days of aeration with dispersed bacterial growths. However, in the laboratory studies, the rate of oxygen transfer was not a limiting factor.

Recirculation of Treated Waste

Recirculation of treated waste was studied to determine whether dilution of the untreated waste with treated waste containing acclimatized

bacteria would have a beneficial effect upon the performance of the treatment system. The initial plan of operation called for a series of experiments in which the recirculation rate would be varied over a range from 1.4 mgd to 5.8 mgd.

To evaluate the effectiveness of recirculating treated waste, the two ponds were operated in parallel with recycle of 2 mgd of treated waste in Pond II from September 19 through October 22, 1969. A schematic diagram of the flow pattern is shown in Figure 15. During the trial, 2,694 lbs./day of ammonia and 33 lbs./day of phosphorous were added to the raw waste. Power consumption during the trial averaged 9,900 kw-hr./day.

The characteristics of the influent and effluent from the two aeration basins and the composite for the test period are shown in Table 12.

In general, recirculation resulted in a deterioration of effluent characteristics. The suspended solids concentration was increased by recirculation and there was a substantial increase in BOD. The average BOD data for the run are summarized in Table 13.

Recycle of 2 mgd of treated effluent in Pond II resulted in a decrease in BOD removal. Pond II has always shown better BOD reductions than Pond I. For example, at an equivalent BOD load to Pond II, the BOD reduction without recirculation should have been about 6,950 lbs./day instead of 6,274 lbs./day. The difference was even more pronounced

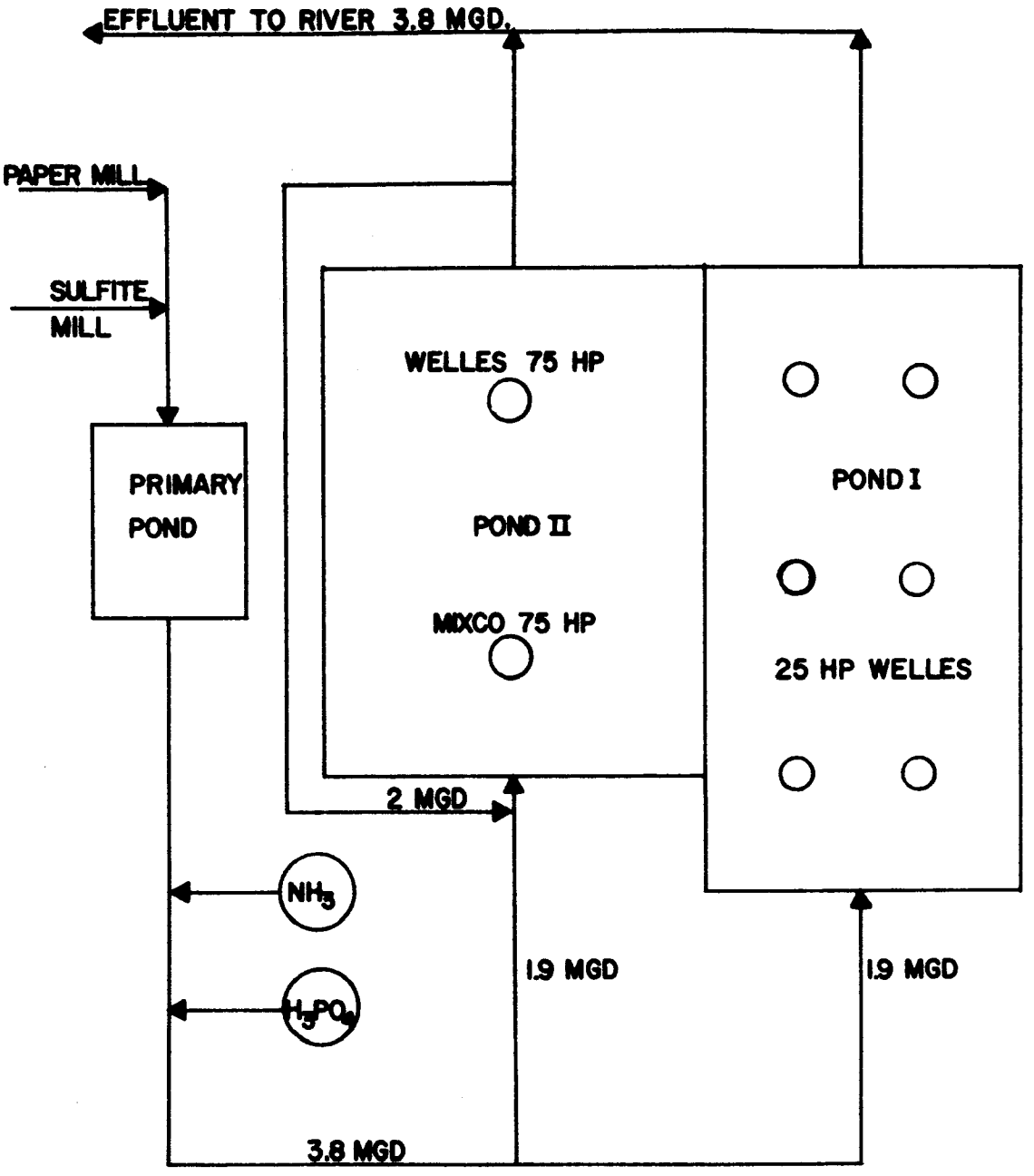


FIGURE 15.—SCHEMATIC FLOW DIAGRAM OF SECONDARY SYSTEM DURING RECIRCULATION EXPERIMENT.

TABLE 12

RECIRCULATION OF TREATED WASTE - CHARACTERISTICS OF INFLUENT, EFFLUENT AND COMPOSITE SAMPLES

	Rated HP	Waste Volume mgd	Recycle mgd	pH	Temp. °C.	BOD ppm	COD ppm	Susp. Sol. ppm	Susp. Vol. Sol. ppm	Tot. Sol. ppm	JTU
Influent	--	--	--	6.9	32.5	529	1,930	163	--	1,930	168
Pond I	150	1.88	0	7.2	20.2	114	1,435	57	49	1,623	205
Pond II	150	1.88	2.00	7.2	21.5	128	1,467	72	44	1,616	220
Composite	300	3.75	--	7.0	21.0	124	1,364	47	37	1,544	213

TABLE 13

RECIRCULATION OF TREATED WASTE - SUMMARY OF BOD DATA

	Waste Flow mgd	Recycle mgd	BOD, Lbs./Day In	Out	Red.	BOD Red. %	BOD Lbs./hp-hr. Added	Removed
Pond I	1.88	--	8,295	1,788	6,507	78.5	2.30	1.81
Pond II	1.88	2.00	8,277	2,003	6,274	75.8	1.54	1.16
Composite	3.75	--	16,572	3,885	12,687	76.6	1.84	1.41

when the power requirements of the 75-h.p. recirculation pump were taken into consideration. Normal operation without recirculation should result in a BOD reduction in Pond II of about 1.93 lbs./hp-hr. whereas the reduction was reduced to 1.16 lbs./hp-hr. when recirculating 2 mgd of treated waste to Pond II.

The negative results of recirculation can probably be attributed to reduction in the waste retention. Since Pond II is uniformly mixed, recycle would not be expected to improve treatment efficiency. However, it would be expected that recirculation would be more effective in aeration basins with a well defined BOD gradient from inlet to outlet. Table 14 presents a comparison of recycle with a previous run without recycle. Because of the negative effects of recirculation, no additional tests were conducted.

TABLE 14

EFFECT OF RECYCLE ON OPERATING PERFORMANCE OF POND II

	Sept. 1 to Sept. 19, 1969 No Recycle	Sept. 19 to Oct. 22, 1969 2 mgd of Recycle
BOD Added, lbs. /day	9,224	8,277
BOD Out, lbs. /day	2,078	2,003
BOD Red., lbs. /day	7,146	6,274
BOD Red., lbs. /hp-hr.	1.98	1.16
BOD Red., %	77.5	75.8

Surface Aerator Comparison

A great deal of flexibility was designed into the secondary treatment system to permit comparisons of large surface aerators versus smaller units and to compare the high speed units with the low speed units employing gear reducers.

To evaluate the difference between different size aerators, Pond I was equipped with six 25-h.p. Welles surface aerators and Pond II with two 75-h.p. units. Selection of optimum size is of utmost importance since it has a sizable impact upon capital cost. A detailed cost analysis of the different size units is shown in Table IV of the Appendix. A plot of

aerator cost as a function of rated horsepower is shown in Figure 16. Because of the limited data used, data taken from this figure are only rough approximations. However, it can readily be seen that the installed cost of the large 75-h.p. units is substantially lower than for equivalent capacity of the smaller 25-h.p. units. For example, the installed cost of the 25-h.p. units was $378/rated horsepower whereas the installed cost for a 75-h.p. unit ranged from $285 to $305/rated horsepower. A reduction of 24% in installed cost can be accomplished by selection of the larger units. It becomes imperative, then, to determine whether equivalent horsepower of small and large units are equally effective in the transfer of oxygen and mixing of the basin contents.

In referring to Figure 16 it can also be seen that the installed cost of the low speed Mixco units was somewhat higher than for equivalent horsepower of the direct drive high speed Welles units. A comparison of performance based upon efficiency of oxygen transfer, mixing and reliability of operation would also be helpful in making a selection between these two different pieces of equipment.

Comparison of operational data for the 17 month experimental period presented an exceptional opportunity for a critical performance evaluation. The average data for each run, shown in Tables I and II of the Appendix, clearly show that Pond II containing the two large 75-h.p. surface aerators consistently performed better than Pond I with the six 25-h.p.

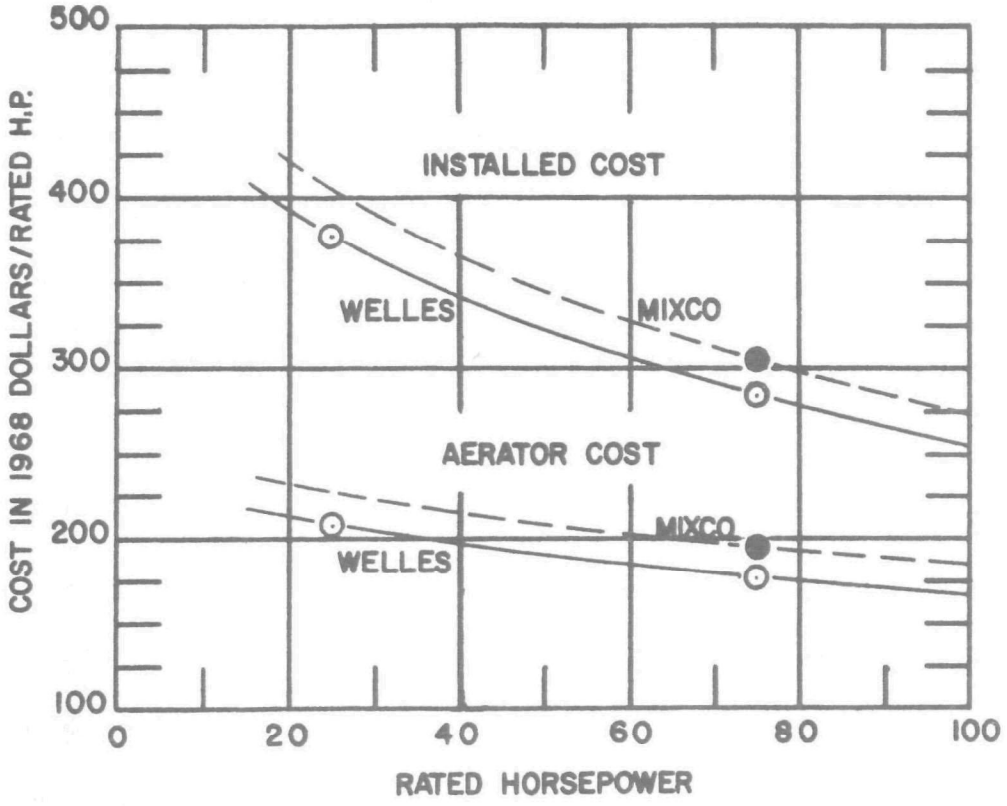
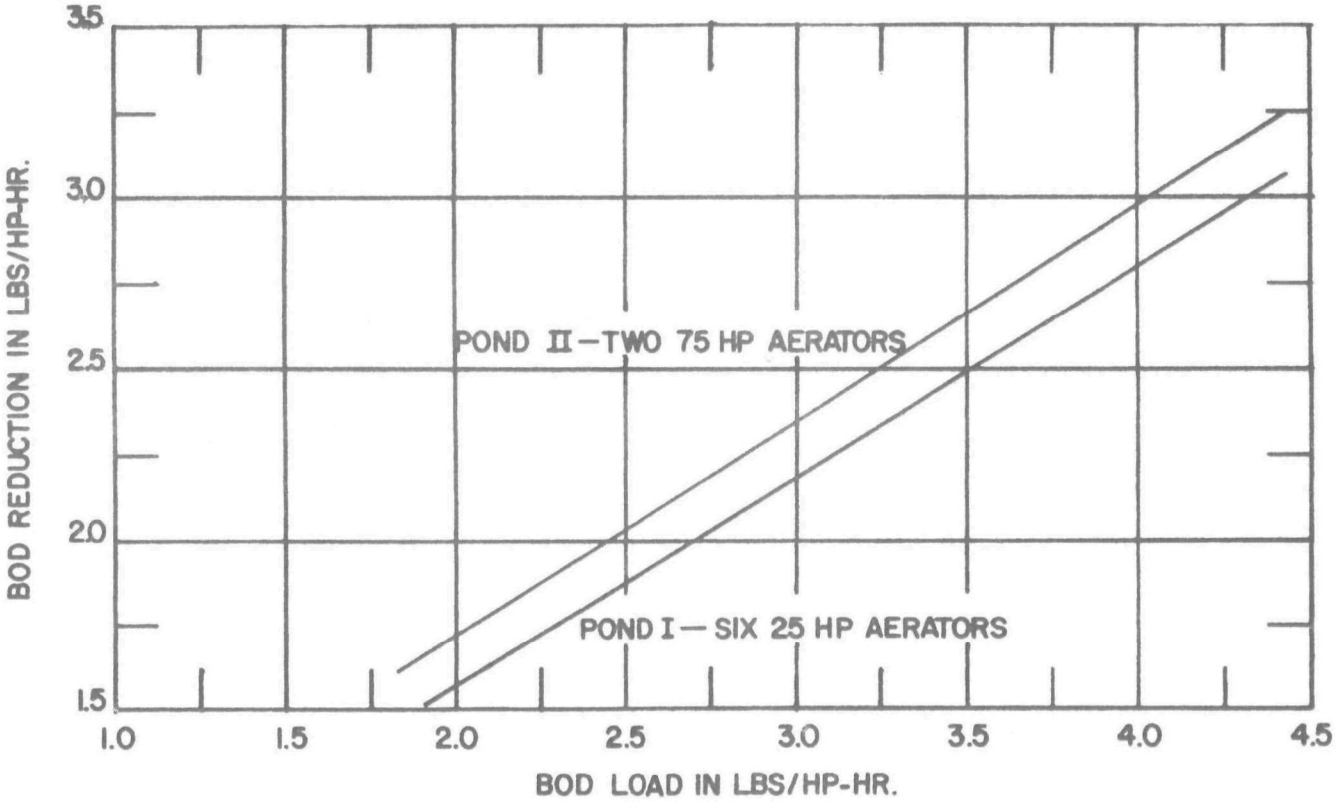


FIGURE 16.—AERATOR COSTS VS RATED HORSEPOWER.

units. The difference between the two sizes has already been demonstrated and can be seen by referring to Figure 17. If 80% BOD reduction in the secondary system is used as a design basis, the two large aerators were capable of treating 9,740 lbs. of BOD/day compared to 6,660 lbs./day for the equivalent horsepower in 25-h.p. aerators (6 units). The relationship between size of aeration equipment and the allowable BOD load for an 80% BOD reduction is shown in Figure 18. If the line is drawn as a straight line and extrapolated beyond 75-h.p. to 100-h.p. units, an allowable BOD load of 3.14 lbs./h.p.-hr. could possibly be achieved. However, if the relationship follows the curve shown by the dotted line, the allowable BOD load would be expected to be somewhat less, i.e., about 2.8 lbs./h.p.-hr.

The improved efficiency of the larger units may also be related to the configuration within the ponds or distance between the units. For example, the distance between aerators in Pond II was about 315 ft. which provided a radius of 157 ft. for each unit or 2.1 ft./h.p. It becomes evident in referring to Figure 19 that the space between the small aerators in Pond I is too great. In the longitudinal dimension the spacing is more than 260 ft. leaving considerable dead area between the aerators for sedimentation of settleable solids. It is questionable whether the small units could do an effective job in either lagoon without additional aerators. It becomes apparent that selection of the proper size unit and

FIGURE 17.--PERFORMANCE COMPARISONS OF LARGE VS SMALL SURFACE AERATORS.



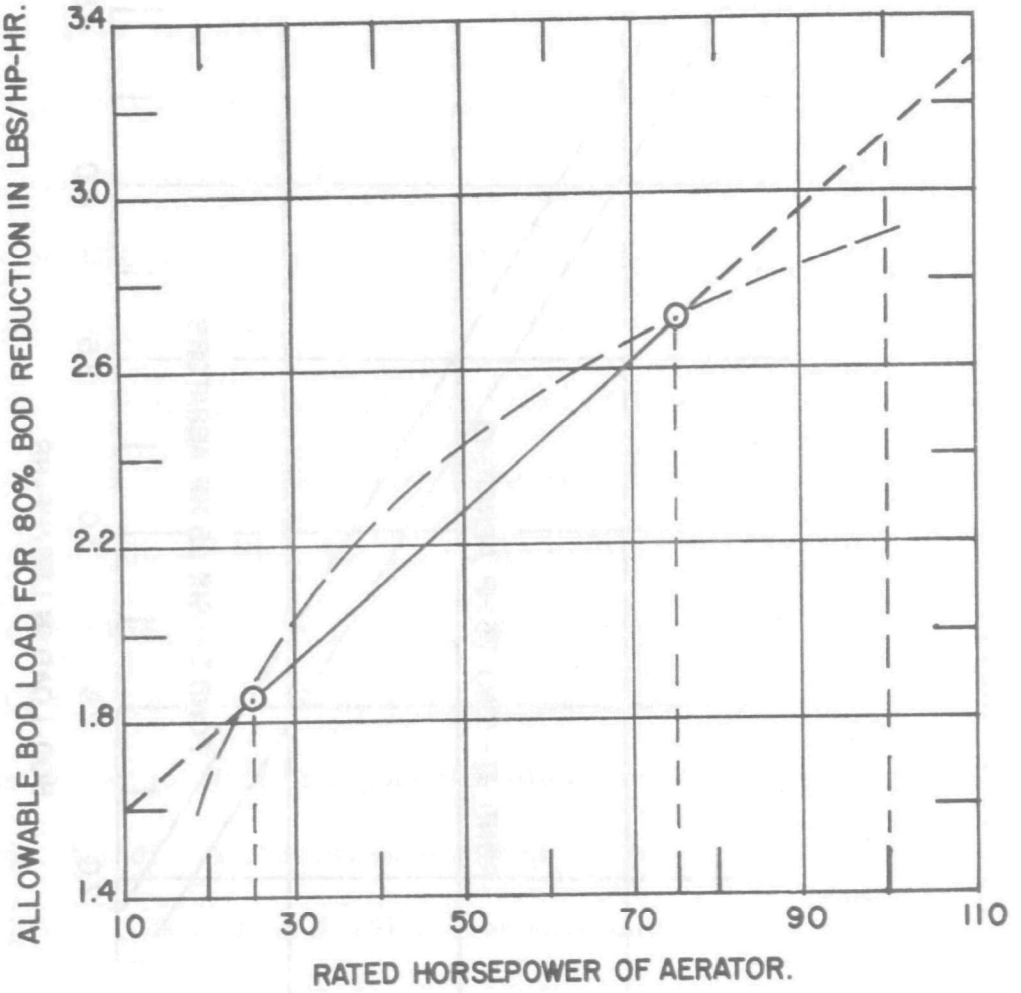
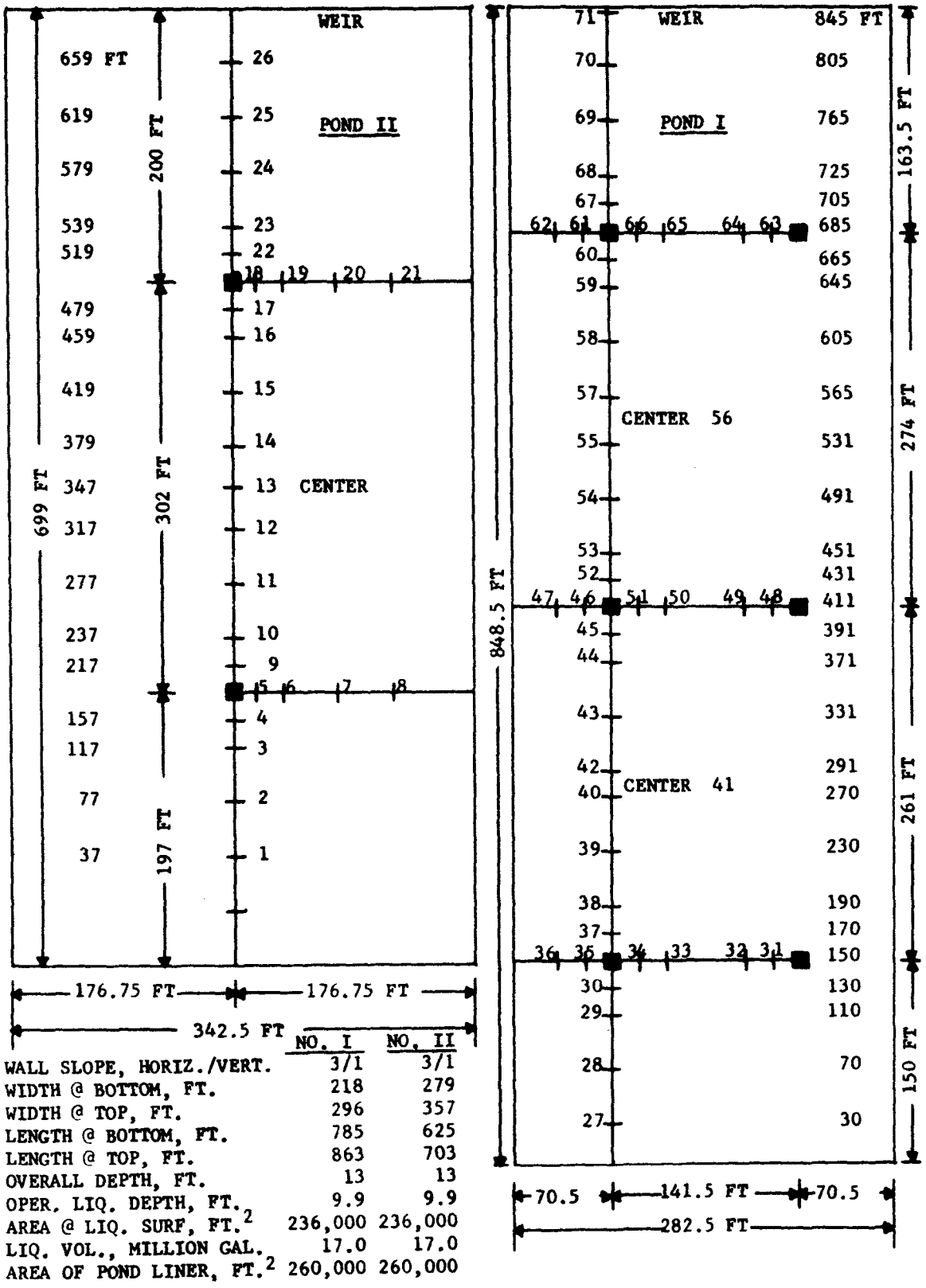


FIGURE 18.—RELATIONSHIP BETWEEN SIZE OF AERATION UNIT AND ALLOWABLE BOD LOAD.



	NO. I	NO. II
WALL SLOPE, HORIZ./VERT.	3/1	3/1
WIDTH @ BOTTOM, FT.	218	279
WIDTH @ TOP, FT.	296	357
LENGTH @ BOTTOM, FT.	785	625
LENGTH @ TOP, FT.	863	703
OVERALL DEPTH, FT.	13	13
OPER. LIQ. DEPTH, FT.	9.9	9.9
AREA @ LIQ. SURF, FT.^{2}	236,000	236,000
LIQ. VOL., MILLION GAL.	17.0	17.0
AREA OF POND LINER, FT.^{2}	260,000	260,000

FIGURE 19--SAMPLE POINTS AND THEIR DISTANCES FROM AERATORS

spacing is of the utmost importance in attaining optimum efficiency.

To gain additional insight into the overall performance of the different aerator sizes and configuration, extensive temperature, D. O. and suspended solids profiles were conducted on July 16, 1969. The location of the sampling stations are shown in Figure 19. The temperature gradients from inlet to outlet are shown in Figure 1A of the Appendix. Although the temperature gradients would have been somewhat steeper during winter, there appears to be a gradient in Pond I as the waste passes through. There was a slight increase in temperature in Pond II from inlet to outlet. The lateral temperature profiles shown in Figure 2A of the Appendix indicate uniform temperature readings across the short pond dimensions.

The D. O. profiles presented in Figure 3A of the Appendix show a substantial difference in D. O. between Pond I and Pond II. For all practical purposes the D. O. in Pond I was zero except in the immediate vicinity of the surface aerators whereas the large aerators and particularly the slow speed geared unit (A2) appeared to have a much greater zone of influence. This was also evident in the lateral profiles as shown in Figure 4A (Appendix).

The average suspended solids profiles for the two ponds are shown in Figure 5A (Appendix). There appeared to be an increase in the suspended solids of Pond I from inlet to outlet whereas there was a slight decrease in

the suspended solids concentration in Pond II.

To gain insight into the mixing characteristics of the different size aerators, velocity profiles were conducted on the two ponds. The velocity profiles from inlet to outlet are shown in Figure 6A of the Appendix. The velocity in Pond II which contained the two 75-h.p. aerators was much greater than in Pond I. Velocity noted in Pond I was limited to the upper 12 inches of depth and dropped rapidly below that depth. The zone of influence of the 25-h.p. units was very restricted. The lateral profiles shown in Figure 7A (Appendix) confirm this observation, i.e., the overall mixing capability of the large units is superior to an equivalent horsepower of smaller units.

Another set of D.O. and BOD profiles was run on the ponds on September 17 and 18, 1969. The ponds again were operated in parallel and samples were taken at the same stations shown in Figure 19. The BOD profiles through the two ponds are shown in Figure 8A. A definite BOD concentration gradient was noted in Pond I from inlet to outlet. The BOD dropped rapidly at the inlet from about 500 ppm to 190 ppm and then gradually decreased in passing through Pond I. The BOD concentration throughout the length of Pond II was uniform indicating complete mixing of the basin contents. The longitudinal aerator spacing in Pond II was 155 ft./aerator or 2.1 ft./h.p. If the two aerators in each section of Pond I are considered as a single entity, the spacing in this pond then

becomes 2.6 ft./h.p. From the data collected it appears that a spacing of about 2 ft./h.p. will ensure complete mixing of the basin contents. A completely mixed basin is to be preferred since it has the capacity to absorb fluctuations in waste strength. Complete mixing also minimizes the potential for odor production.

The D.O. profiles taken on September 17, 1969 are shown in Figure 9A (Appendix). It appears that the Welles aerator in Pond II is actually maintaining a higher D.O. level than the Mixco unit. This may, however, be due to aerator location. For example, the Mixco unit receives the brunt of the BOD load since it is located near the raw waste inlet. The D.O. in Pond I was somewhat higher than in the previous run shown in Figure 3A.

D.O., BOD and temperature profiles were again conducted on November 3 and 17, 1969. The 75-h.p. Welles surface aerator in Pond II was out of order which permitted an evaluation of the 75-h.p. Mixco unit. There was a slight BOD concentration gradient through Pond II whereas the gradient was considerably steeper in Pond I as shown in the BOD profiles in Figures 10A and 11A of the Appendix. The one 75-h.p. aerator was more effective in mixing than the six 25-h.p. units in Pond I. The single 75-h.p. aerator appeared to have an effective D.O. zone of 240 ft. as shown in the November 17 D.O. and temperature profiles in Figures 12A and 13A of the Appendix whereas the remainder of the pond

had very little D. O.

From March 1 through March 12, 1970, the 75-h.p. Mixco surface aerator was shut off and the 75-h.p. Welles unit was moved to the inlet end of Pond II. The two ponds were operated in parallel during this short trial to permit an evaluation of the mixing and reaeration potential of the 75-h.p. Welles unit. The BOD and temperature profiles for the two ponds are shown in Figures 14A and 15A (Appendix). The BOD concentrations throughout Pond II were quite uniform indicating complete mixing with but one 75-h.p. surface aerator whereas there was a definite BOD concentration gradient from inlet to outlet of Pond I. On the basis of the data collected, there appears to be little difference in mixing characteristics and aeration capacity between the high speed, direct drive aerator and the low speed unit.

A comparison of the two large 75-h.p. surface aerators in Pond II was made showing the effectiveness of each individual aerator as well as the two aerators together. The results are presented in Table 15.

The March 1 to March 12, 1970 and May 13 to June 3, 1969 runs were conducted at similar BOD and volumetric waste loads. A comparison of these two runs appears to indicate that the Mixco aerator is a more efficient aeration device than the Welles. However, the results of the October 22 to November 19, 1969 run did not show a significant difference in the pounds of BOD removed. The data collected including the

TABLE 15

COMPARISON OF PERFORMANCE OF 75-H.P. SURFACE AERATORS IN POND II

Run No.*	Aerators Operating	Retention Days	Waste Volume, mgd	pH	Temp., °C.	BOD, Lbs./Day In	BOD, Lbs./Day Out	BOD, Lbs./Day Red.	BOD Red. %	BOD Lbs./hp-hr. Added	BOD Lbs./hp-hr. Removed
1	Welles	7.2	2.37	6.5	18.7	9,426	3,794	5,692	59.7	5.24	3.13
2	Mixco	10.2	1.67	7.2	19.0	7,786	2,312	5,474	70.4	4.33	3.04
3	Mixco	7.5	2.27	7.5	23.0	9,520	2,710	6,810	71.6	5.28	3.78
4	Both	7.8	2.18	7.2	16.0	10,988	3,420	7,809	71.1	3.05	2.17

*Run 1 - March 1 to March 12, 1970
Run 2 - Oct. 22 to Nov. 19, 1969
Run 3 - May 13 to June 3, 1969
Run 4 - Nov. 20 to Jan. 16, 1970

BOD, D.O. and temperature profiles although extensive do not conclusively demonstrate significant differences between the two different types of aerators. Additional profiles taken during the 17 month experimental period are included in the Appendix (Figures 16A, 17A, 18A, 19A, 20A, 21A and 22A).

In summation, it can be concluded that the large horsepower units were more efficient aeration and mixing devices than equivalent horsepower of smaller units, i.e., one 75-h.p. surface aerator will be more effective than three 25-h.p. units. The data are inconclusive in regards to comparing the two large surface aerators (direct drive versus geared unit).

Solids Production in Secondary System

A certain amount of suspended solids were always present in the waste pumped to the aeration basins and the concentration of suspended solids varied quite widely depending upon the condition of the primary settling lagoon. The average influent and effluent characteristics of the waste are presented in Tables V and VI of the Appendix.

The average suspended volatile solids concentration of the influent to the aeration ponds was 62 ppm, whereas the average suspended volatile solids of the treated effluent was 62 ppm. Because of the carryover from the primary system, it was difficult to determine the bacterial solids buildup per unit of BOD destroyed. Turbidity measurements

were actually more indicative of cell buildup than suspended solids. The average JTU's going to the aeration ponds was 112 whereas the treated effluent had an average JTU reading of 214. Most of the turbidity in the final effluent could not be removed by settling but required ultra-filtration or high speed centrifugation. If it is assumed that most of the suspended solids leaving the aeration basins were biological in nature, then 0.16 lbs. of bacterial cells were discharged per pound of BOD destroyed. This is considerably lower than what would be expected from activated sludge which usually averages 0.4 to 0.5 lbs. /lb. of BOD destroyed when treating similar wastes (14).

Removal of the biological cells would reduce the final BOD somewhat, but it is questionable whether this would have any beneficial effect upon the receiving stream. For example, Rader (15) found that simulated streams receiving the treated wastes supported a heavy population of the protozoan, Vorticella. The growth rate of this organism increased in proportion to the suspended bacterial load in the treated waste added to the simulated streams whereas the untreated waste and control supported low concentrations of Vorticella. The number of attached individuals on one side of a microscopic slide (1612 mm^2) after a seven day period is shown in Table 16. It becomes apparent that the bacterial cells discharged readily serve as food for higher forms of life in the food chain which could have an overall beneficial effect upon

productivity of aquatic life in the receiving stream providing D. O. is not adversely affected by discharge of the biological suspended solids.

TABLE 16

THE EFFECT OF BACTERIAL SUSPENDED SOLIDS ON THE GROWTH OF VORTICELLA IN SIMULATED STREAMS (15)

Waste Added to Stream	TOC in Stream, ppm	Total Susp. Sol. in Stream, ppm	Number of Vorticella
Control	--	--	5
Untreated	31	2.5	7
Treated	38	12.7	51
Treated	19	6.4	28
Treated	9.5	3.2	18

Nutrient Content of Waste Discharged

Since the pulping base used at Lebanon was ammonia, considerable ammonia-nitrogen would be expected in the final effluent. The nutrient characteristics of the influent and treated effluent are presented in Table VII of the Appendix. The average nutrient concentration into and out of the secondary system were as follows:

	Kjeldahl-N ppm	Ammonia-N ppm	Total Phosphorous ppm	Soluble Phosphorous ppm
Influent	156	145	1.54	0.96
Effluent	155	139	1.73	0.57

No significant difference in Kjeldahl-nitrogen could be detected between the influent and effluent over the 17 month experimental period whereas a decrease of 6 ppm in ammonia-nitrogen was noted after treatment. Based upon the 62 ppm of suspended volatile solids leaving the secondary ponds, the nitrogen content of the suspended solids would then be about 9.7% which is quite typical of bacterial cells.

A slight increase in total phosphorous was noted after treatment. Whether this difference is statistically significant is questionable. Soluble phosphorous decreased by 41% indicating a significant utilization for cell synthesis or precipitation in the aeration basins. Reduction in the ammonia usage for neutralization would bring down the ammonia-nitrogen concentration in the final effluent to about 98 ppm and elimination of phosphorous additions would reduce the concentration of this element to less than 0.5 ppm.

Composite Effluent Characteristics

A tabulation of the physical and chemical characteristics of the final effluent discharged for each of the individual trials is presented in Table VI of the Appendix. The lowest average BOD concentration per trial was 58 ppm.

An attempt was made to correlate COD and BOD using the average concentrations from each run. A plot of COD versus BOD is presented in Figure 20. Although a line of best fit can be drawn through the points,

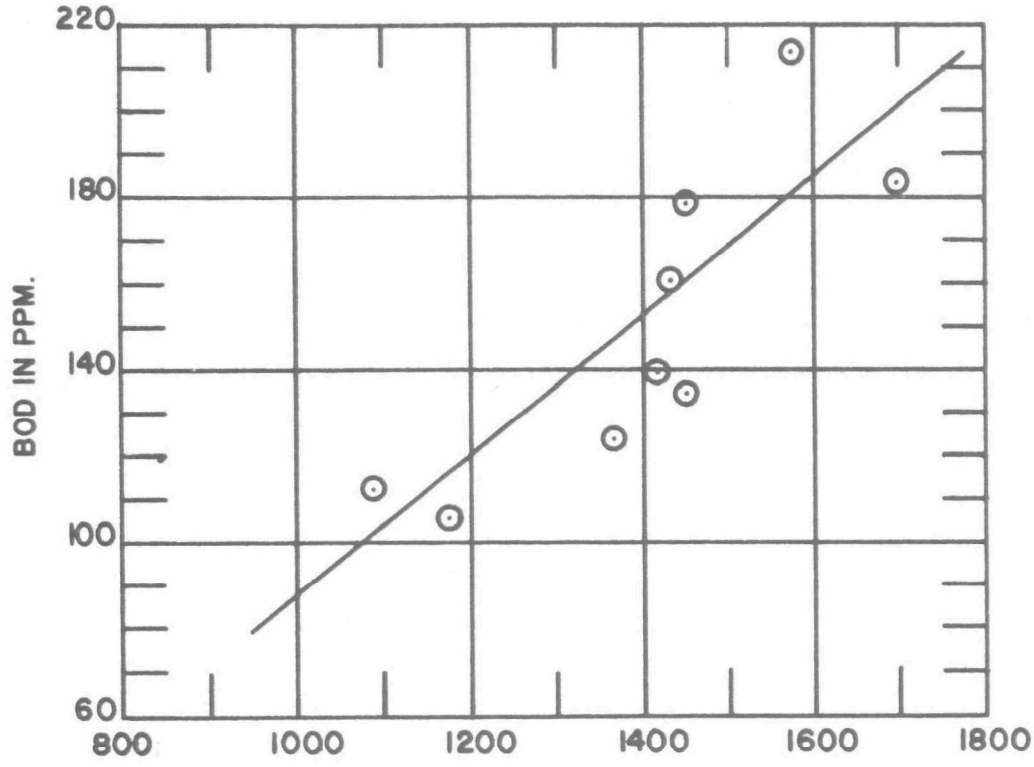


FIGURE 20.—RELATIONSHIP BETWEEN COD AND BOD COMPOSITE EFFLUENT FROM THE SECONDARY TREATMENT SYSTEMS.

using the COD to predict BOD values does not appear to have application for accurate prediction of treatment plant efficiency.

Waste Load Discharged to South Santiam River

The average waste load discharged to the South Santiam River during each run is presented in Table VIII of the Appendix. The average waste volume was 4.2 mgd. The average BOD discharge from June 12, 1969 through October 22, 1969 was 3,120 lbs./day which is probably the lowest level attainable with the existing treatment system. Ammonia-nitrogen discharges can probably be reduced to 4,000 lbs./day by operating at a somewhat lower pH and soluble phosphorous discharge can be maintained below 20 lbs./day without sacrificing operational efficiency.

Slime Growth from Treated and Untreated Waste

The major compounds in spent sulfite liquor which serve as a readily available source of carbon for Sphaerotilus natans are the six carbon sugars such as glucose and mannose, the five carbon sugar xylose, and acetic acid. Scheuring and Höhnl (16) demonstrated by extensive laboratory experimentation that these compounds support luxuriant growths of Sphaerotilus.

A series of experiments was conducted using the experimental streams described in a previous section of this report to determine the amount of slime growth that would be produced by adding various amounts

of treated and untreated waste to South Santiam River water. The amount of slime obtained after 2, 4 and 6 days of continuous operation is shown in Table IX of the Appendix and the average results are presented in Table 17. In general, slime growth was closely related to the amount of BOD added to the simulated streams. However, the experiments conducted indicated that the treated waste always produced considerably less slime per unit BOD added than the untreated waste. For example, if streams 2 and 6 are compared, it can be seen that although the BOD additions to these two streams were almost identical, the amount of slime produced was considerably greater in the stream receiving the untreated waste. After treatment most of the readily available BOD is destroyed leaving a substantial amount of BOD which evidently cannot be used by Sphaerotilus or is used at a very slow rate. This has also been confirmed by Amberg and Cormack (5, 17) who found that aerobic bacterial treatment of ammonia base spent sulfite liquor resulted in much lower slime growth than raw waste at equivalent BOD concentrations. These experiments are also in agreement with Wuhrman (6) who found that equal concentrations of BOD achieved in a river by dilution of settled or biologically treated sewage did not produce comparable associations of microorganisms. Wuhrman concluded that biological treatment of domestic sewage produced qualitative as well as quantitative alteration of sewage compounds, which could not be

detected by the usual comprehensive criteria such as BOD, organic nitrogen, organic carbon, etc.

TABLE 17

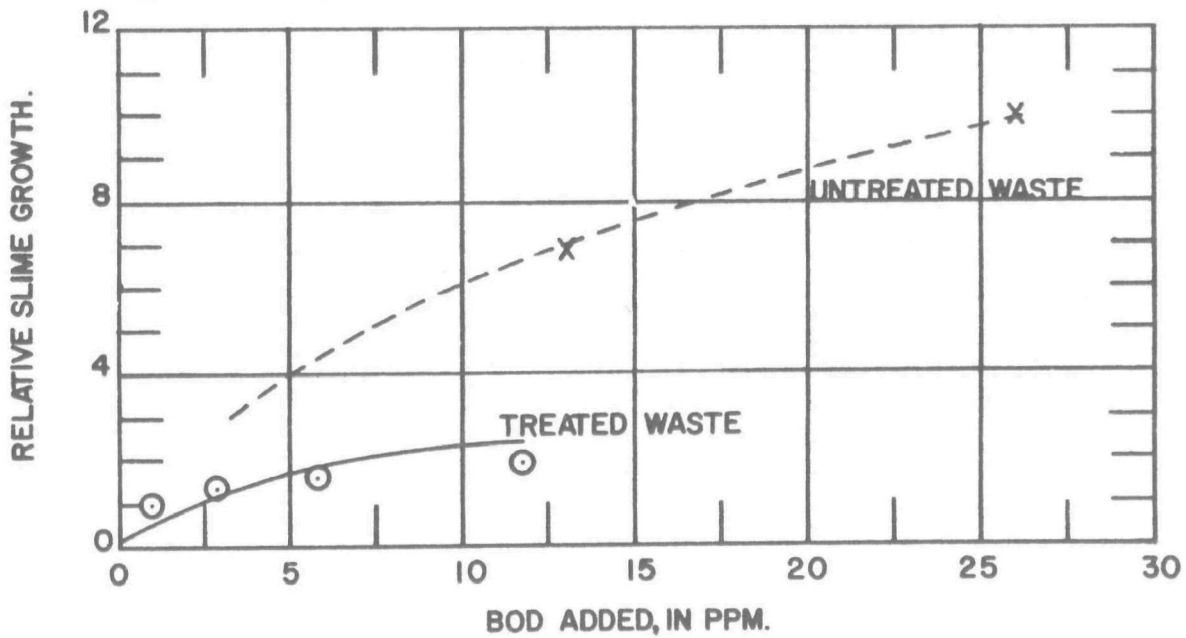
SLIME GROWTH POTENTIAL OF TREATED AND UNTREATED WASTE ADDED TO SIMULATED STREAMS

Stream Number	Waste Added	BOD in Stream, ppm	Slime Growth in mgm/ft.^{2}/day			
			Total Solids	Relative Growth	Volatile Solids	Relative Growth
1	None	1.0	107	1.0	17	1.0
4	Treated	2.9	106	1.0	23	1.4
3	Treated	5.8	122	1.1	27	1.6
2	Treated	11.7	163	1.5	42	1.9
6	Untreated	13.0	295	2.8	117	6.9
5	Untreated	26.1	428	4.0	170	10.0

In general, the studies conducted at Lebanon showed conclusively that treatment of the mill waste to a BOD reduction of 80 to 85% produced a waste which did not readily support slime growth. The effect of treatment can readily be seen by referring to Figure 21. Two to three times as much slime was produced from untreated waste than for equivalent BOD additions of treated waste.

It becomes apparent that biological treatment of the Lebanon waste serves two very important functions: the first, destruction of oxygen

FIGURE 21.—SIMULATED STREAM STUDIES AND THE EFFECT OF BOD UPON SLIME GROWTH FROM SEPTEMBER 26 TO OCTOBER 13, 1970.



depleting organic material which could affect the D.O. of the South Santiam River during the critical low flow period and the second, reduction or elimination of the waste's ability to support troublesome filamentous slime growths.

Capital Costs of Secondary Treatment System

A detailed breakdown of capital costs is shown in Table X of the Appendix and a summary of the major capital items is presented in Table 18. Total capital cost for the secondary system was $665,000. Of the total capital cost, 29.3% was attributable to labor and 70.7% to materials. Capital costs based upon waste volume, BOD and pulp tonnage capacity were as follows:

Dollars/Daily AD Ton of Pulp	6,650
Dollars/mg of waste treated/day	166,000
Dollars/lb. of Daily BOD Removed*	55.50

*Based on 12,000 lbs. of BOD removed/day.

Because of the small size of the mill, unit capital costs based upon tonnage are quite high. Furthermore, since the waste being treated had a BOD of about 500 ppm, capital costs based upon volume were also high. If the calculations are adjusted to a waste BOD of 200 ppm, the volume would then become 10.5 mgd and the unit capital cost would be $63,400/mgd of treated waste. Because of the experimental program,

the capital costs were somewhat higher than would normally be expected. For example, the simulated streams, recirculation system, series, etc. added close to $100,000 to the cost of the installation.

TABLE 18

CAPITAL COST OF SECONDARY TREATMENT SYSTEM

Item	Cost in Dollars		
	Labor	Materials	Labor + Materials
Aeration Ponds	62,796	67,178	129,974
Aerators	2,010	65,225	67,235
Pumps and Sumps	6,579	73,123	79,702
Nutrient Tanks	316	6,187	6,503
Piping	28,377	113,542	141,919
Instrumentation	8,354	19,426	27,780
Control Building	5,476	12,817	18,293
Electrical	15,952	55,375	71,327
Miscellaneous	18,660	57,152	75,812
Engineering	46,455	--	46,455
TOTALS	194,975	470,025	665,000

Operating Costs

The items which make up the operating costs in the calculations presented are: electric power, operating labor, repair labor, repair

materials, water, chemicals, administrative overhead, fringe benefits, interest on capital and depreciation. Electric power rates averaged about 5 mils/kw-hr. during the 17 month period. The chemical costs included a small amount of phosphoric acid nutrient and ammonia for neutralization. Interest on the $665,000 capital investment was calculated at 9% and straight line depreciation was taken over 15 years.

A breakdown of the direct operating costs exclusive of interest, depreciation and research and development costs is presented in Table 19. The total direct operating costs averaged $5,430 per month. A summary of the operating costs including interest on the capital and depreciation is presented in Table 20. Monthly total operating costs averaged $14,120. The largest items were the fixed costs, interest on the capital investment and depreciation which accounted for 61.5% of the total operating costs. Electric power and chemicals were the largest cost items of the direct operating costs and they accounted for 22.53% of the total operating costs. The ease of operation of the secondary treatment system is reflected in the low operating labor cost of 1.35% of the total or $191/month.

TABLE 19

MONTHLY DIRECT OPERATING COSTS EXCLUSIVE OF INTEREST AND DEPRECIATION (DOLLARS)

Month	Electric Power	Operating Labor	Repair Labor	Repair Material	Water	Chemicals	Adm. Overhead	Fringe Benefits	Total
April, 1969	1,155	37	751	557	-	3,143	388	85	6,076
May	1,092	-	332	511	319	3,570	388	40	6,253
June	1,193	19	1,025	1,984	353	2,214	388	141	7,317
July	1,315	-	646	2,829	341	2,374	388	84	7,977
Aug.	1,198	215	824	718	278	2,191	388	135	5,947
Sept.	1,167	292	392	755	284	2,417	388	79	5,774
Oct.	1,180	242	468	173	269	2,810	388	102	5,632
Nov.	967	189	774	172	325	1,531	388	124	4,470
Dec.	1,149	266	732	531	256	1,916	388	88	5,326
Jan., 1970	1,583	210	1,044	730	239	1,866	388	156	6,216
Feb.	1,304	231	883	492	232	1,218	388	139	4,887
Mar.	1,039	231	297	701	246	1,487	388	40	4,429
April	1,107	289	229	116	232	1,358	388	63	3,782
May	1,145	231	306	220	251	563	388	65	3,169
June	1,220	231	649	363	264	2,014	388	107	5,236
July	1,310	281	648	274	276	1,824	379	111	5,103
Aug.	1,098	277	773	769	263	1,395	-	126	4,701
Total	20,222	3,241	10,773	11,890	4,428	33,891	6,199	1,685	92,295
Average	1,190	191	633	699	261	1,992	365	99	5,430
% of Total	21.9	3.5	11.7	12.9	4.8	36.7	6.7	1.8	100.0

TABLE 20

SUMMARY OF DIRECT AND INDIRECT OPERATING COSTS - AVERAGE OF 17 MONTH PERIOD APRIL 1969 THROUGH AUGUST 1970

Item	Dollars/Month	% of Total
Electric Power @ $.005 kw/hr.	1,190	8.43
Operating Labor	191	1.35
Repair Labor	633	4.48
Repair Material	699	4.95
Water	261	1.85
Chemicals	1,992	14.10
Administrative Overhead	365	2.58
Fringe Benefits	99	0.70
Interest on Capital @ 9%	4,990	35.80
Depreciation, S. L. - 15 years	3,700	26.20
TOTAL	14,120	99.94

Direct operating costs (exclusive of interest and depreciation) have been calculated per unit of production, BOD, waste volume bases as shown in Table 21. The following table summarizes the direct operating costs and the total operating costs including interest and depreciation:

TABLE 21

DIRECT OPERATING COSTS EXCLUSIVE OF INTEREST AND DEPRECIATION APRIL 1969 THROUGH AUGUST 1970

Month	Dollars/ Month	Dollars Per Ton A. D. Pulp	Dollars Per mg	Dollars Per Lb. BOD Added	Dollars Per Lb. BOD Removed
April, 1969	6,076	2.02	49.90	.0092	.0136
May	6,253	2.35	44.90	.0100	.0143
June	7,317	2.62	63.10	.0151	.0191
July	7,977	2.65	61.00	.0176	.0212
Aug.	5,947	1.93	47.00	.0129	.0149
Sept.	5,774	2.00	43.60	.0110	.0142
Oct.	5,632	1.85	48.40	.0110	.0143
Nov.	4,470	1.50	41.40	.0089	.0127
Dec.	5,326	1.87	39.90	.0079	.0121
Jan., 1970	6,216	2.07	46.60	.0092	.0141
Feb.	4,887	1.73	38.90	.0080	.0108
Mar.	4,429	1.41	32.70	.0072	.0113
April	3,782	1.27	27.80	.0058	.0084
May	3,169	1.00	25.40	.0061	.0084
June	5,236	1.75	41.80	.0098	.0131
July	5,103	1.79	39.60	.0092	.0123
Aug.	4,701	1.46	36.10	.0098	.0133
	5,430	1.84	42.80	.0099	.0134

	Direct Costs Without Interest and Depreciation	Total Costs Including Interest and Depreciation
Dollars/Month	5,430	14,120
Dollars/Year	65,200	169,500
Dollars/A D Ton of Production	1.84	4.79
Dollars/mg	42.80	111.20
Dollars/lb. BOD Added	.0099	.0257
Dollars/lb. BOD Removed	.0134	.0348

The average unit cost over the 17 month period was $4.79/ton of production or about 11.1 cents/1,000 gallons treated. On a BOD basis, the operating costs averaged 2.57 cents/lb. of BOD added and 3.48 cents/lb. of BOD destroyed. Although some minor economies could be realized in the operation of the facilities such as reduction in chemicals, it is doubtful whether the total operating costs would be significantly affected. It becomes evident that secondary treatment is quite costly and certainly adds a substantial amount to production costs.

ACKNOWLEDGEMENTS

This project was conducted at the Lebanon Division of Crown Zellerbach Corporation. Those involved at the mill in ensuring the success of the development program were:

Mr. R. G. Kott, Manager

Mr. A. M. Neelley, Manager

Mr. E. C. Mays, Manager

Mr. K. F. Byington, Technical Director

Mr. A. C. Moncini, Plant Engineer

Mr. H. P. Burrelle, Office Manager

The treatment plant facilities were designed by Mr. J. J. Ehli of the Crown Zellerbach Central Engineering Division, Seattle, Washington and Mr. Kenneth R. Blaney served as Acting Deputy Project Director during the engineering and construction phases of the project.

The technical aspects of the program such as testing and evaluation of data were undertaken at the Crown Zellerbach Central Research Division by the following personnel:

Dr. H. R. Amberg, Manager, Environmental Research Dept. (Project Director)

Dr. T. R. Aspitarte, Supervisor, Microbiological Research

Mr. S. H. Watkins, Research Microbiologist

Mr. J. G. Coma, Supervisor, Process Engineering

Mr. O. Hamblen, Technician

Mr. R. Bafus, Technician

The support of the project by the Federal Water Quality Administration and the help provided by Messrs. A. Cywin and G. R. Webster is gratefully acknowledged and appreciated. We were particularly pleased with the help and guidance provided by Mr. R. H. Scott, the Project Officer and Dr. H. K. Willard of the Pacific Northwest Water Laboratory. A substantial portion of the analytical work was conducted by the staff of the Pacific Northwest Water Laboratory and we wish to acknowledge the following who were active in the analytical program: Mrs. F. Cole, Mrs. M. Carpenter, Mr. J. O'Donnell, Mr. C. Greenup and Mr. F. Roberts.

Advice and help was received from the staff of the National Council for Air and Stream Improvement and we would like to express our thanks to Messrs. R. O. Blosser, A. L. Caron and E. L. Owens.

The suggestions and advice provided by Dr. E. J. Ordal, Professor Microbiology at the University of Washington were very helpful in the planning and execution of the experimental program. The cooperation received from the Oregon State Department of Environmental Quality is gratefully acknowledged. Messrs. W. C.

Westgarth, A. Hose and G. Carter of the Department served as advisors to the project.

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TABLE I

AVERAGE PERFORMANCE DATA FOR POND I (SIX 25 HP. SURFACE AERATORS)

Date of Run	Ret. Days	Temp. °C.	Vol. mgd	Hp.	BOD, Lbs./Day In	Out	Red.	% BOD	BOD Lbs./Hp.Hr. Added	Red.
April 17-April 29, 1969	8.3	19	2.05	150	12,200	3,020	9,180	75.3	3.39	2.55
May 3-May 10	7.6	22	2.23	150	10,680	3,450	7,230	67.8	2.97	2.01
May 13-June 3	7.5	23	2.27	100	9,400	2,730	6,670	71.0	3.92	2.78
June 12-June 26	8.4	24	2.03	150	8,480	2,100	6,380	75.3	2.36	1.78
July 7-July 21	8.2	25	2.08	150	7,194	1,383	5,811	80.8	2.00	1.61
Aug. 1-Sept. 1	8.3	25	2.05	150	7,449	1,139	6,310	84.7	2.07	1.75
Sept. 1-Sept. 19	8.1	23	2.09	150	8,265	1,897	6,368	77.1	2.30	1.77
Sept. 19-Oct. 22	9.0	20	1.88	150	8,295	1,788	6,507	78.5	2.30	1.81
Oct. 22-Nov. 19	8.8	19	1.94	150	9,026	2,729	6,297	69.8	2.51	1.74
Nov. 20-Jan. 16, 1970	8.0	16	2.13	150	10,741	4,129	6,562	61.1	2.98	1.82
Jan. 16-Feb. 18	3.8	15	4.49	150	9,667	6,033	3,634	37.6	2.76	1.01
Mar. 1-Mar. 12	7.8	17	2.17	150	8,626	3,309	5,317	61.6	2.40	1.48
Mar. 23-April 7	16.7	17	1.02	150	5,329	1,200	4,129	77.5	1.48	1.15
April 17-May 6	7.8	18	2.18	150	10,514	3,904	6,610	62.9	2.92	1.84
May 6-June 9	8.2	23	2.08	150	8,710	2,909	5,801	66.6	2.42	1.61
June 27-July 13	8.2	26	2,08	150	8,956	2,661	6,295	70.3	2.49	1.75
July 25-Sept. 5	8.8	25	1.93	150	7,081	1,920	5,161	72.9	1.97	1.43

TABLE II

AVERAGE PERFORMANCE DATA FOR POND II (TWO 75 HP. SURFACE AERATORS)

Date of Run	Ret. Days	Temp. °C.	Vol. mgd	Hp.	BOD, Lbs./Day In	BOD, Lbs./Day Out	BOD, Lbs./Day Red.	% BOD Red.	BOD Lbs./Hp.Hr. Added	BOD Lbs./Hp.Hr. Red.
April 17-April 29, 1969	8.3	19	2.05	75	11,150	4,150	7,000	62.8	6.78	4.58
May 3-May 10	7.6	22	2.23	150	10,680	3,070	7,610	71.3	2.96	2.11
May 12-June 3	7.5	23	2.27	75	9,520	2,710	6,810	71.6	5.28	3.78
May Av.	7.6	22	2.25	99	--	--	--	--	3.93	2.75
June 12-June 27	9.2	25	1.84	150	7,690	1,335	6,355	82.7	2.14	1.77
July 7-July 21	8.0	26	2.14	150	7,430	1,115	6,315	85.0	2.06	1.75
Aug. 1-Sept. 1	8.4	26	2.03	150	7,384	826	6,558	88.8	2.05	1.82
Sept. 1-Sept. 19	7.3	24	2.33	150	9,224	2,078	7,146	77.5	2.56	1.98
Sept. 19-Oct. 22	9.1	22	1.88	150	8,277	2,003	6,274	75.8	2.30	1.74
Oct. 22-Nov. 19	10.0	19	1.67	75	7,786	2,312	5,474	70.4	4.32	3.04
Nov. 20-Jan. 16, 1970	7.8	16	2.18	150	10,988	3,420	7,809	71.1	3.05	2.17
Jan. 16-Feb. 18	3.8	19	4.49	150	22,200	9,667	12,533	56.5	6.17	3.48
Mar. 1-Mar. 12	7.2	19	2.37	75	9,426	3,794	5,632	59.7	5.24	3.13
Mar. 23-April 17	5.3	21	3.21	150	16,779	6,621	10,158	60.5	4.66	2.82
April 7-May 6	7.2	19	2.35	150	11,364	2,610	8,754	77.0	3.16	2.43
May 6-June 9	8.2	25	2.08	150	8,735	1,962	6,773	77.5	2.43	1.88
June 17-July 13	8.2	27	2.08	150	8,952	1,929	7,023	78.5	2.49	1.95
July 25-Sept. 5	7.5	26	2.28	150	8,345	2,090	6,255	75.0	2.32	1.74

TABLE III

AVERAGE PERFORMANCE DATA FOR COMBINED SECONDARY SYSTEM (AERATION CAPACITY 300 HP.)

Date of Run	Vol. mgd	Temp. °C.	Hp.	BOD, Lbs./Day In	Out	Red.	% Red.	BOD Lbs./Hp.Hr. Added	Red.
April 17-April 29, 1969	4.10	19	225	23,350	5,910	17,440	74.8	4.33	3.23
May 3-May 10	4.46	22	300	21,360	6,520	14,840	69.7	2.96	2.06
May 12-June 3	4.54	23	175	18,920	5,440	13,480	71.3	4.51	3.21
June 12-June 26	3.87	24	300	16,180	3,385	12,795	79.1	2.25	1.78
July 7-July 21	4.22	25	300	14,620	2,484	12,140	84.1	2,03	1.69
Aug. 1-Sept. 1	4.08	26	300	14,833	1,964	12,869	86.8	2.06	1.79
Sept. 1-Sept. 19	4.42	23	300	17,489	3,903	13,586	77.6	2.43	1.89
Sept. 19-Oct. 22	3.75	21	300	16,572	3,885	12,687	76.6	2.30	1.76
Oct. 22-Nov. 19	3.61	19	225	16,812	5,041	11,771	70.0	3.11	2.18
Nov. 20-Jan. 16, 1970	4.31	16	300	21,729	7,447	14,282	65.7	3.01	1.98
Jan. 16-Feb. 18	4.49	17	300	22,000	6,033	16,167	72.8	3.08	2.25
Mar. 1-Mar. 12	4.54	17	225	18,052	6,926	11,136	61.7	3.34	2.06
Mar. 23-April 7	4.23	19	300	21,754	7,558	14,196	65.3	3.02	1.97
April 7-May 6	4.53	18	300	21,878	6,764	15,114	69.1	3.01	2.10
May 6-June 9	4.16	24	300	17,445	4,821	12,624	72.4	2.42	1.75
June 27-July 13	4.17	26	300	17,908	4,590	13,318	74.4	2.49	1.85
July 25-Sept. 5	4.21	25	300	15,426	4,010	11,416	74.0	2.14	1.59

TABLE IV

CALCULATION OF AERATOR DELIVERED COST AND INSTALLED COST

POND I - Six 25 hp. Welles Aerators

A. Delivered Cost Basis:

Motors	$ 3,776	
Aerators	27,481	
Delivered Cost	$31,257	
Delivered Cost/hp.	= $31,257/150	= $208

B. Installed Cost Basis:

Aerators & Motors	$31,257	
Mooring Cables	2,729	
Installation Mtls.	102	
Installation Labor	1,097	
Electrical Gear & Hookup	21,480	
Installed Cost	$56,665	
Installed Cost/hp.	= $56,665/150	= $378

POND II - One 75 hp. Mixco and One 75 hp. Welles

A. Mixco Aerator (75 hp.)

1. Delivered Cost Basis:

Motor	$ 838
Aerator	13,891

TABLE IV (CONTINUED)

CALCULATION OF AERATOR DELIVERED COST AND INSTALLED COST

Delivered Cost	$14,729		
Delivered Cost/hp.	= $14,729/75	=	$196

2. Installed Cost Basis:

Aerator and Motor	$14,729
Mooring Cables	557
Installation Matls.	800
Installation Labor	377
Electrical Gear & Hookup	6,445
Installed Cost	$22,908

Installed Cost/hp.	= $22,908/75	=	$305

B. Welles Aerator (75 hp.)

1. Delivered Cost Basis:

Motor	$ 2,298
Aerator	11,075
Delivered Cost	$13,373

Delivered Cost/hp.	= $13,373/75	=	$178

2. Installed Cost Basis:

Aerator and Motor	$13,373
Mooring Cables	557

TABLE IV (CONTINUED)

CALCULATION OF AERATOR DELIVERED COST AND INSTALLED COST

Installations Matls.	800
Installation Labor	377
Electrical Gear & Hookup	6,445
Installed Cost	$21,552
Installed Cost/hp. =	$21,552/75 = $287

TABLE V

AVERAGE ANALYSES OF UNTREATED WASTE FEED TO SECONDARY TREATMENT SYSTEM

Date of Run	Vol. mgd	pH	Temp. °C.	BOD, ppm	Susp. Sol., ppm	Susp. Vol. Sol., ppm	Total Sol., ppm	JTU	COD ppm
June 12-June 26-1969	3.87	7.5	29.4	501	102	94	1,802	-	228
July 7-July 21	4.22	6.2	33.4	415	36	30	1,452	-	215
Aug. 1-Sept. 1	4.08	7.5	33.7	438	51	43	1,585	-	145
Sept. 1-Sept. 19	4.42	7.3	31.5	475	78	40	1,845	119	1,433
Sept. 19-Oct. 22	3.75	6.9	32.5	529	163	-	1,930	168	1,930
Oct. 22-Nov. 19	3.60	6.9	30.0	559	87	32	2,006	146	2,168
Nov. 20-Jan. 16, 1970	4.31	7.3	28.0	604	88	76	2,661	116	2,211
Jan. 16-Feb. 18	4.49	7.1	29.0	593	117	92	1,580	112	1,864
Mar. 1-Mar. 12	4.54	6.6	29.2	477	98	87	1,944	95	1,690
Mar. 23-April 7	4.23	6.7	30.4	626	164	145	1,878	114	1,809
April 17-May 6	4.53	6.5	30.1	579	110	101	1,416	87	2,580
May 6-June 9	4.16	5.7	32.0	503	29	24	1,405	81	1,793
June 27-July 18	4.17	6.1	35.0	515	20	17	1,596	91	1,614
July 25-Sept. 5	4.21	6.6	34.4	439	32	27	1,211	108	1,412

TABLE VI

AVERAGE ANALYSES OF TREATED EFFLUENT FROM COMBINED TREATMENT SYSTEM

Date of Run	Vol. mgd	pH	Temp. °C.	BOD, ppm	Susp. Sol., ppm	Susp. Vol. Sol., ppm	Total Sol., ppm	JTU	COD ppm
May 13-June 3, 1969	4.54	7.1	22.0	140	92	-	-	216	-
June 12-June 26	3.87	7.2	24.3	105	48	48	1,660	301	-
July 7-July 21	4.22	7.0	24.9	70	54	73	1,433	220	-
Aug. 1-Sept. 1	4.08	7.1	25.6	58	77	60	1,329	177	-
Sept. 1-Sept. 19	4.42	7.0	23.5	106	73	70	1,305	181	1,176
Sept. 19-Oct. 22	3.75	7.0	21.0	124	47	37	1,544	213	1,364
Oct. 22-Nov. 19	3.60	6.9	19.0	169	60	25	1,902	208	-
Nov. 20-Jan. 16, 1970	4.31	6.9	16.0	207	-	-	1,873	274	-
Jan. 16-Feb. 18	4.49	6.8	15.0	161	114	96	1,639	229	1,431
Mar. 1-Mar. 12	4.54	6.6	17.3	183	51	49	1,650	217	1,698
Mar. 23-April 7	4.23	6.9	19.5	214	79	68	1,587	170	1,569
April 17-May 6	4.53	6.5	18.5	179	69	75	1,815	175	1,450
May 6-June 9	4.16	5.7	24.0	139	111	107	1,463	202	1,415
June 27-July 13	4.17	6.4	26.0	135	72	42	1,443	244	1,448
July 25-Sept. 5	4.21	6.7	25.3	114	71	55	1,175	183	1,093

TABLE VII

AVERAGE NITROGEN AND PHOSPHOROUS CONTENT OF UNTREATED AND TREATED WASTE

Date of Run	Influent Waste, ppm		Phosphorous, ppm		Treated Effluent, ppm			
	Kjeldahl-N	Ammonia-N	Total	Sol.	Kjeldahl-N	NH_3-N	Tot. P	Sol. P
July 7-July 21, 1969	136	128	2.60	2.30	159	142	2.60	1.40
Aug. 1-Sept. 1	173	159	0.45	0.19	160	153	0.92	0.21
Sept. 1-Sept. 19	141	138	0.75	0.46	150	136	1.11	0.50
Sept. 19-Oct. 22	183	180	1.57	0.87	173	165	1.55	0.41
Oct. 22-Nov. 19	204	189	2.00	0.99	200	177	1.96	0.82
Nov. 20-Jan. 16, 1970	193	181	2.40	1.20	178	158	2.32	0.82
Jan. 16-Feb. 18	166	153	1.57	0.71	163	147	1.85	0.36
Mar. 1-Mar. 12	165	155	0.98	0.59	158	136	1.05	0.29
Mar. 23-April 17	158	146	1.46	0.88	161	143	1.91	0.34
April 17-May 6	147	134	1.58	0.94	147	131	1.93	0.43
May 6-June 9	116	111	1.53	1.16	122	113	1.72	0.45
June 27-July 13	107	96	1.62	1.16	118	98	1.88	0.64
July 25-Sept. 5	136	113	1.51	1.06	127	109	1.73	0.76
Average	156	145	1.54	0.96	155	139	1.73	0.57

TABLE VIII

AVERAGE LOAD DISCHARGED TO SOUTH SANTIAM RIVER JUNE 1969 THROUGH JULY 1970

Date of Run	Vol. mgd	BOD Lbs. /Day	Susp. Sol., Lbs. /Day	Vol. Susp. Sol., Lbs. /Day	Ammonia-N Lbs. /Day	Sol. Phosphorous Lbs. /Day
June 12-June 27, 1969	3.87	3,385	1,550	-	-	-
July 7-July 21	4.22	2,484	1,900	-	5,000	49.3
Aug. 1-Sept. 1	4.08	1,964	2,620	2,040	5,210	7.1
Sept. 1-Sept. 19	4.42	3,903	3,320	2,560	5,010	18.5
Sept. 19-Oct. 22	3.75	3,885	1,472	1,159	5,168	12.8
Oct. 22-Nov. 19	3,60	5,041	3,638	3,175	5,323	24.7
Nov. 20-Jan. 16, 1970	4.31	7,447	4,568	4,280	5,684	29.5
Jan. 16-Feb. 18	4.49	6,033	4,272	3,597	5,433	16.1
Mar. 1-Mar. 12	4.54	6,926	1,932	1,856	5,152	11.0
Mar. 23-April 7	4.23	7,557	2,789	2,400	5,047	12.0
April 7-May 6	4.53	6,764	2,608	2,835	4,952	16.3
May 6-June 9	4.17	4,821	3,850	3,711	3,919	15.6
June 17-July 13	4.17	4,580	2,504	1,460	3,408	22.3
July 25-Sept. 5	4.21	3,783	2,494	1,933	3,829	26.0

TABLE IX

SLIME GROWTH IN SIMULATED STREAMS - SEPT. 26 - OCT. 13, 1970

Growth in Grams/Sq. Ft./Day

Channel	Age of Slime on Boards												Grand
	2 Days				4 Days				6 Days				
	9/29	10/6	10/13	Av.	9/22	10/1	9/22	Av.	9/24	10/3	10/10	Av.	Av.
1	.166	.155	.119	.147	.113	.100	.117	.110	.068	.061	.059	.063	.107
2	.260	.271	.128	.220	.101	.290	.087	.159	.057	.128	.145	.110	.163
3	.175	.146	.126	.149	.077	.134	.096	.102	.041	.148	.122	.104	.122
4	.150	.125	.104	.126	.112	.141	.107	.120	.029	.076	.115	.073	.106
5	.670	.382	.359	.470	.604	.472	.384	.487	.252	.285	.442	.321	.428
6	.586	.295	.312	.398	.261	.306	.226	.251	.146	.310	.255	.237	.295

Grams of Volatile Solids/Sq. Ft./Day

Channel	Age of Slime on Boards												Grand
	2 Days				4 Days				6 Days				
	9/29	10/6	10/13	Av.	9/22	10/1	9/22	Av.	9/24	10/3	10/10	Av.	Av.
1	.0267	.0298	.0190	.0195	.0235	.0178	.0138	.0185	.0109	.0126	.0131	.0124	.0168
2	.0874	.0794	.0390	.0439	.0292	.0966	.0204	.0455	.0140	.0544	.0537	.0381	.0425
3	.0481	.0333	.0268	.0254	.0181	.0379	.0192	.0244	.0112	.0492	.0373	.0320	.0273
4	.0347	.0270	.0207	.0205	.0222	.0373	.0138	.0233	.0059	.0230	.0559	.0241	.0226
5	.4730	.1681	.1572	.1427	.2126	.2544	.1590	.2118	.0761	.1907	.2099	.1571	.1705
6	.3891	.1230	.1185	.1143	.0796	.1658	.0667	.0956	.0721	.2021	.1604	.1403	.1167

TABLE X

CAPITAL COST DETAILS

Item	$ Labor	$ Materials	$ Labor + Materials
1. Aeration Ponds			
Land Clearing	10,949	-	10,949
Earth Moving	32,950	-	32,950
Pump Rental	-	1,564	1,564
Sand Liner (520,000 sq. ft.)	7,436	11,999	19,435
Plastic Liner (520,000 sq. ft.)	4,304	34,990	39,294
Overflow Weirs	7,157	18,625	25,782
	62,796	67,178	129,974
2. Aerators, Pond No. 1			
6 - 25 h.p. Aerators & Motors	-	31,257	31,257
Mooring Cables	-	2,729	2,729
Installation	1,097	102	1,199
	1,097	34,088	35,185
3. Aerators, Pond No. 2			
1 - 75 h.p. Mixco Aerator & Motor	-	16,110	16,110
1 - 75 h.p. Welles " " "	-	13,671	13,671
Mooring Cables	-	1,114	1,114
Installation	913	242	1,155
	913	31,137	32,050

TABLE X (CONTINUED)

CAPITAL COST DETAILS

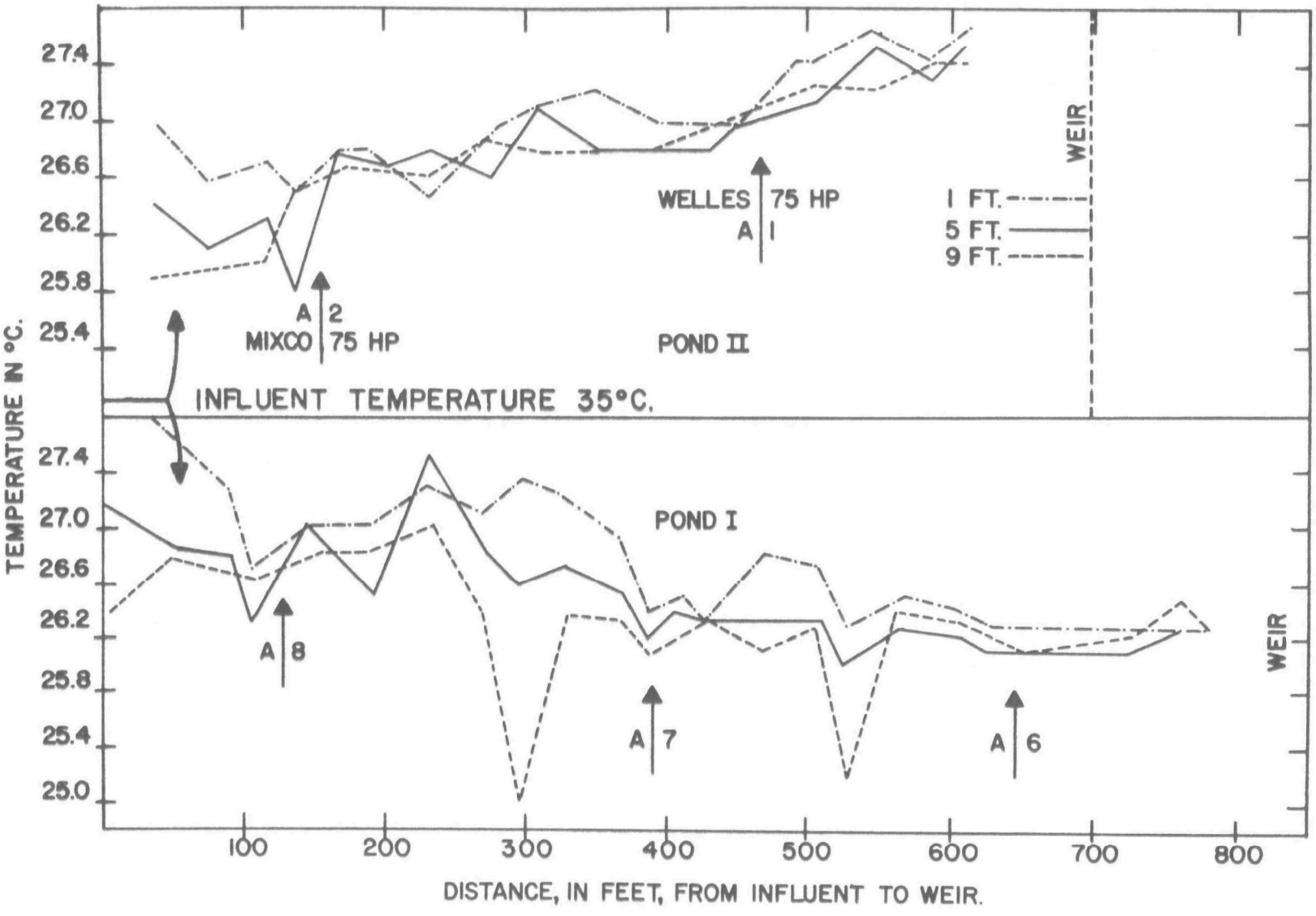
Item	$ Labor	$ Materials	$ Labor + Materials
4. Pumps & Sumps			
Pumps & Motors	-	35,260	35,260
Installation	6,579	37,863	44,442
	6,579	73,123	79,702
5. Nutrient Tanks	316	6,187	6,503
6. Piping	28,377	113,542	141,919
7. Instrumentation	8,354	19,426	27,780
8. Control Building & Tank Slab	5,476	12,817	18,293
9. Electrical System	15,952	55,375	71,327
10. Experimental Streams	12,873	28,155	41,028
11. Miscellaneous			
Boats	-	360	360
Samplers	240	1,462	1,702
Roads	490	5,384	5,874
Footbridge	1,146	3,281	4,427
Fencing	2,843	5,000	7,843
Ejector	1,068	897	1,965

TABLE X (CONTINUED)

CAPITAL COST DETAILS

Item	$ Labor	$ Materials	$ Labor + Materials
Spare Parts	-	12,613	12,613
	5,787	28,997	34,784
12. Engineering	46,455	-	46,455
Totals	194,975	470,025	665,000

FIGURE IA.—TEMPERATURE PROFILES FOR PONDS ON JULY 16, 1969.



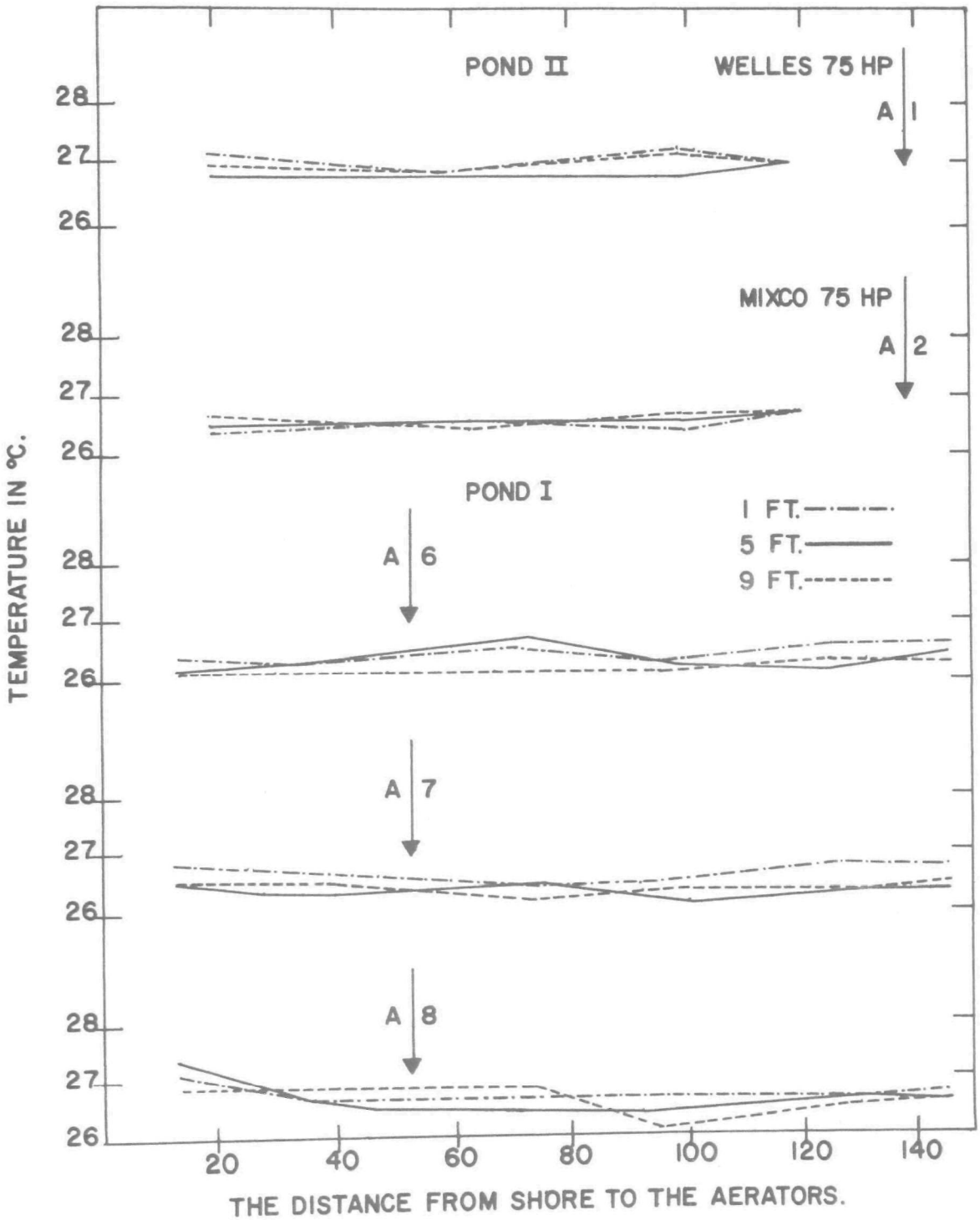
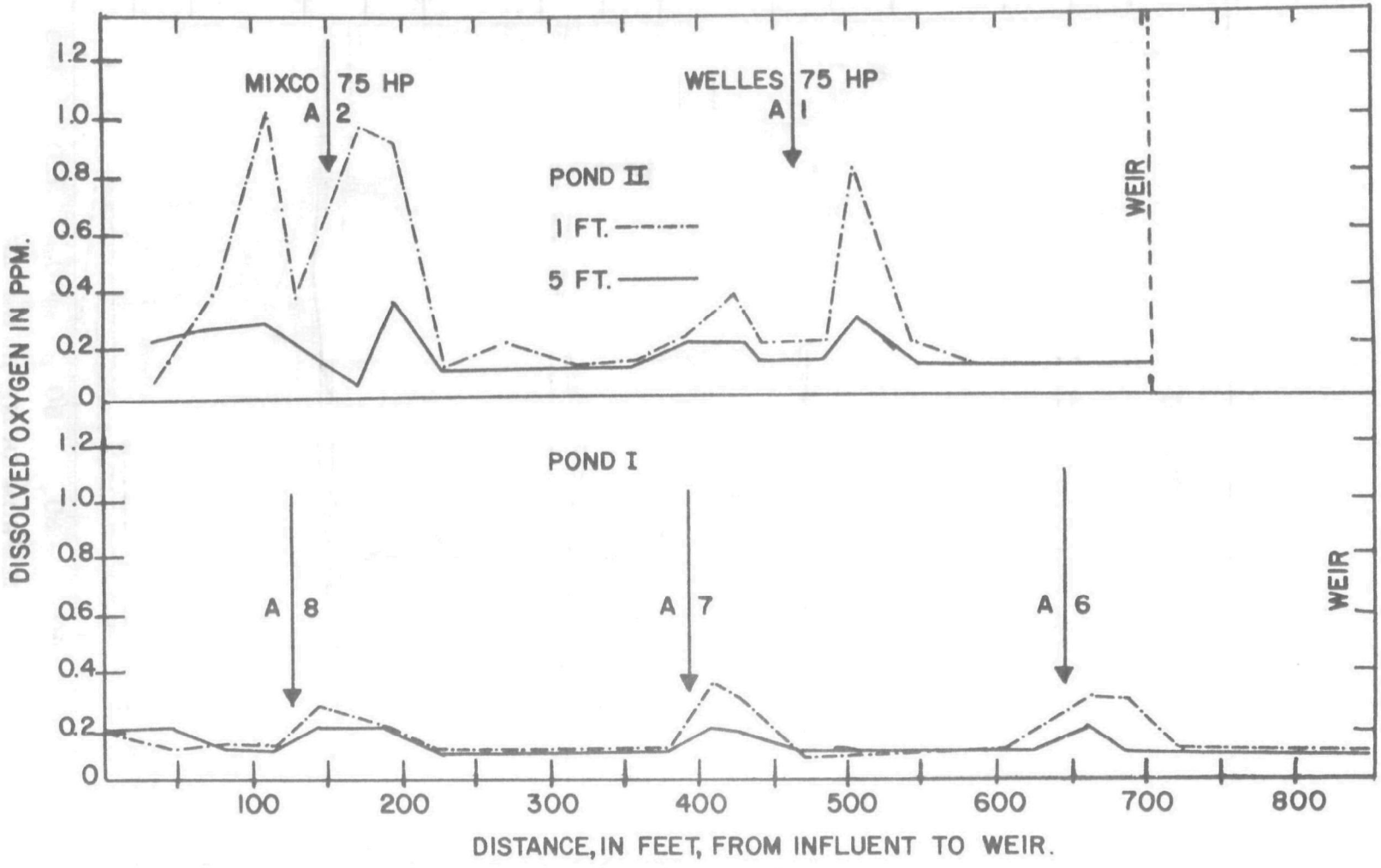


FIGURE 2A.—TEMPERATURE PROFILES ON JULY 16, 1969.

FIGURE 3A.—DISSOLVED OXYGEN PROFILES FOR PONDS ON JULY 16, 1969.



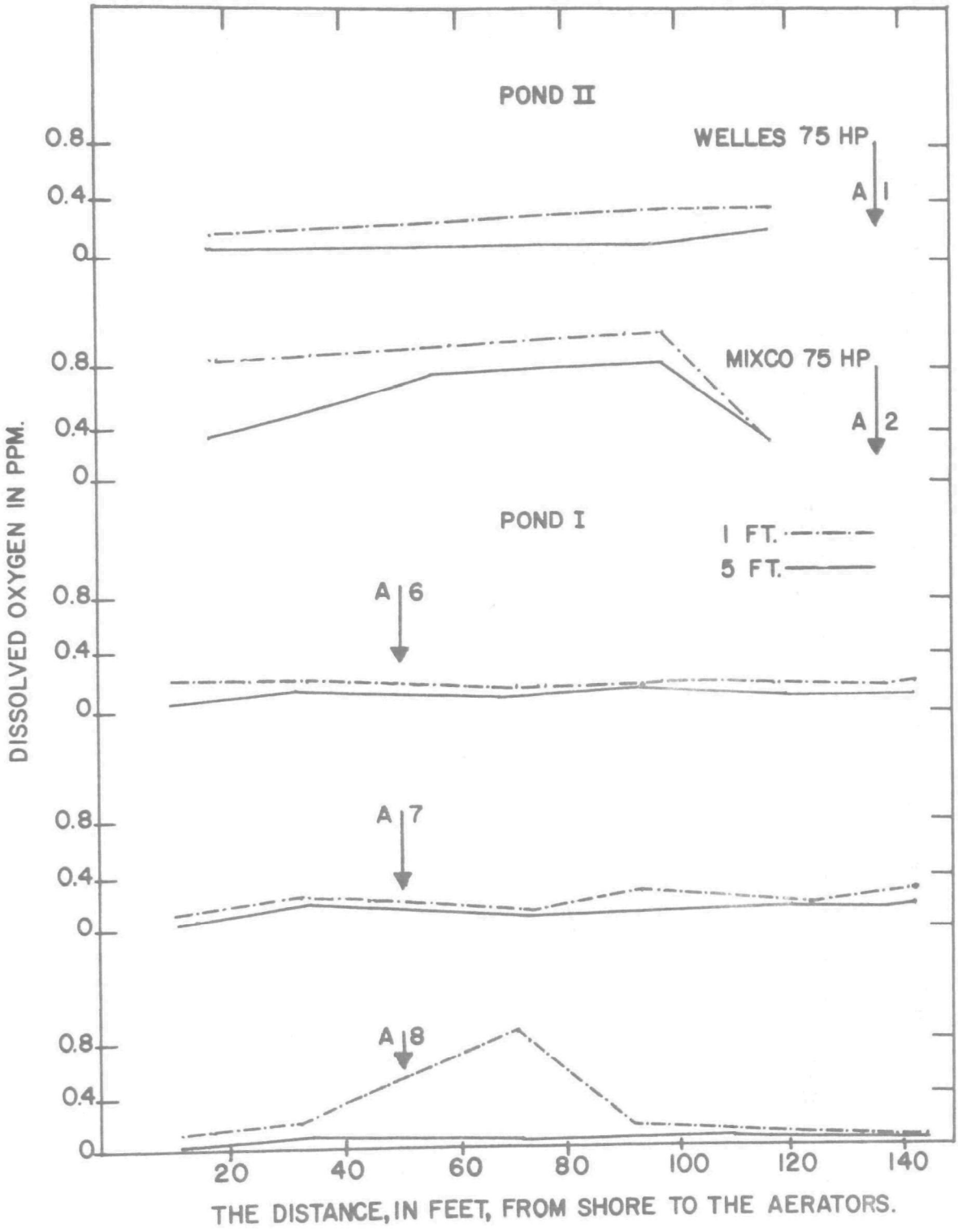


FIGURE 4A.—DISSOLVED OXYGEN PROFILES ON JULY 16, 1969.

FIGURE 5A-AVERAGE TOTAL SUSPENDED SOLIDS PROFILE FOR PONDS ON JULY 16, 1970.

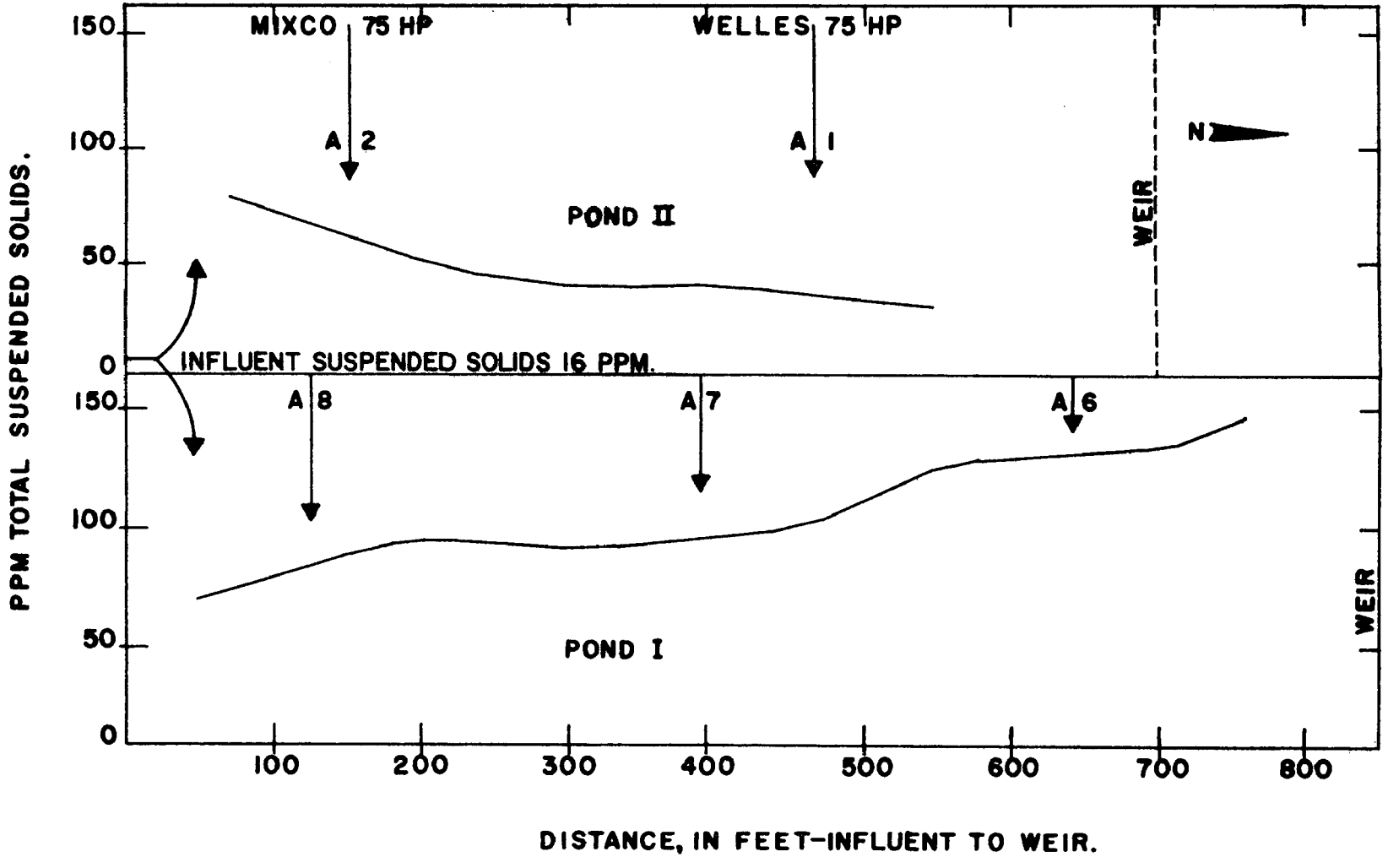
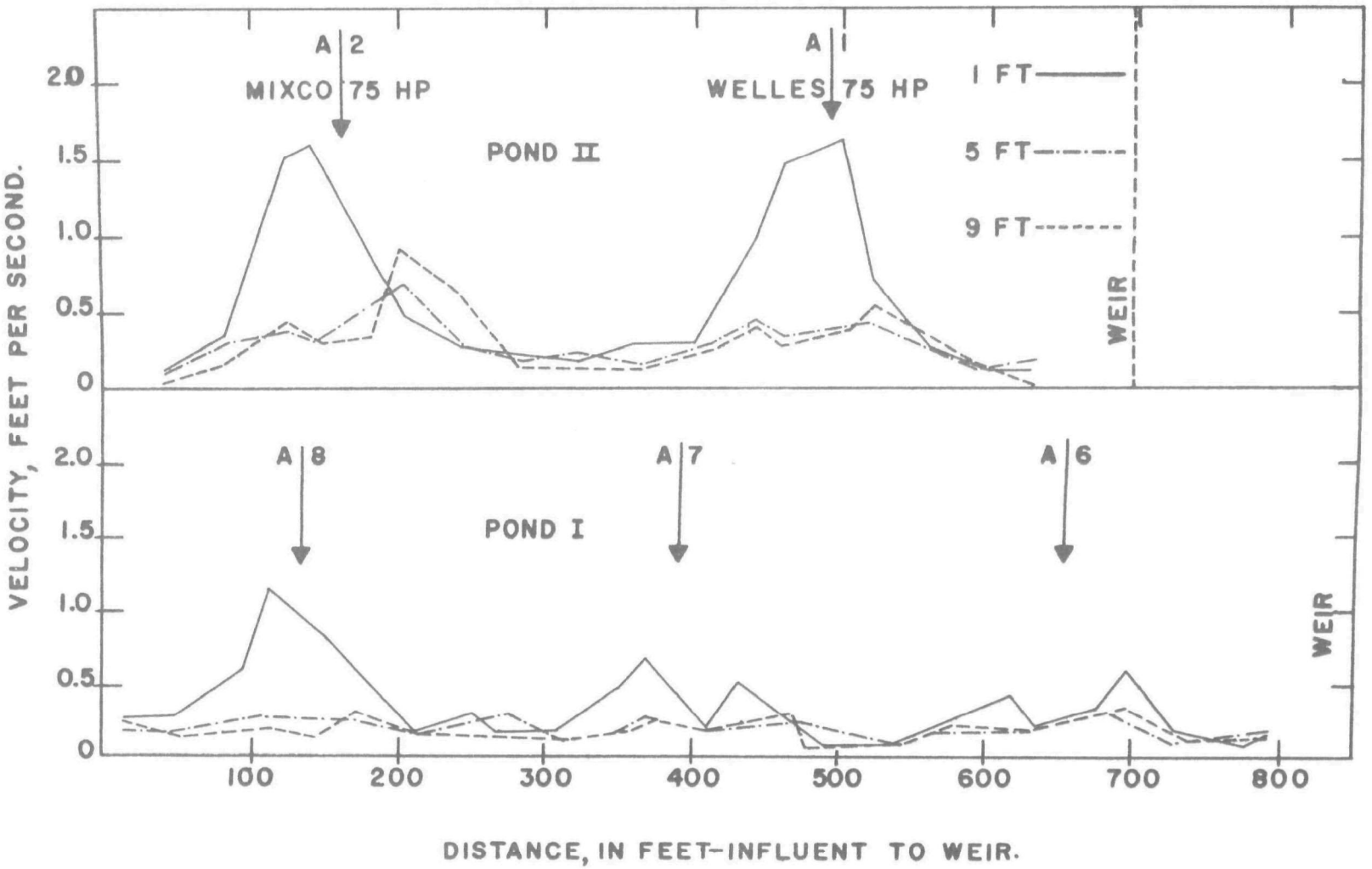


FIGURE 6A-VELOCITY PROFILES IN THE PONDS ON JULY 16, 1969.



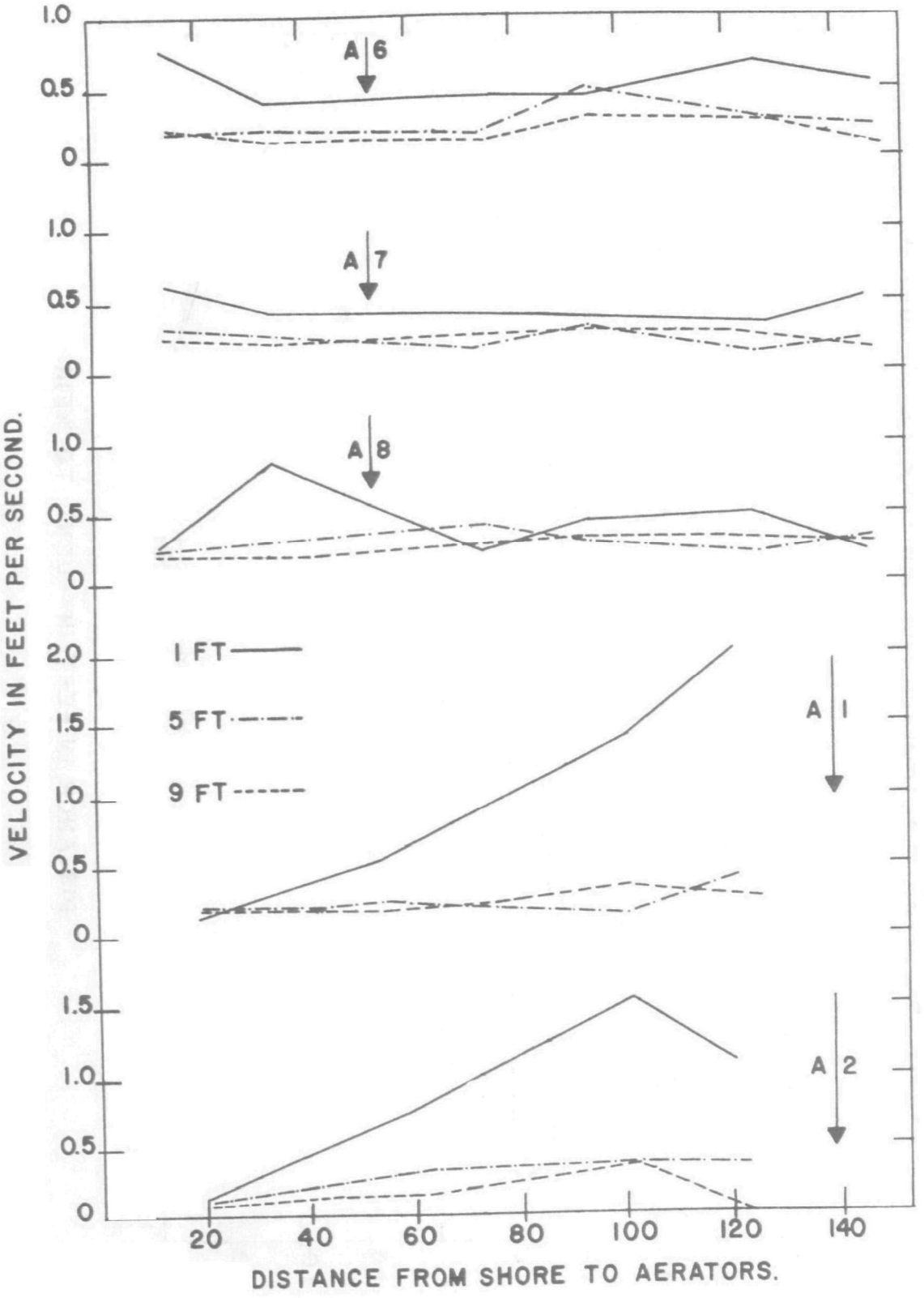


FIGURE 7A.—VELOCITY PROFILES IN THE PONDS.

FIGURE 8A.—BOD PROFILES FOR PONDS ON SEPTEMBER 17, 1969.

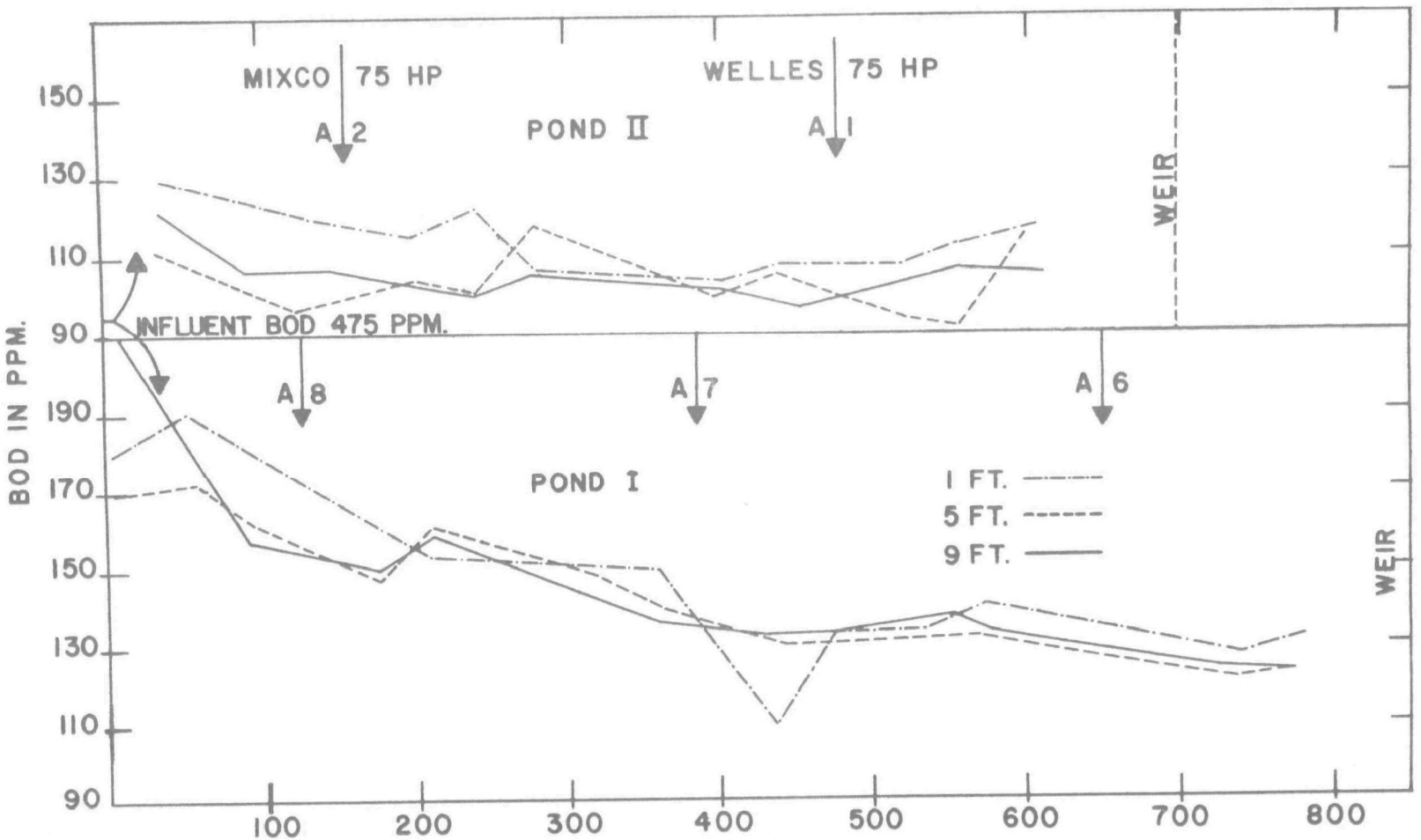


FIGURE 9A.—DISSOLVED OXYGEN PROFILES FOR PONDS ON SEPTEMBER 17, 1969.

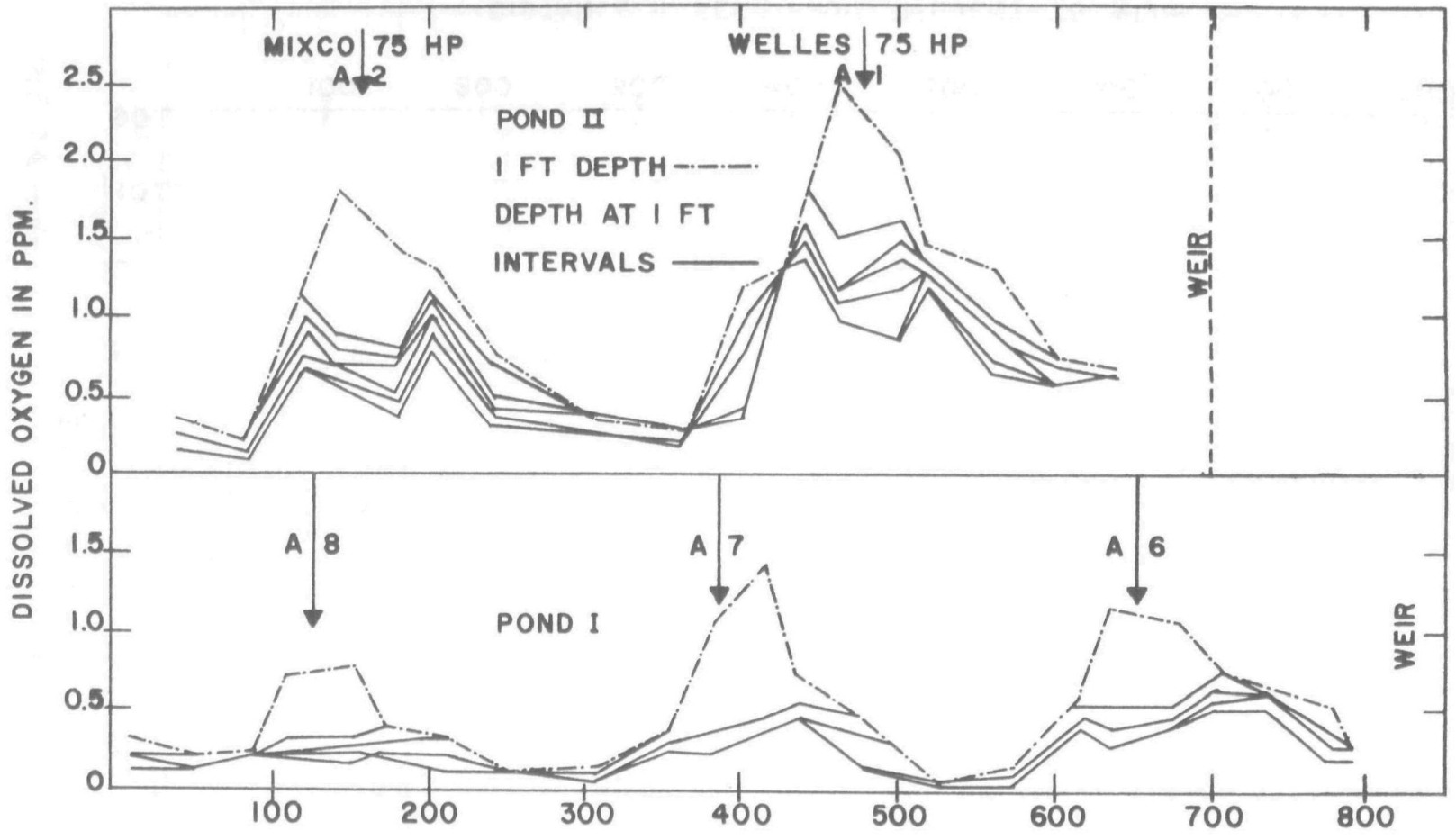


FIGURE 10A.—BOD PROFILES FOR PONDS ON NOVEMBER 3, 1969.

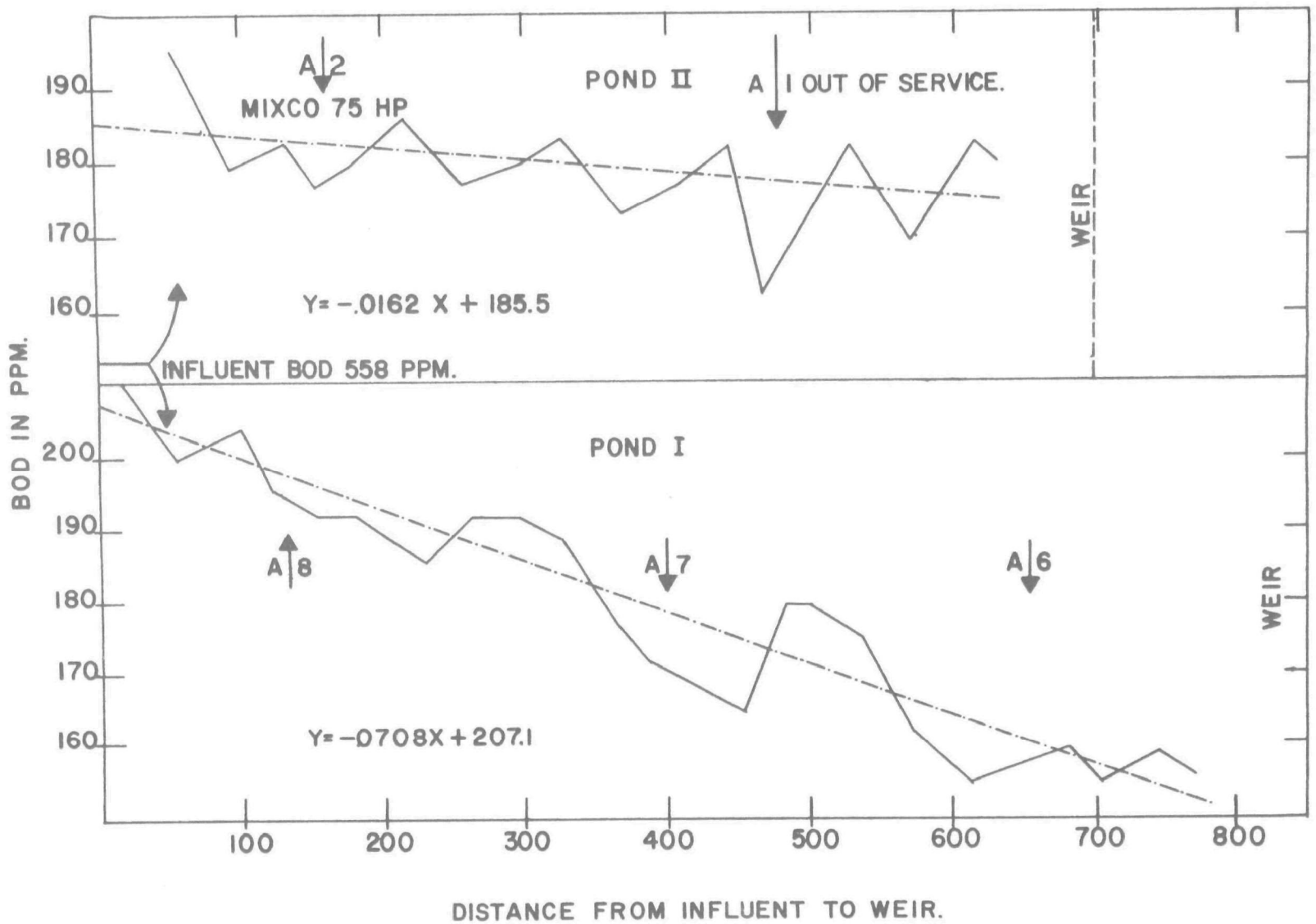


FIGURE IIA.—BOD PROFILES ON NOVEMBER 17, 1969.

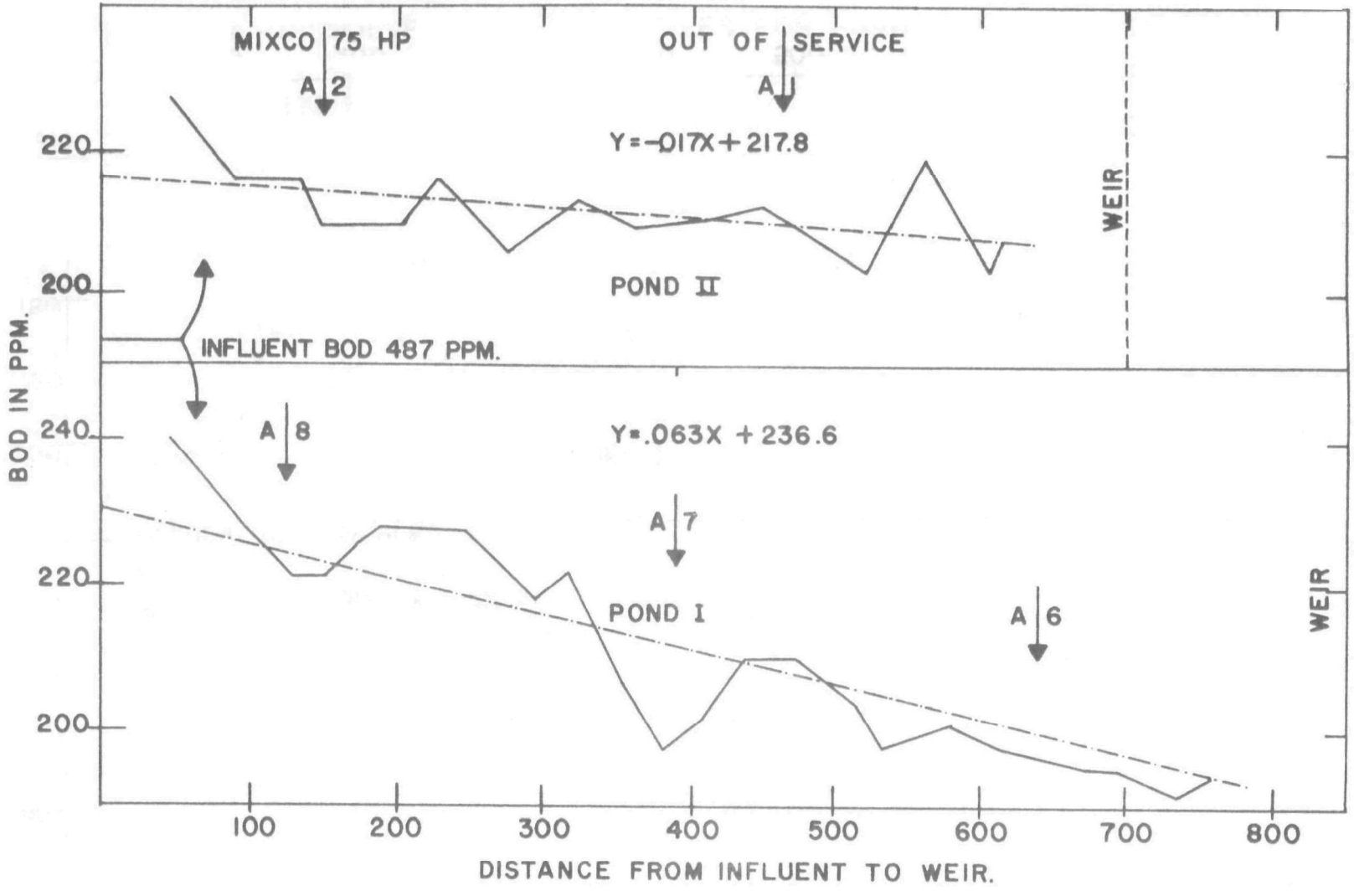


FIGURE 12A.—TEMPERATURE AND D.O. PROFILES FOR POND II ON NOVEMBER 3, 1969.

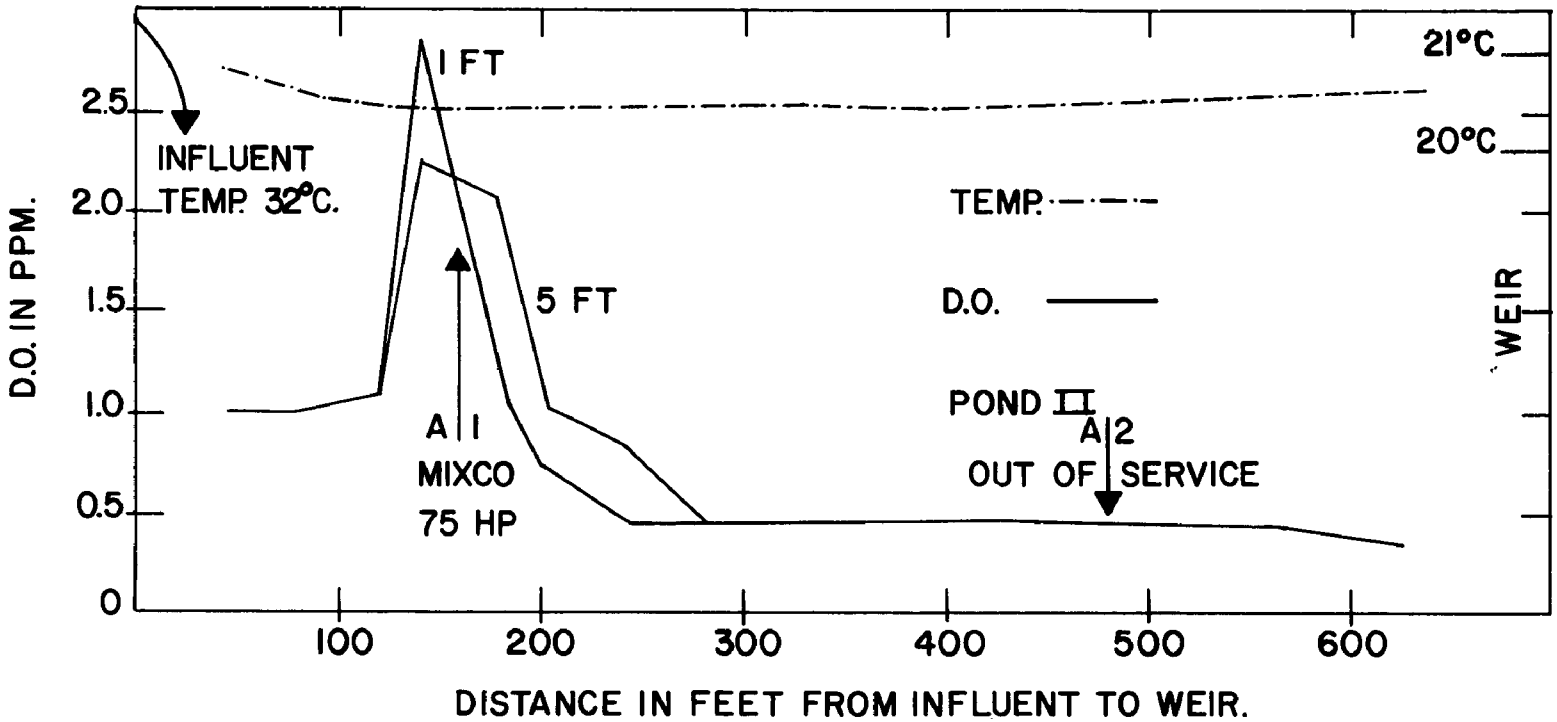


FIGURE 13A.—DISSOLVED OXYGEN AND TEMPERATURE PROFILES FOR PONDS ON NOVEMBER 17, 1970.

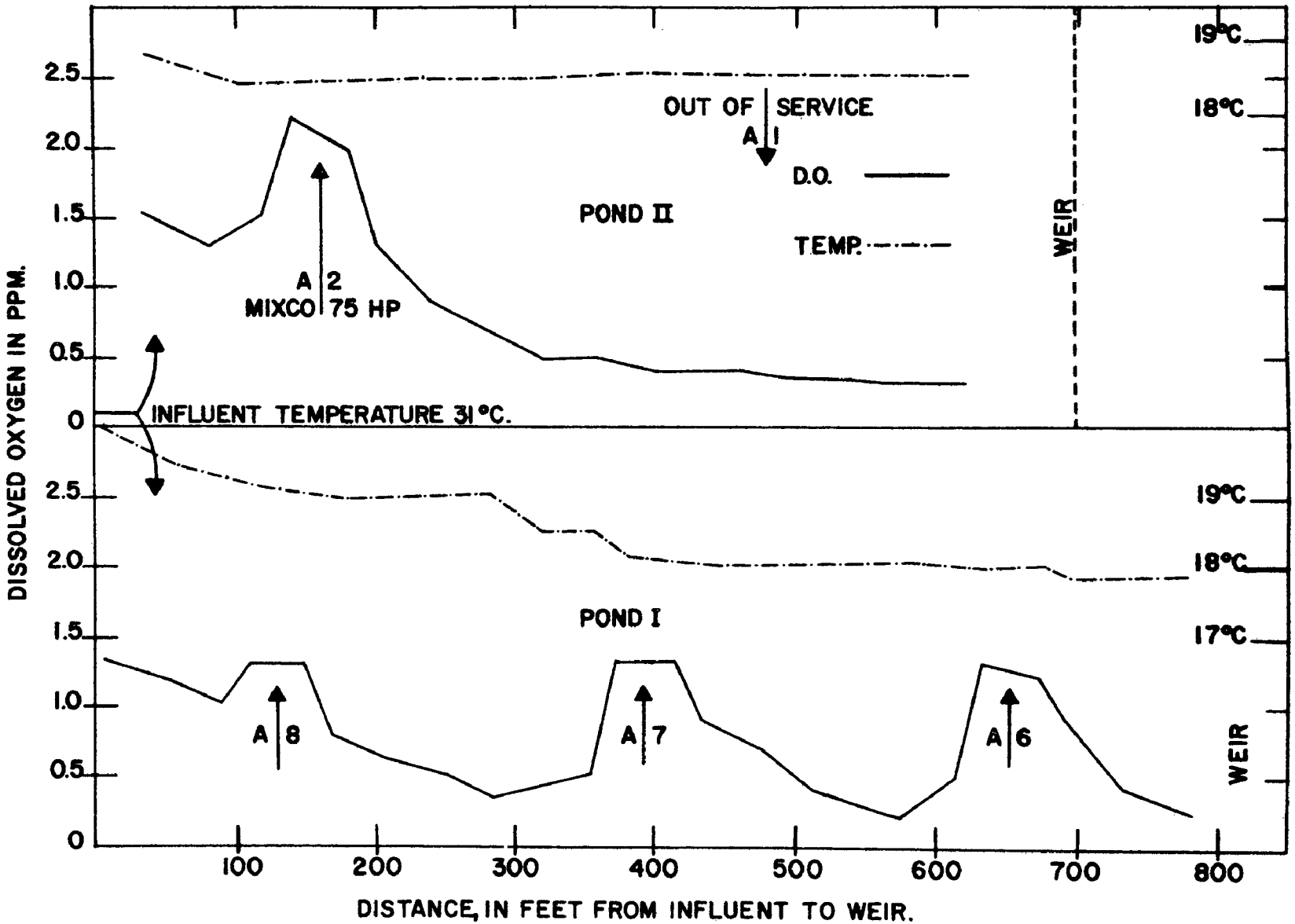


FIGURE 14A.—BOD PROFILES FOR AERATION PONDS IN PARALLEL OPERATION ON MARCH 5,1970.

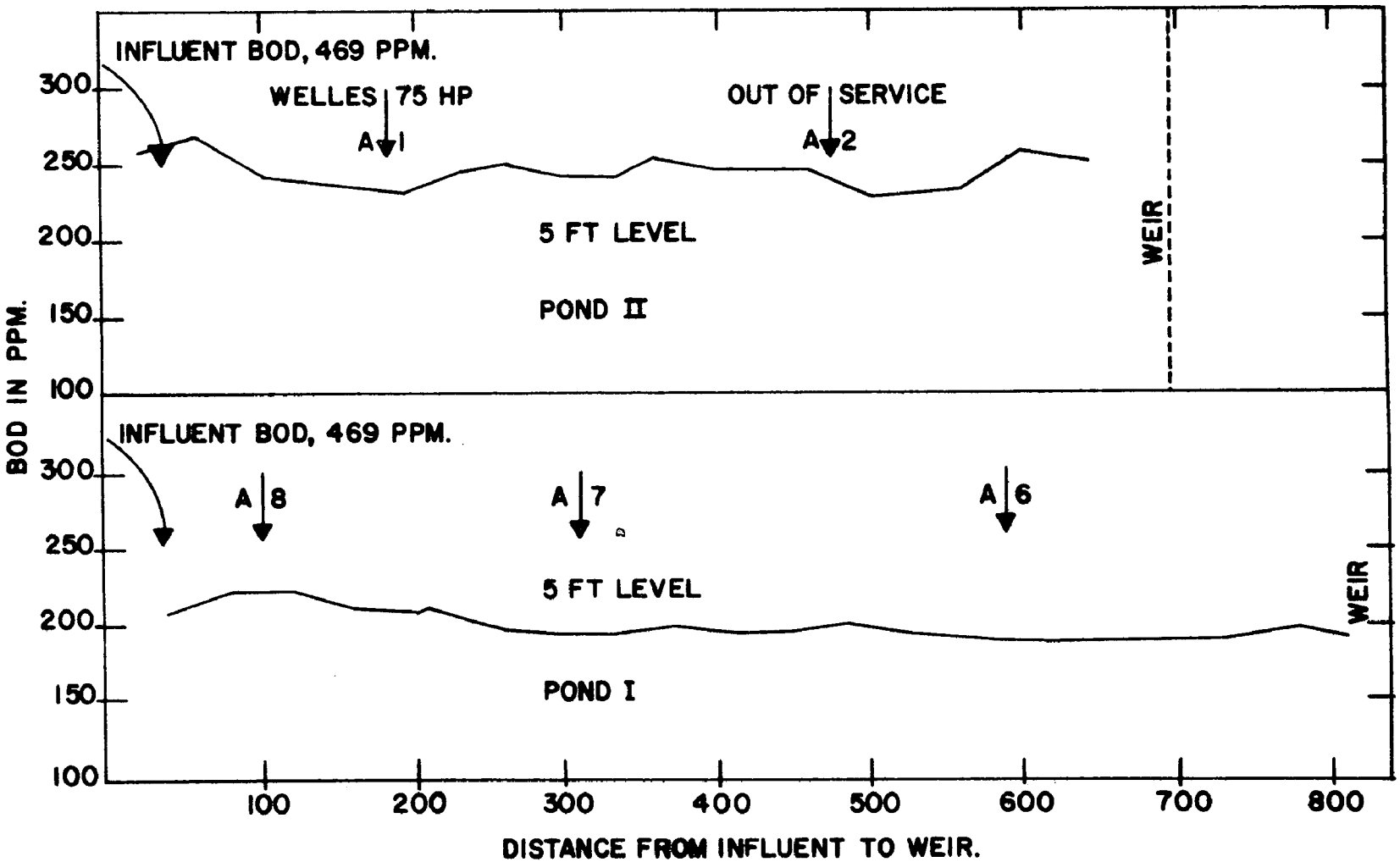


FIGURE 15A.—TEMPERATURE PROFILES FOR PONDS IN PARALLEL OPERATION ON MARCH 5, 1970.

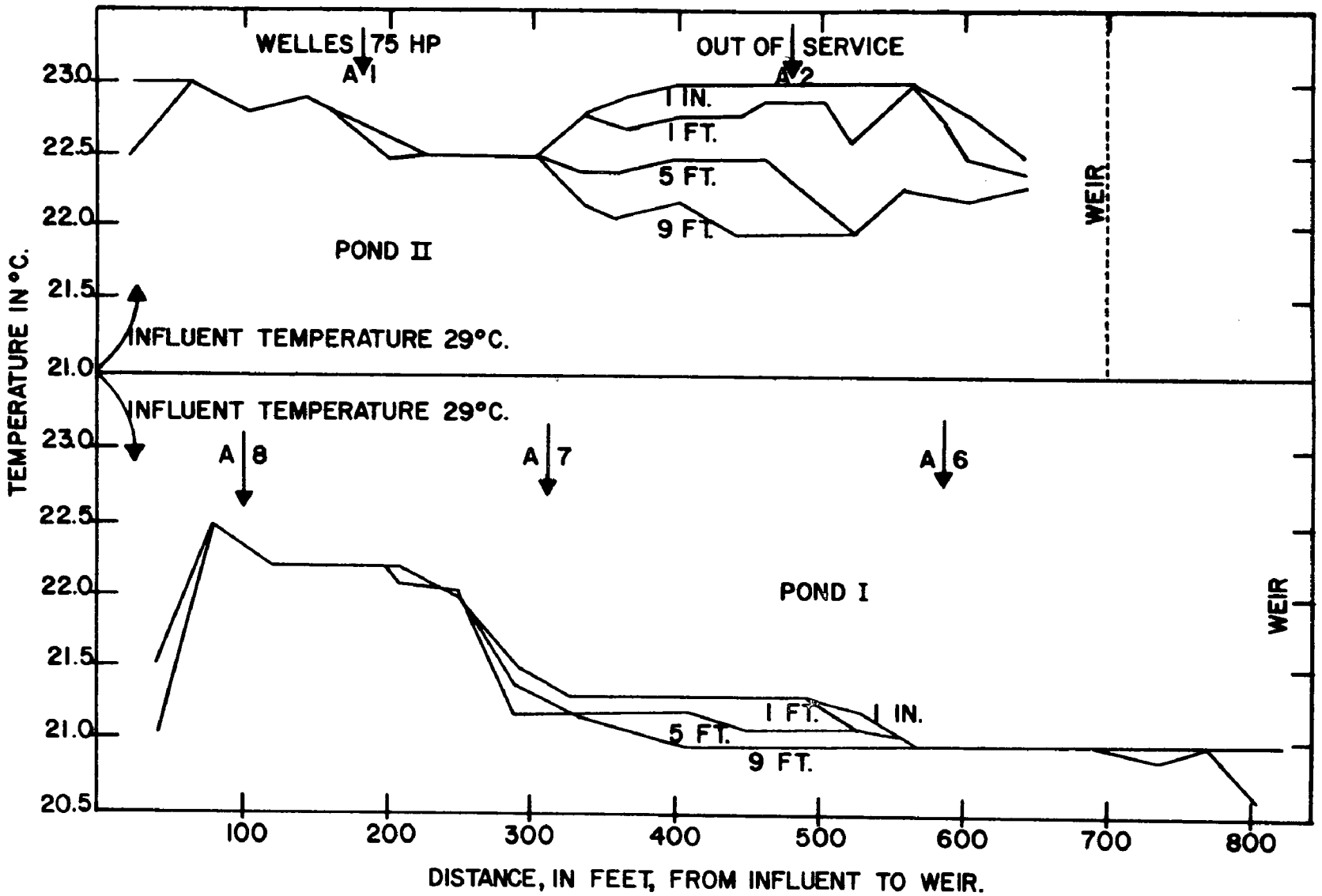


FIGURE 16A—BOD PROFILES FOR PONDS IN SERIES OPERATION, POND II TO POND I, ON FEBRUARY 16, 1970.

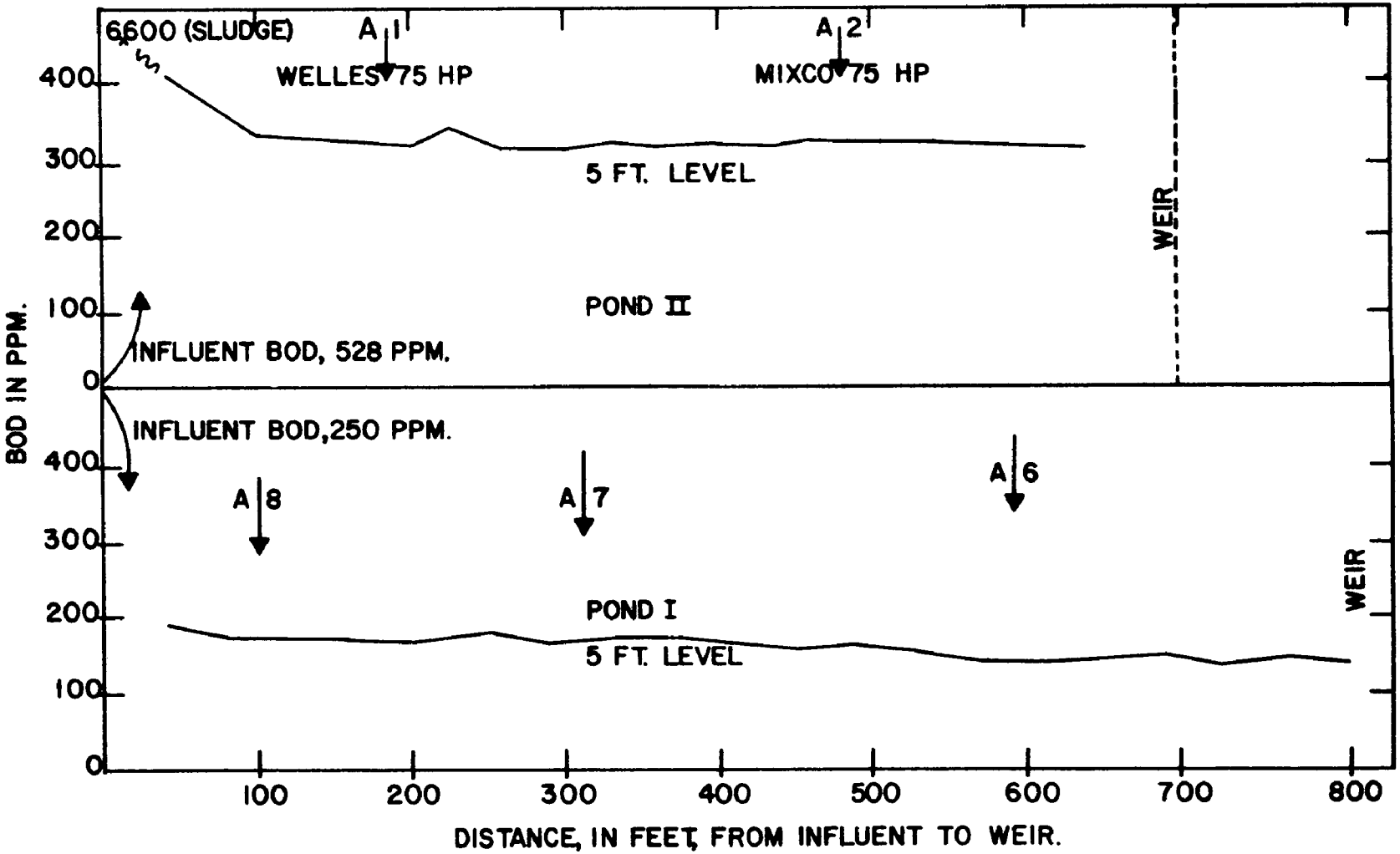


FIGURE 17A.–TEMPERATURE PROFILES FOR PONDS IN SERIES OPERATION ON FEBRUARY 16, 1970.

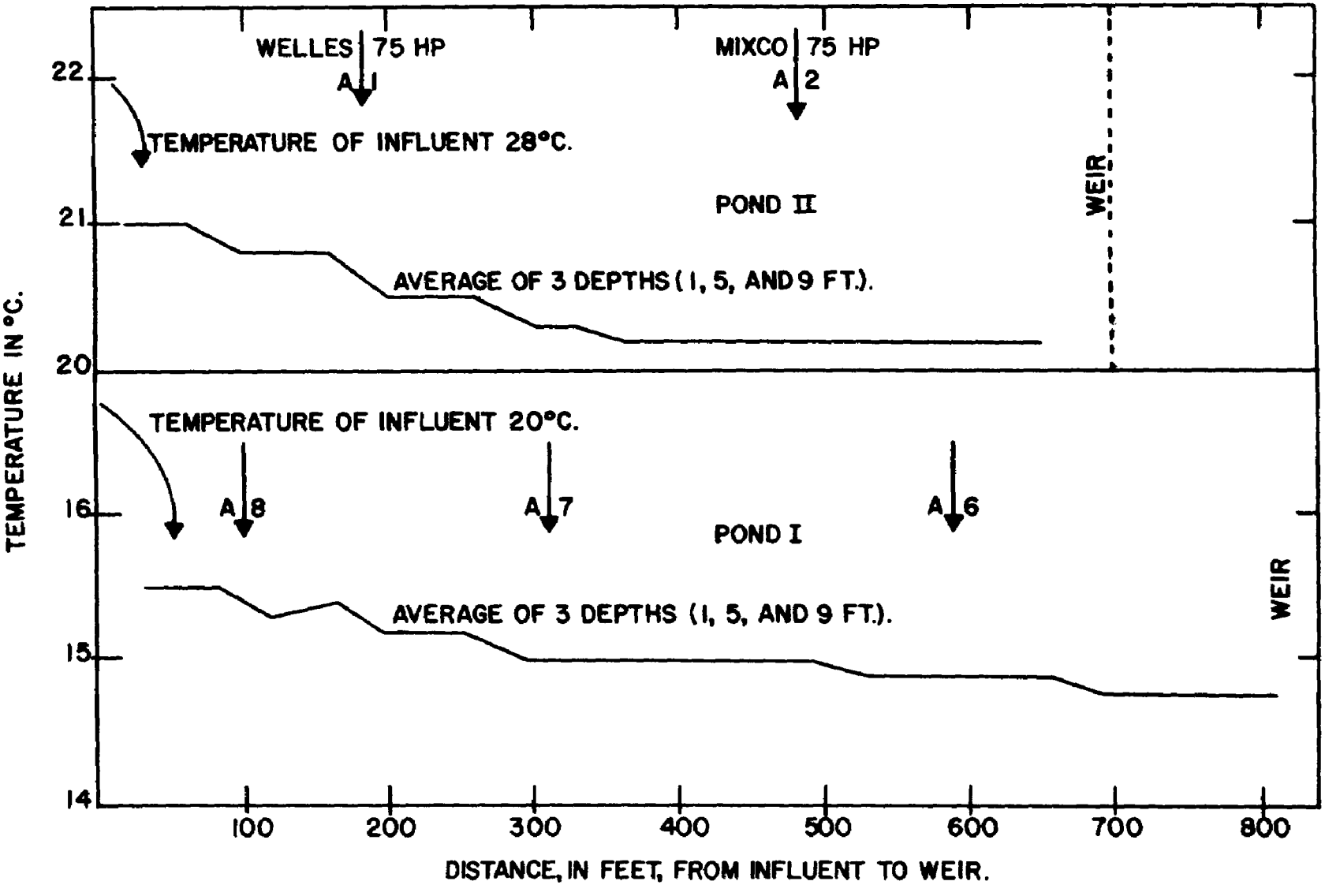


FIGURE 18A.—VELOCITY PROFILES FOR PONDS IN SERIES OPERATION, POND II TO POND I, ON FEBRUARY 16, 1970.

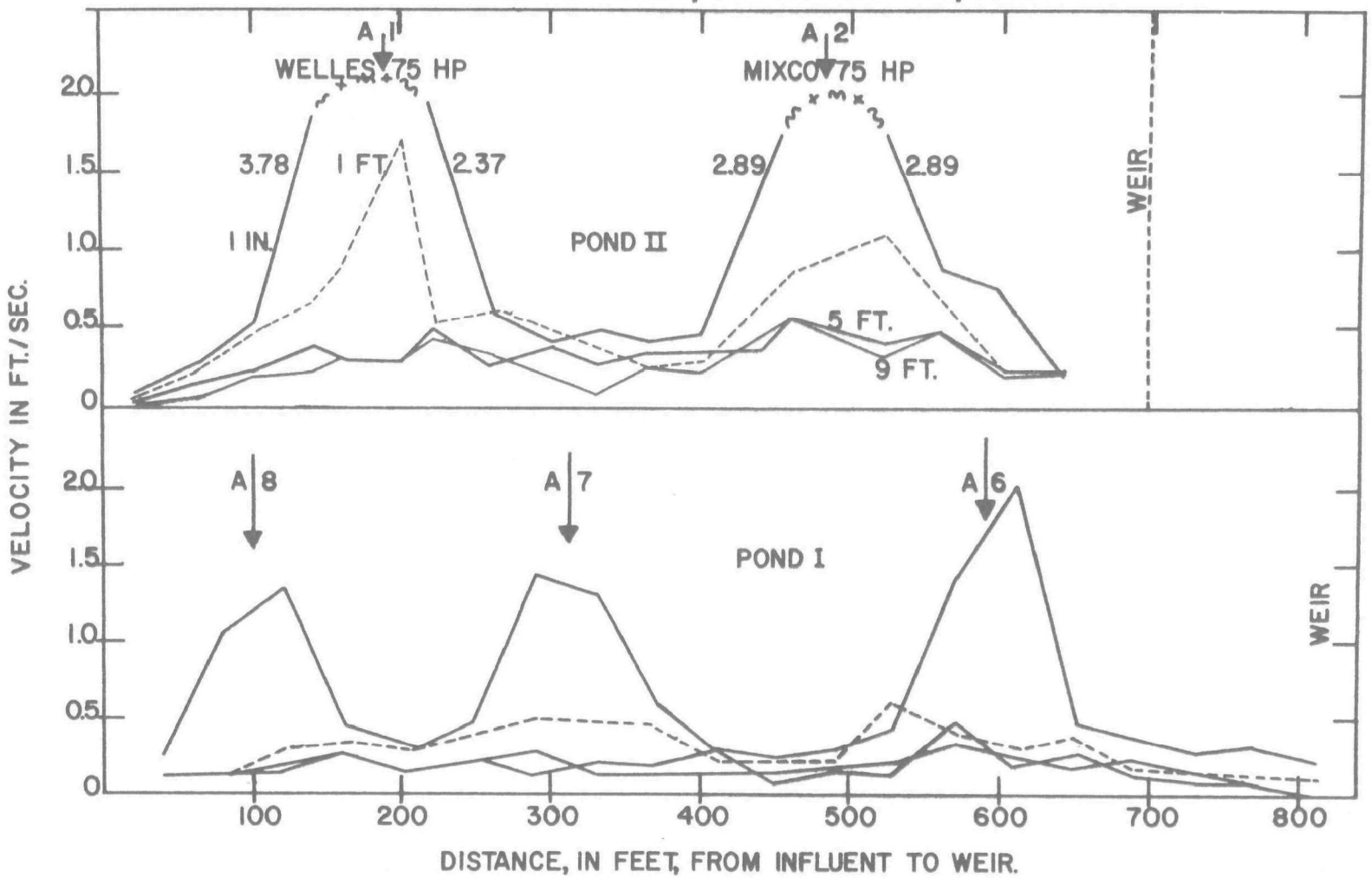


FIGURE 19A.—D.O. PROFILES FOR PONDS IN SERIES OPERATION, POND II TO POND I, ON FEBRUARY 16, 1970.

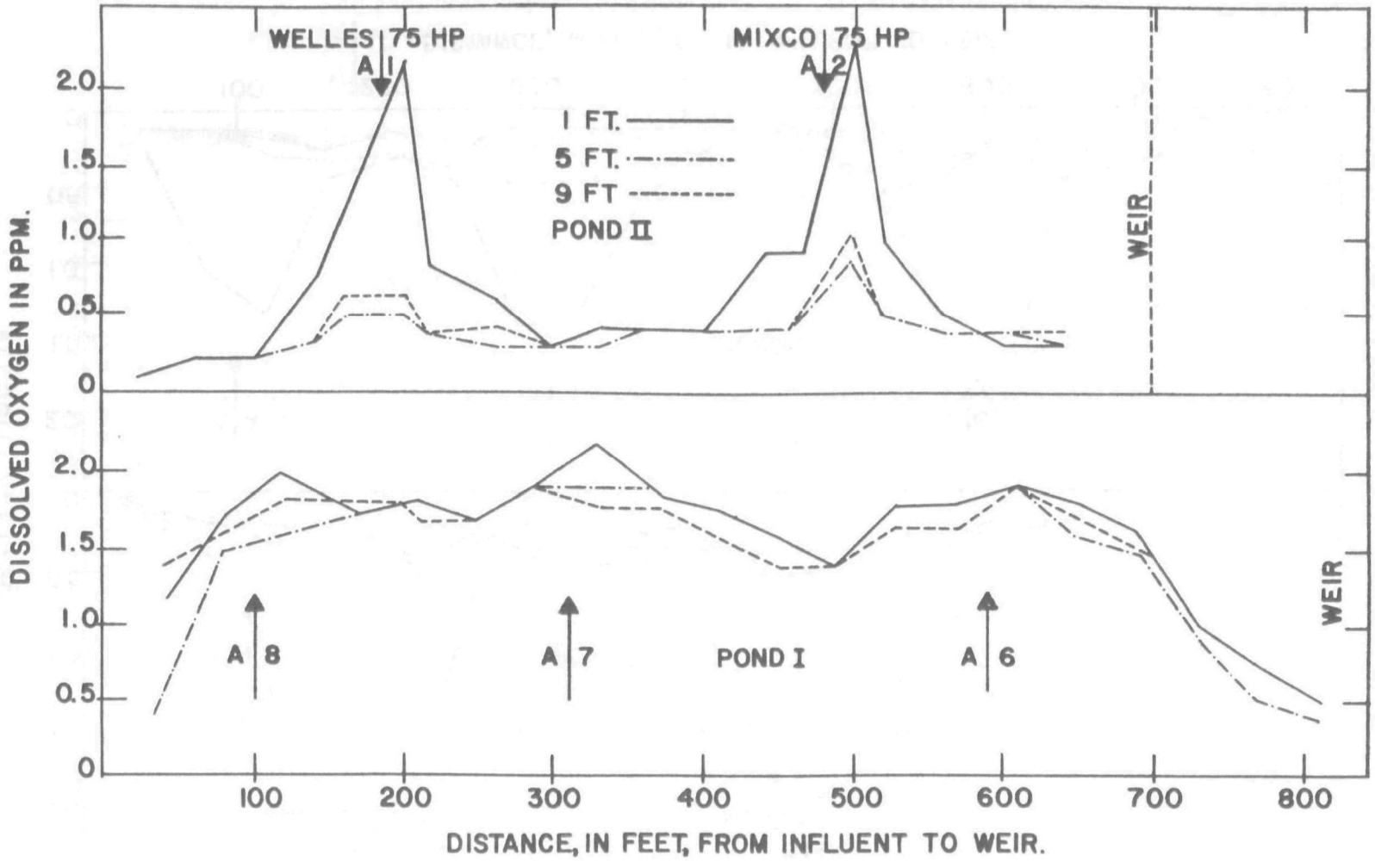


FIGURE 20A.–D.O. PROFILES FOR PONDS IN PARALLEL OPERATION ON FEBRUARY 23, 1970.

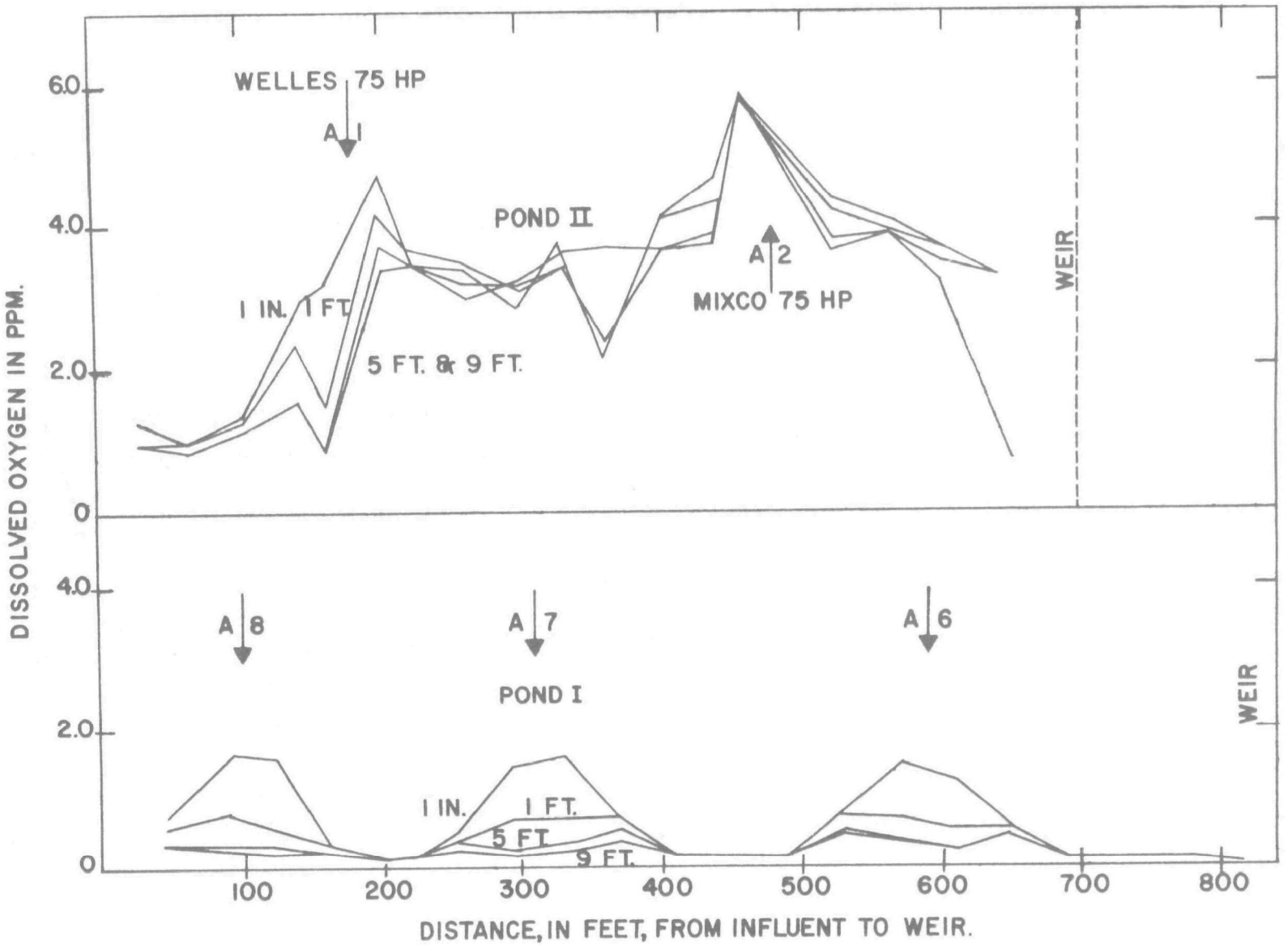


FIGURE 21A.–TEMPERATURE PROFILES FOR PONDS IN PARALLEL ON FEBRUARY 23, 1970.

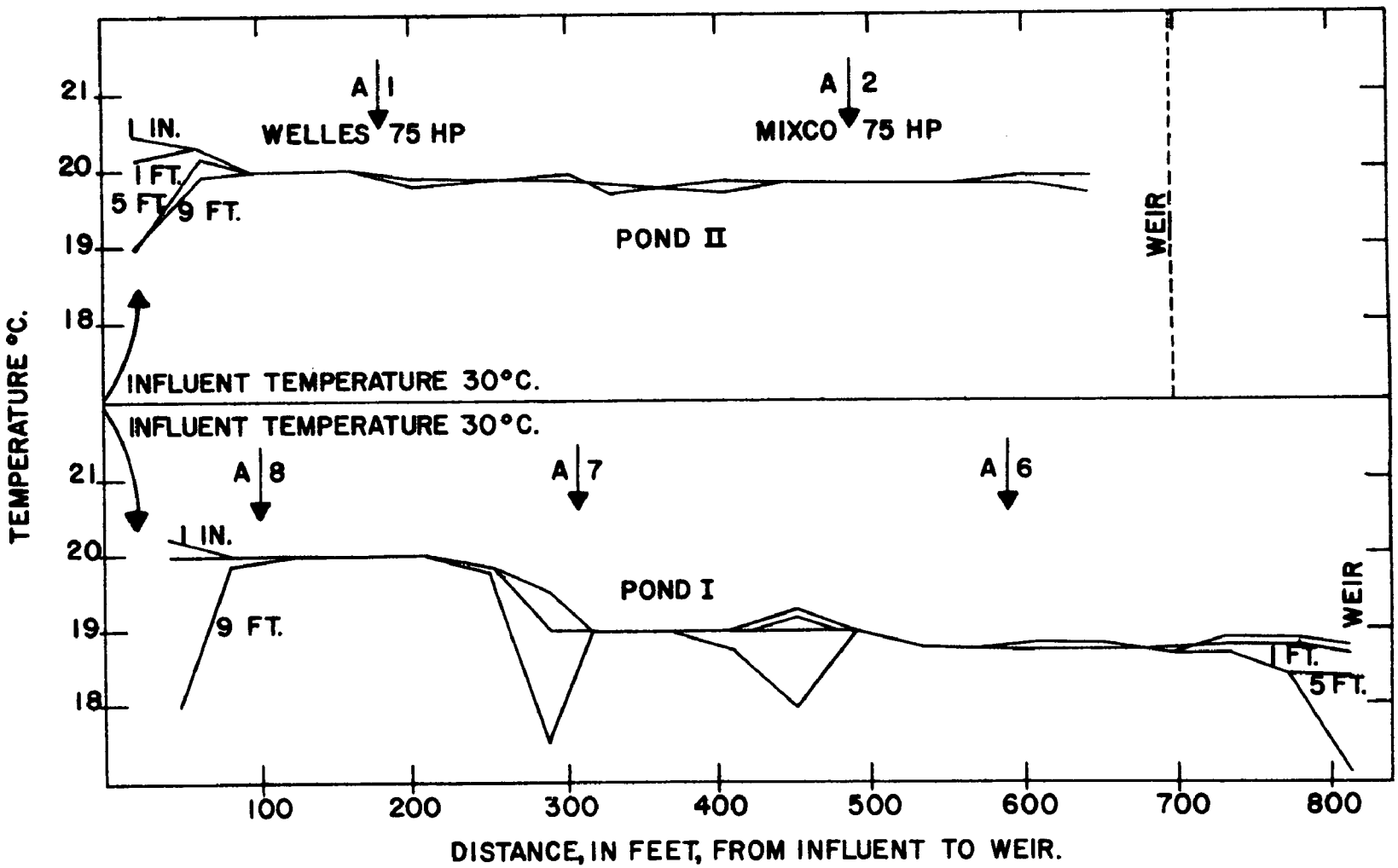
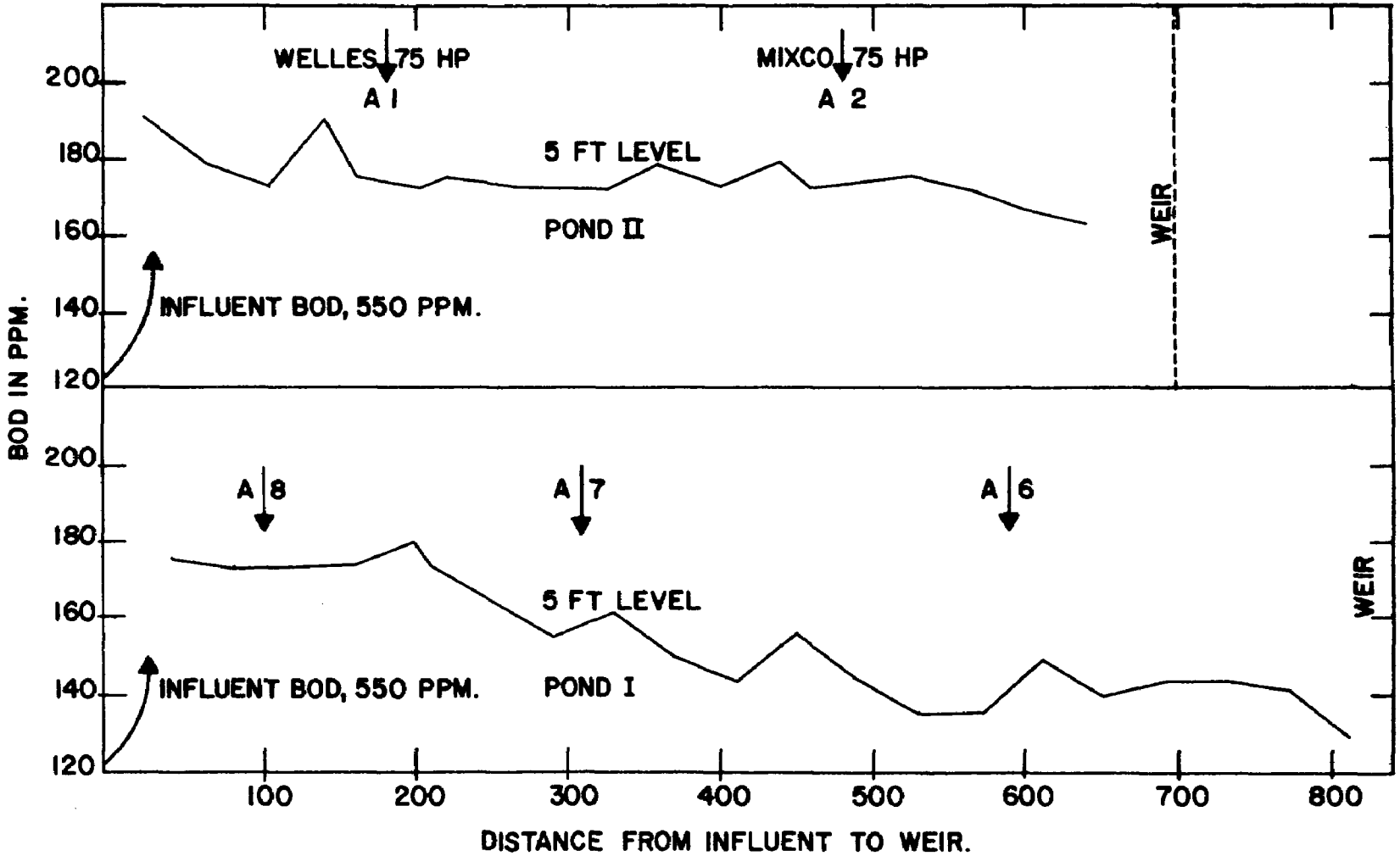


FIGURE 22A.—BOD PROFILES FOR PONDS IN PARALLEL OPERATION ON FEBRUARY 23, 1970.



1 Accession Number	2 Subject Field & Group	SELECTED WATER RESOURCES ABSTRACTS INPUT TRANSACTION FORM

5 Organization: Crown Zellerbach Corporation
Lebanon Division
Lebanon, Oregon

6 Title

Aerated Lagoon Treatment of Sulfite Pulping Effluents

10 Author(s)
Amberg, H. R.
Aspitarte, T. R.
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Byington, K.
Ehli, J.

16 Project Designation
WPRD 69-0-68 12040 ELW

21 Note

22 Citation

23 Descriptors (Starred First)
*Aeration basin, *Pulping wastes, *Capital costs, *Operating costs, *Surface aerators, *Slime growth, *Sphaerotilus natans, Sulfite waste, Water pollution control, Waste water treatment.

25 Identifiers (Starred First)
*Aeration basin, *Pulping wastes, *Slime growth, *Surface aerators, *Treatment costs.

27 Abstract Secondary treatment of sulfite pulp and paper mill effluents in aerated stabilization basins was tested on a full-scale basis over a 17 month period of continuous operation. The secondary treatment plant consisted of two aeration basins. One basin was equipped with two 75-h.p. surface aerators and the other basin of equal volume was equipped with six 25-h.p. aeration units. Piping was designed to permit series and parallel operation of the two basins and provisions were made to recycle treated waste. The waste treated was a mixture of weak wash water from the pulp mill, evaporator condensate from the spent liquor recovery system and paper machine white water.

Experimentation showed that series operation was more efficient than parallel operation and that the 75-h.p. surface aerators were much more efficient mixing and aeration devices than equivalent capacity of 25-h.p. units. An 80% BOD reduction could be achieved at a BOD load of 3.53 lbs./1,000 cu. ft. of aeration capacity of 2.2 lbs./h.p. -hr. This was equivalent to a daily BOD load of 16,000 lbs. Biological treatment to a BOD reduction of 80 to 85% produced a waste which did not readily support slime growth when added to simulated experimental streams.

Total operating cost including interest on investment and depreciation was $169,500 per year or $4.79/ton of production. Total operating cost per pound of BOD destroyed was 3.48 cents.

Abstractor H. R. Amberg | Institution Crown Zellerbach Corp., Camas, Wash. 98607

WR:102 (REV. JULY 1969)
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