Research Project Technical Completion Report
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EVALUATING A LOW-ENERGY, HIGH-VOLUME PUMP FOR ODOR REDUCTION FROM LIVESTOCK WASTE LAGOONS BY MIXING

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Statement of original objectives:

The objectives of the project study were:

1. To evaluate the effectiveness of the thorough mixing of lagoons receiving livestock manure on the reduction of offensive odors from the lagoons.
2. To evaluate the effectiveness and operating characteristics of a low-energy, high-volume pump in the mixing of small reservoirs of shallow depth.
3. To develop a dynamic mathematical model to predict the performance and operating characteristics of a system comprising the pump and a lagoon.

Objective one, the major objective of the project, was achieved satisfactorily. Data such as the pH, conductivity, temperature, odor level, COD and BOD_5 were obtained for the lagoon and for a companion lagoon that permitted evaluation of the mixing due to the pump.

Objective two was achieved for the particular physical environment used. However, the pump used was oversized for the lagoon studied so the extrapolation of results from this study to make general statements or recommendations relative to other systems may be misleading.

Objective three was not completely realized. The nature of the results was such that complete achievement of the objective would have resulted in a trivial solution which would have no application to another situation.

Procedure:

To accomplish the objectives, a livestock manure system, an anaerobic lagoon system that handles the feces, urine and wash water from a swine production operation, was selected. The lagoon systems are shown in Figure 1. The swine production operations are owned and operated by Wilson and Company and are located about four miles northwest of Calumet, in central Oklahoma. These systems appeared to be a good selection for the research as there were two lagoon systems that had somewhat similar treatments and were subjected to the same climatic conditions. It was thought this would provide a direct comparison of a treated and an untreated system.

The east facility started operation in the fall, 1971, and the west facility in the fall, 1972. Both have operated continuously since their initiation.

The swine production operations have the full cycle in production, starting with the farrowing of the pigs through the finished animal. The operations produce a SPF product, animals resistant to certain diseases that often plague producers of swine in large confined systems. The gilts are sold for production stock and the barrows are sold as slaughter animals. The east facility produces only gilts and the west facility produces some boars as well as gilts.

The operations use confined housing with aluminum slatted floors and a pit collection of the manure material. There is a detention time of six weeks or more of the manure in the pits before they are drained into the lagoons. The pits can overflow liquid material through a standpipe and some pits discharge liquid to the lagoons a large part of the time.

The east facility, which is the treated system, has the following buildings:

sow barn	40.4 m x 11.0 m
farrowing house	42.8 m x 7.3 m
Nursery I	30.0 m x 11.0 m
Nursery II	30.0 m x 11.0 m

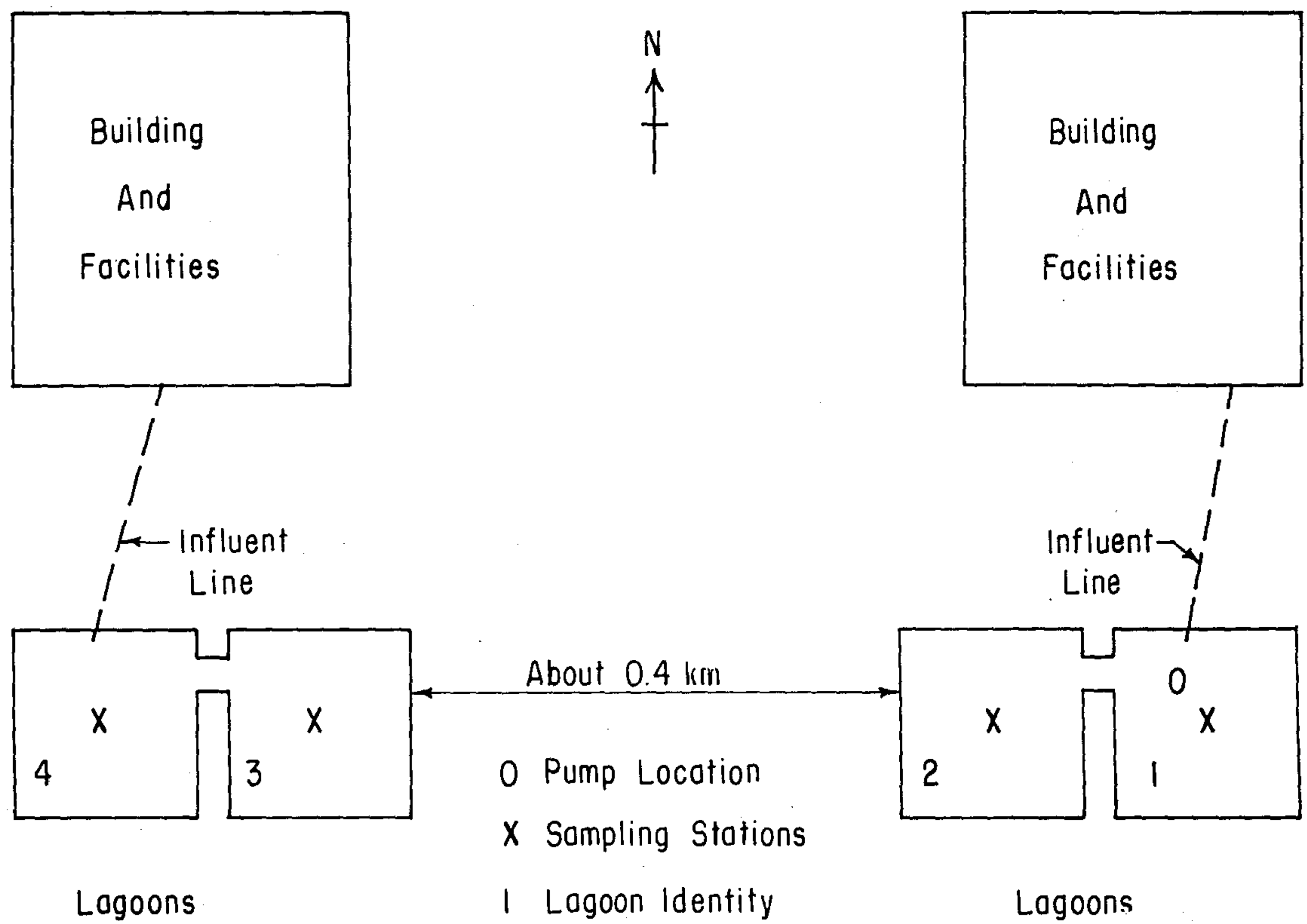

Figure 1. Swine Production Operations and Manure Lagoons

Grower	62.6 m x 11.0 m
Finisher	60.7 m x 11.0 m

Except for the sow barn, the pit area is the same as the floor area of the building. The pits are about 0.61 m deep.

The total number of animals on hand in the east facility generally varies from about 3500 to 4000. For example, on September 18, 1975, there was the following distribution of animals:

Sows and Boars	421
Farrowing (birth to three weeks)	417
Nurseries I and II (two to 12 weeks)	740
Grower (12 to 16 weeks)	1030
Finisher (16 to 32 weeks)	1274
TOTAL	3882

The approximate weight of these animals was 238 Mgm.

The west facility, built one year after the east facility, had the farrowing and nursery combined so it has only four buildings. This facility generally has about 3200 - 3300 animals at any time. At the time the east facility had 3882 animals, the west facility had 3200 animals. The west facility also differs from the east facility in that the building roofs are guttered such that the rooftop runoff from rainfall runs directly into the influent line into the lagoons.

A pair of lagoons was constructed to hold the manure material from each facility. Initially, one lagoon of each pair was used for primary treatment and the second lagoon for secondary treatment. This system did not perform as intended in that there was an odor problem. Thus, a cut was made in the dike between the pair of lagoons in effect making them a single lagoon. The cut was made by a backhoe with the cut size being limited by the reach of the backhoe. The resulting cuts are about 1.2 m deep by about 1.8 m wide.

The dikes separating the lagoon pair had a top width of about three meters.

Each lagoon had a surface area of 0.405 hectares, a liquid depth of about 2.2 m and side slopes of three horizontal to one vertical. The two lagoon systems are about 0.4 km apart in an east-west direction. The influent enters the lagoon systems through a single six-inch PVC pipe off center on the north side of lagoons one and four.

The east system is the treated system, that is, the system with the pump to artificially mix the lagoon. The pump was located at about the center of the northwest quarter of lagoon one. This location was selected, instead of at the center of the lagoon, in the hope that the mixing or circulation pattern would carry through the cut dike into lagoon two. The sampling stations were located near the center of each lagoon. The pump was operated from July 17, 1975 to January 6, 1976.

The pump and raft assembly constructed and used for mixing the lagoon liquid is shown in schematic in Figure 2. The raft was a sandwich type construction made of redwood and styrofoam. A 373 watt, variable speed, electric motor with a 30 to one right-angle gear reducer was used to drive the propeller. The propeller was a crop drying propeller, had seven blades and was made of cast aluminum. The propeller diameter was 1.07 m and it was mounted to operate about 1.22 m below the liquid surface. The rotational speed could be varied from 25 to about 60 RPM but it was operated at about 45 RPM for this study. The pump moved the water from the surface to the bottom.

Measurements, samples and observations were obtained on a weekly basis, as nearly as possible, on each lagoon system prior to, after start-up and shut-down, of the pump. Data obtained included:

1. Order of magnitude concentration of odorant in air measured using a Scentometer;

2. Water samples to determine

    a. DO (dissolved oxygen)

    b. BOD_5 (Biochemical Oxygen Demand)

    c. COD (Chemical Oxygen Demand);

3. Temperature;

    a. ambient air

    b. lagoon liquid at surface, one meter and two meter depths

4. pH;

5. Conductivity;

6. Climatic conditions including: wind speed and direction, general weather comments, and rainfall data; and

7. General condition of lagoons such as: surface condition, bubbling and boiling activity, lagoon elevation, and liquid color and condition.

The odor data were taken downwind of the lagoons. The prevailing winds are from the south so it was rare when there was odor interference between the lagoon systems. There was a large vegetative (trees) windbreak south and adjacent to the lagoon systems that reduced the wind velocities over the lagoons when the wind direction was from the south. The water samples for the BOD_5, COD, pH and conductivity were taken at about one meter depth.

Results:

General Observations

Both lagoon systems were full at the start of the observation period. This was due in part to the above average rainfall that had occurred in the Calumet area prior to the study. There was a definite difference, as noted by visual inspection, in the liquid in the east lagoons and that in the west lagoons. The liquid in the east lagoons was thicker and more turbid than that in the west lagoons. This was probably due to the fewer number of animals

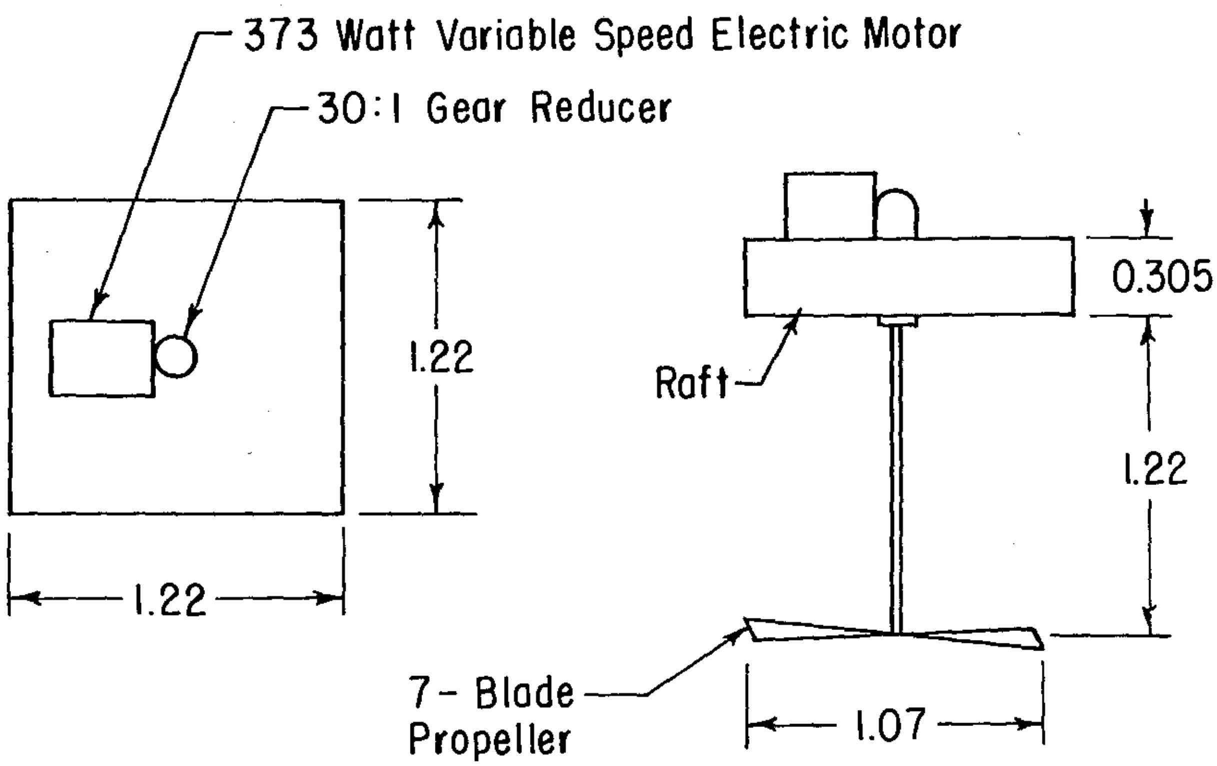

Figure 2. Pump and Raft Assembly

in the west facility and because the rooftop runoff from the west buildings was diverted into the west lagoons. The liquid in the east lagoons was a muddy-brown color and in the west lagoons it was a weak reddish-clay color. The visibility in both lagoon systems varied from about zero to about two centimeters. However, the visibility was near zero most of the time.

Lagoons one and four, Figure 1, the lagoons that received the influent, had considerable boiling activity occurring. This was caused by the accumulation of gases in the solids on the bottom. The gases were generated by bacterial activity. When sufficient gases had accumulated, the gases, along with some solid material, would rise to the surface. The gases were released to the atmosphere and the solids remained on the surface and formed a scum. There was considerable scum on the surfaces of lagoons one and four when the observation period began in June, 1975. There were only small amounts of scum on lagoons two and three, the scum present probably coming from the adjoining lagoons by wind action or the circulation pattern. The scum color on lagoon one was a dark gray most of the time: on lagoon two it was a pale red-pink color; and on lagoons three and four it was a white-green color. There was continuous bubbling activity on all lagoons, but it was more active on lagoons one and four.

There was significant offensive odors associated with the boiling activity. Odor measurements taken before the start of pumping, using a scentometer, are given in Table I. All measurements were taken adjacent and downwind of the lagoons.

TABLE I. Odor Levels from Lagoons

Lagoon	Dilution to Threshold
One	Zero to 31
Two	Zero to seven
Three	Zero to seven
Four	Zero to seven

There was considerable variation in odor levels.

The pump was installed in lagoon one and was started at 11:45 a.m., July 17, 1975. A slightly stronger odor was observed from lagoon one immediately after the start up of the pump. This did not continue for a very long period of time.

The pump did not cause a noticeable increase in the circulation between lagoons one and two. The pump was essentially affecting only lagoon one. The pump was pumping about 30,000 liters per minute and was able to completely turn over the liquid in lagoon one about every four hours.

The boiling activity in lagoon four continued throughout the observation period at a fairly high level. However, the boiling activity in lagoon one decreased slightly with time and by September, 1975 there was almost no boiling activity occurring in the lagoon. There was a slight increase in boiling activity in October in lagoon one but then very little occurred in November, December and in January to the time of stopping of the pump (January 6, 1976).

The lagoon levels were lowered in February and March, 1976, by withdrawal of water for pre-irrigation. During the week following February 27, 1976, lagoons one and two were lowered about 0.4 m. The following week they were lowered another 0.4 m. The two weeks following March 11, 1976, lagoons three and four were lowered about 0.6 m. Because of sediment deposition in the lagoon one side of the dike cut, the liquid level in lagoons one and two was at the elevation of the cut. Because of this, very little exchange could take place between lagoons one and two.

The lowering of the liquid levels in the lagoons revealed the sediment deposition patterns in the lagoons. Only lagoon one had significant deposition and this occurred around all edges of the lagoon. It appeared that the capacity of the lagoon was reduced by one-fourth to one-third because of the sediment

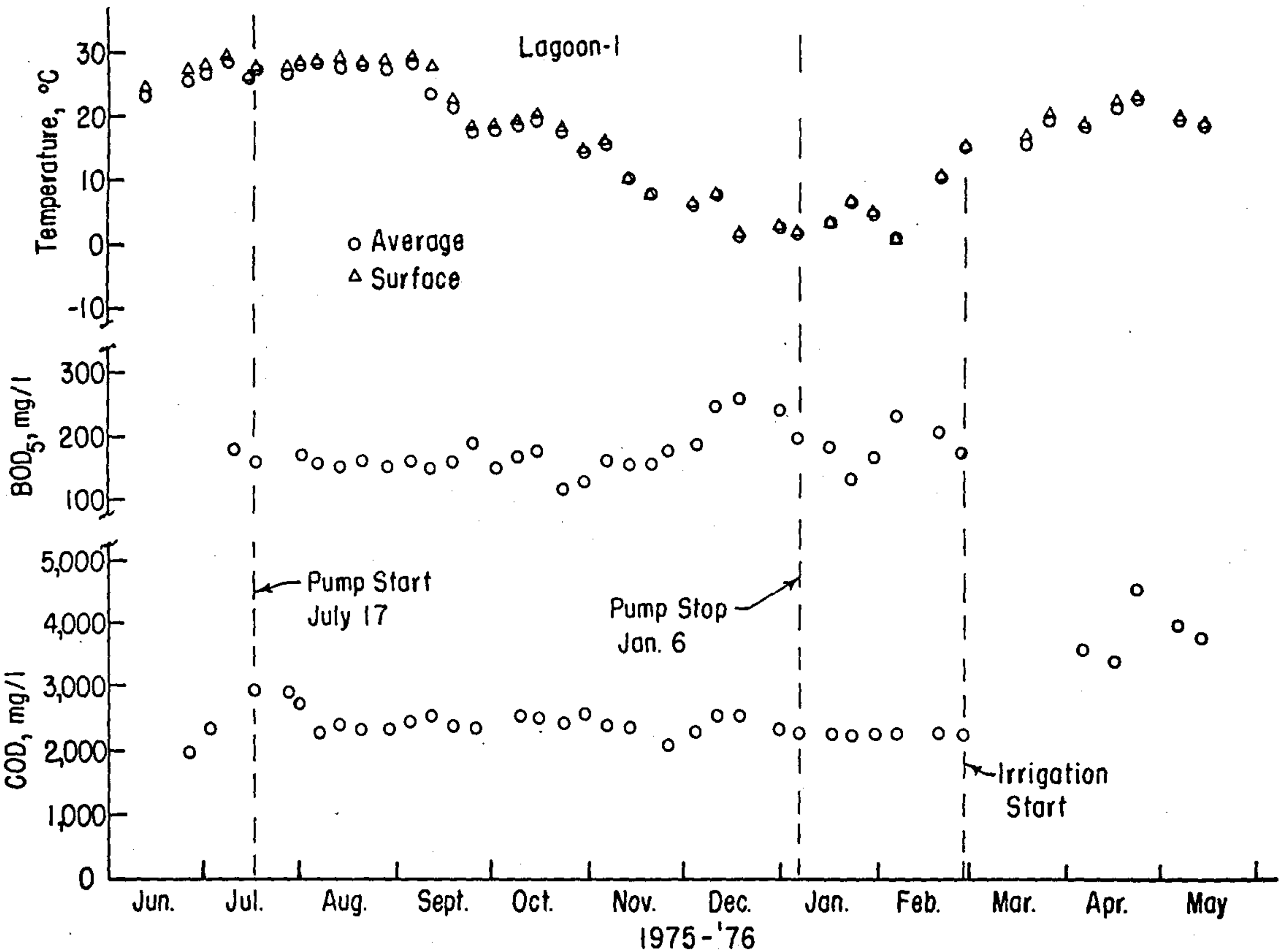

Figure 3. COD, BOD_5 and Temperatures for Lagoon 1

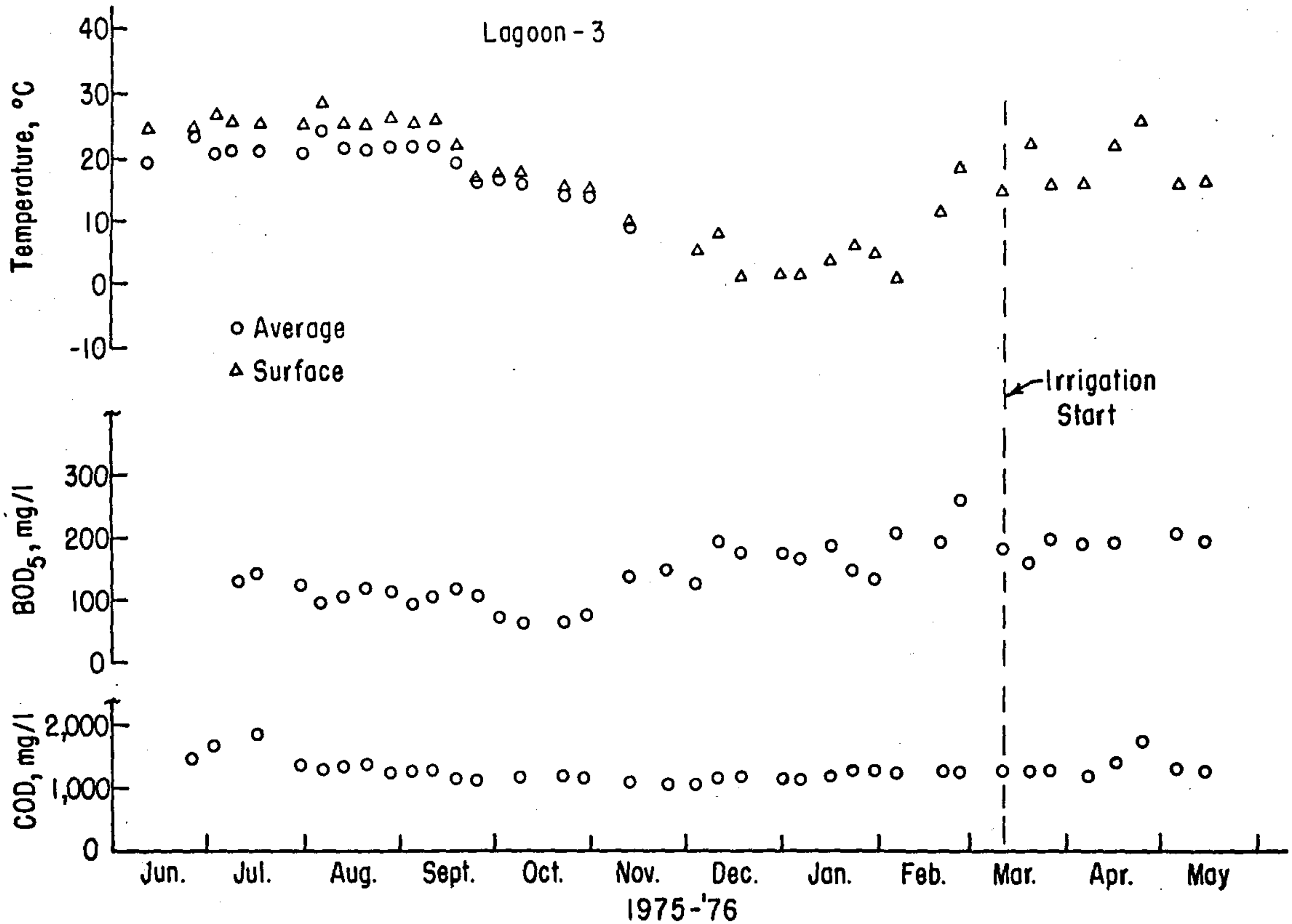

Figure 5. COD, BOD_5 and Temperatures for Lagoon 3

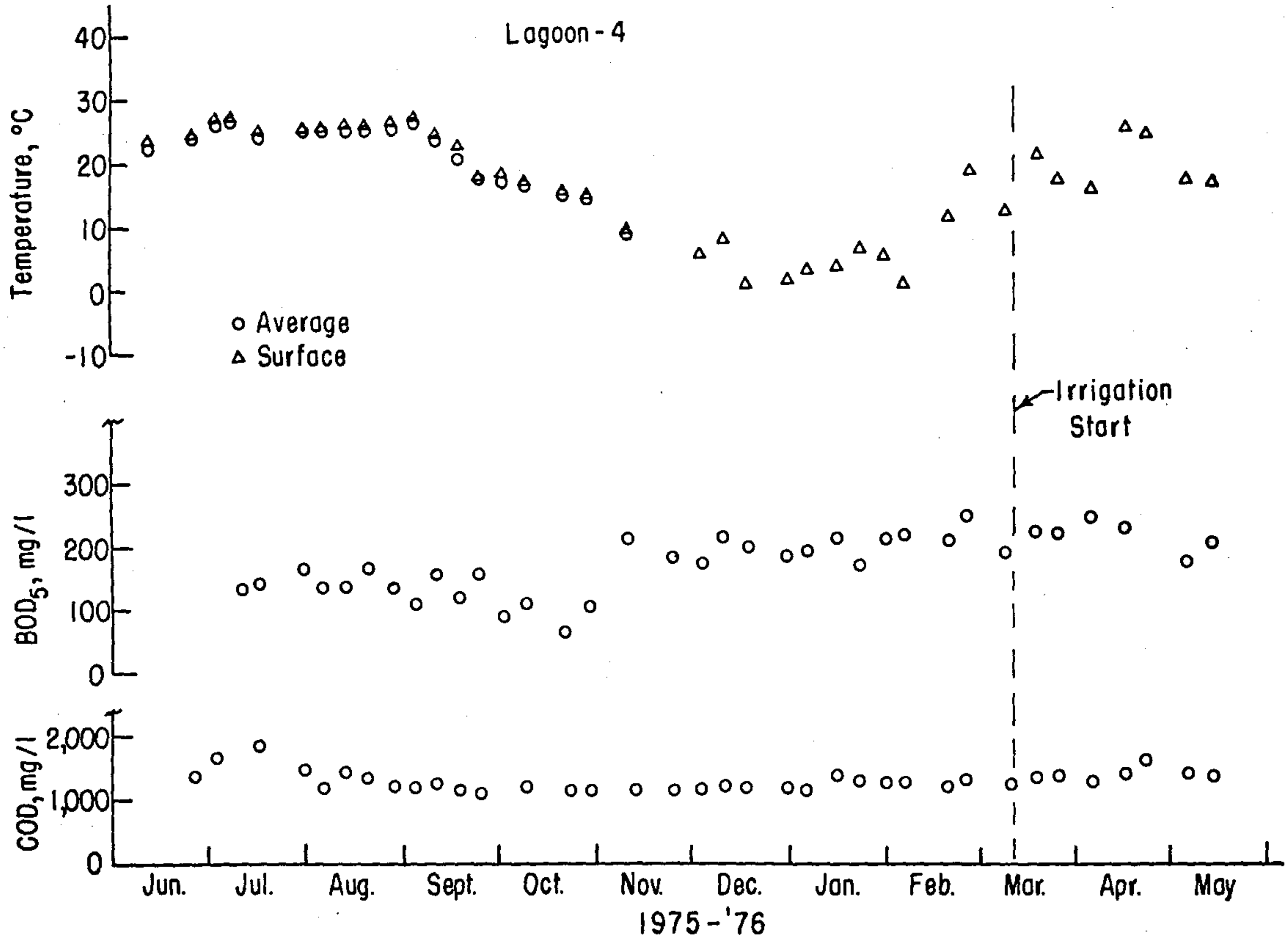

Figure 6. COD, BOD_5 and Temperatures for Lagoon 4.

deposition. There was very little sediment deposition observed in lagoon four and none observed in lagoons two and three.

The lagoons remaining full throughout the summer and fall created a problem for the east facility in that the pits filled to capacity and could not be drained when needed, so some overflowed a little on to the grounds. The pits could not be drained until the lagoon levels were lowered by withdrawal of the water. After the lagoons were lowered, some of the pits were drained into the lagoons raising the level 12 to 15 cm. This was a concentrated influent, and for the east facility, probably all of this material remained in lagoon one. This caused a thickened liquid in lagoon one resulting in heavy boiling activity with significant offensive odors occurring intermittently. The effect is more evident in the increased values for COD, BOD_5 and conductivity.

By June, 1976, the levels in lagoons one and two were still down about 0.5 m below full. The levels in lagoons three and four were up to within about 0.15 m of full.

COD Values

The Chemical Oxygen Demand (COD) is a measure of the total chemical demand exerted on the oxygen assets of a material due to the organic matter in the material. The COD values for lagoons one, two, three and four are presented, respectively in Figures 3, 4, 5 and 6. The procedures for all chemical analyses as defined in Standard Methods (1) were followed.

The COD values for lagoons one and two were about the same until the liquid was withdrawn for irrigation and some of the pits had been drained into lagoon one. After this, the COD values for lagoon one increased sharply. The COD value for lagoon two increased only a little after withdrawal of the liquid for irrigation. Before irrigation the COD values in lagoons one and two were normally in the range 2000-2500 mg/l. These values are considerably reduced from the COD values for the material in the pits. For examples, on

October 23, 1975, the following COD values were found for the pits (2):

Sow barn	31,000 mg/l
Farrowing	23,000 mg/l
Nursery I	70,000 mg/l
Nursery II	33,000 mg/l
Grower	75,000 mg/l
Finisher	41,000 mg/l

The COD values for lagoons three and four were about equal but they were only about half as large as the normal values for lagoons one and two. The values were normally in the range 1000-1500 mg/l. The COD was only slightly affected by removal of the liquid for irrigation.

BOD_5 Values

The Biochemical Oxygen Demand (BOD_5) is the amount of elemental oxygen utilized by aerobic organisms in degrading organic material maintained in an aerobic atmospheric for five days at 20^oC. The BOD_5 values for lagoons one, two, three and four are presented, respectively in Figures 3, 4, 5 and 6. These values were obtained by using a dilution of the lagoon liquids without addition of seed material. A seed material was used for a short period of time, but the results using the seed material were more erratic and variable than the results without the addition of seed. In general, the addition of seed gave BOD_5 values from about 1.5 to 2.5 greater than when seed was not added. However, the differences were not consistent so the addition of seed was discontinued and the BOD_5 values were determined without addition of seed.

The BOD_5 values for the lagoon systems followed the same pattern as the COD values. That is, the values for the east lagoons were larger than those for the west lagoons. Lagoons one and two were affected more than lagoons three and four by the removal of the liquid for irrigation. Lagoons three and four showed no effect; lagoon two only a slight effect; but lagoon one had a significant effect. The BOD_5 values for lagoon one are not plotted on Figure 3 after irrigation but they are three to five times as great as the normal values. The BOD_5 values for lagoon one after irrigation and the drainage of some pits into the lagoon ranged from about 500 to 600 mg/l, but a value of 1036 mg/l was found on March 3, 1976.

Dissolved Oxygen

The values for COD and BOD_5 indicate a high demand for oxygen. This may be, in part, the reason that no dissolved oxygen was ever detected in the lagoons. Another reason may have been due to the high turbidity of the lagoon liquids. This prevented penetration of sunlight into the lagoon liquid which created an environment which is not conducive to oxygen production. The little oxygen that may have been exchanged at the air-liquid interface was quickly consumed resulting in no dissolved oxygen in the lagoon liquid.

Temperatures

The surface and average temperatures for lagoons one, two, three and four are presented, respectively, in Figures 3, 4, 5 and 6. The surface temperature was that observed about six to eight centimeters below the surface. The average temperature is the average of the surface temperature, the temperature at one meter depth and the temperature at the two meter depth. After November, 1975, only the surface temperatures were observed in lagoons three and four.

The temperature data show that the surface and average temperatures for lagoons one and four were almost the same while for lagoons two and three the surface temperatures and the average temperatures were different during the warmer season. These results indicate that lagoons one and four were completely mixed and that lagoons two and three were stratified thermally during the warmer season. When the temperature cooled in the fall, lagoons two and three mixed naturally due to the density changes that occur with temperature changes.

Since the liquid in lagoon one was completely mixed about every four hours by the pump, it should have had uniform temperatures. The results for lagoons one and four before the start-up of the pump show that the lagoons were destratified thermally. There are two possible reasons for this. First, and probably most important, is the action in the lagoon caused by the boiling activity. The boiling activity continuously released gases from the bottom causing a mixing action and circulation pattern in the lagoons. Second, the influent lines enter the lagoons one and four off-center, and since there is usually a continuous inflow into the lagoons, though usually small, a circulation action is developed in the lagoons.

pH

The pH is an indicator of the concentration of hydrogen ions in a solution. It indicates whether a solution is alkaline or acidic. A pH value of seven is neutral. If the value is greater than seven, the solution is alkaline and if it is less than seven the solution is acidic. The pH values are presented in Figure 7 for the lagoons. These results show that the pH for all four lagoons was nearly the same and that a value of 8.0 would be representative for the observation period. The greatest variation in pH occurred in lagoon one after the withdrawal of liquid for irrigation and after some pits had been drained into the lagoon.

Conductivity

The conductivity of a solution is a measure of the total soluable salts in the solution and is indicative of its applicability for irrigation water. The conductivity values, presented in Figure 7 for the lagoons, show considerable variation. The values for lagoons three and four are very similar

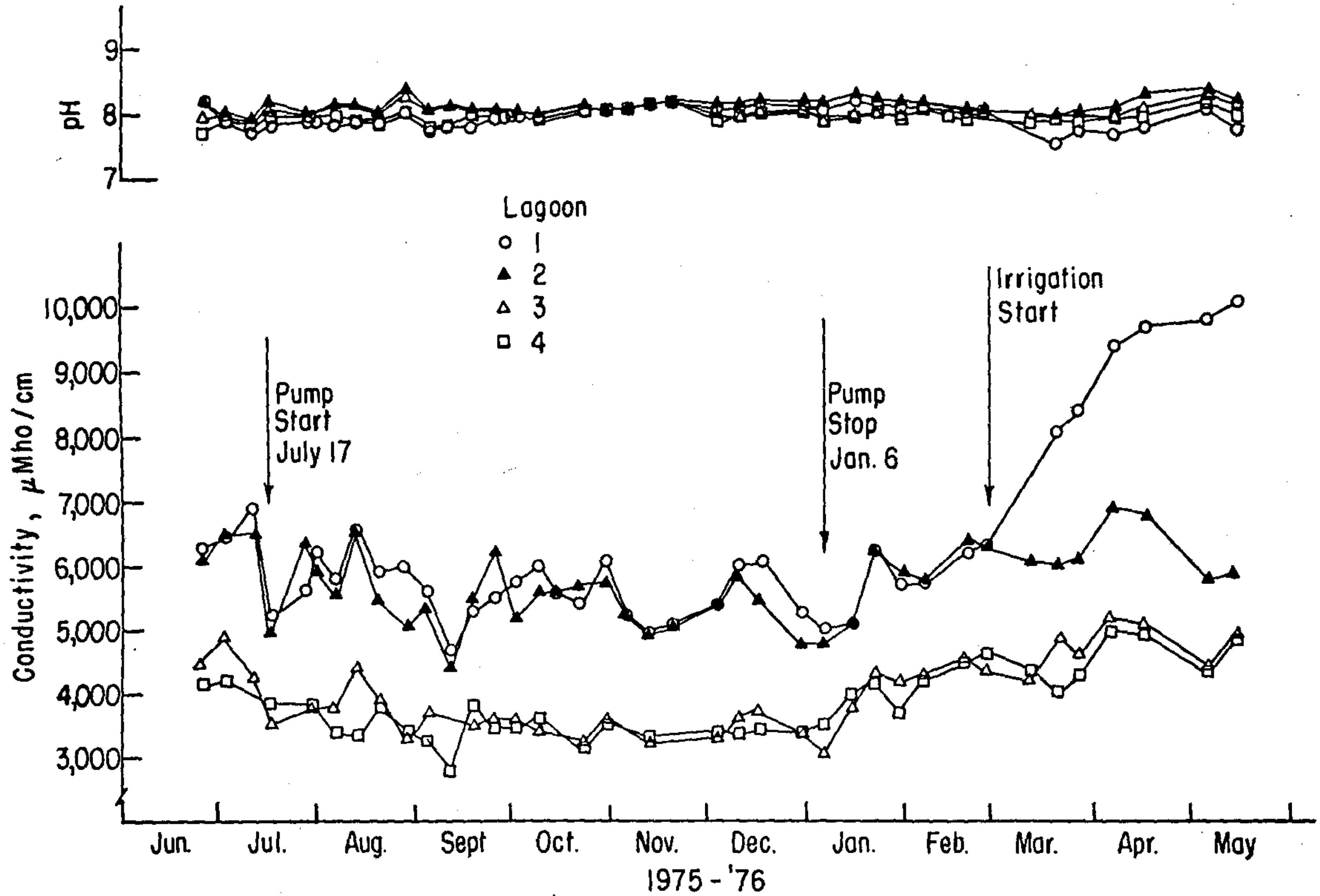

Figure 7. Conductivity and pH for Manure Lagoons

as are those for lagoons one and two before withdrawal of the liquid for irrigation. The variation in conductivity for each lagoon system follows the same pattern. The values are higher at the start of the observation period, declined during colder weather, and increased as the temperature increased after winter. The conductivity for lagoons two, three and four was affected little by the withdrawal of liquid for irrigation. The conductivity for lagoon one increased sharply after the withdrawal of liquid and the draining of some pits into the lagoon. The conductivity values for the lagoon liquids indicate that the liquid is not very suited for irrigation. However, some liquid is withdrawn and used on the lands adjacent to the lagoons. This liquid is used only for pre-irrigation and is applied to sandy, highly permeable soils. Under these conditions the liquid may be beneficial for crop production even though the conductivity is higher than would normally be recommended for irrigation water.

Discussion:

The major objective of this study was to evaluate the effectiveness of the thorough mixing of lagoons receiving livestock manure material on the reduction of odors from the lagoons. The pump did not make as significant a contribution in reducing odors from an anaerobic lagoon as had been expected. Comparing the results from lagoon one, the lagoon with the pump, with the results from lagoon four, a similar lagoon without a pump, the observed results were very similar. Lagoon four was thoroughly mixed naturally due to the boiling activity. The BOD_5, COD, pH, temperatures and conductivity of lagoon four followed the same trend or pattern as did lagoon one.

The most noticeable effect of the pump was that it tended to reduce the boiling activity in the lagoon, which would to a small extent, reduce some of the intermittent, offensive odors given off by the more active boiling activity. A reason for the lack of more positive results may be because of the heavy sediment deposition in lagoon one. There was over four years of solids deposition in lagoon one with the capacity being reduced by about one-fourth to one-third. These solids were redistributed some by the pumps' action and they could not be reduced significantly in the short time period that the pump was operated. If the pump had been installed in a new lagoon system, then it may have been more effective in reducing the solids and the potential for odor production.

Lagoons two and three were strongly stratified thermally during the summer months though they are relatively shallow, 2.2 m. This was because the liquid was so turbid that the sunlight did not penetrate the liquid. This prevented much warming below the surface.

The surface of lagoon one was slightly warmer than the surface of lagoon two. This might result in a greater evaporation total from lagoon one compared to lagoon two. However, there was more scum material on lagoon one than on lagoon two and this would tend to reduce the evaporation total from lagoon one compared to lagoon two.

Conclusions:

The forced mixing of an anaerobic lagoon, using a propeller pump, did not reduce the odor production from the lagoon as much as had been expected. The benefit obtained probably does not justify the use of the pump.

The pump thoroughly mixed the liquid in the lagoon with a complete turnover occurring about every four hours.

The lagoons receiving the effluent from the pits of the confined swine operations were completely mixed due to the boiling activity caused by gas releases and the circulation caused by the entry of the effluent into the lagoons.

The lagoons that did not receive effluent, but were connected by a cut in the dike to ones that did, stratified thermally in the summer months because the liquid was so turbid that sunlight could not penetrate and warm the bottom waters.

The COD values in the lagoons normally ranged from 1000 to 2500 mg/l and the BOD_5 values normally ranged from 100 to 250 mg/l. These values indicate a high demand for oxygen and are, in part, the reason no dissolved oxygen was ever detected in the lagoons.

A pH value of 8.0 for the lagoon was representative for the observation period.

The conductivity values for the lagoons normally ranged from about 3500 to 6500 micromhos per centimeter.

References:

1. ______________________. 1971. Standard Methods for the Examination of Water and Wastewater. 13th Edition, Washington, DC, American Public Health Association.

2. Personal correspondance with Barry Frey, graduate student, Ph.D. candidate, Agricultural Engineering, Oklahoma State University. June, 1976.