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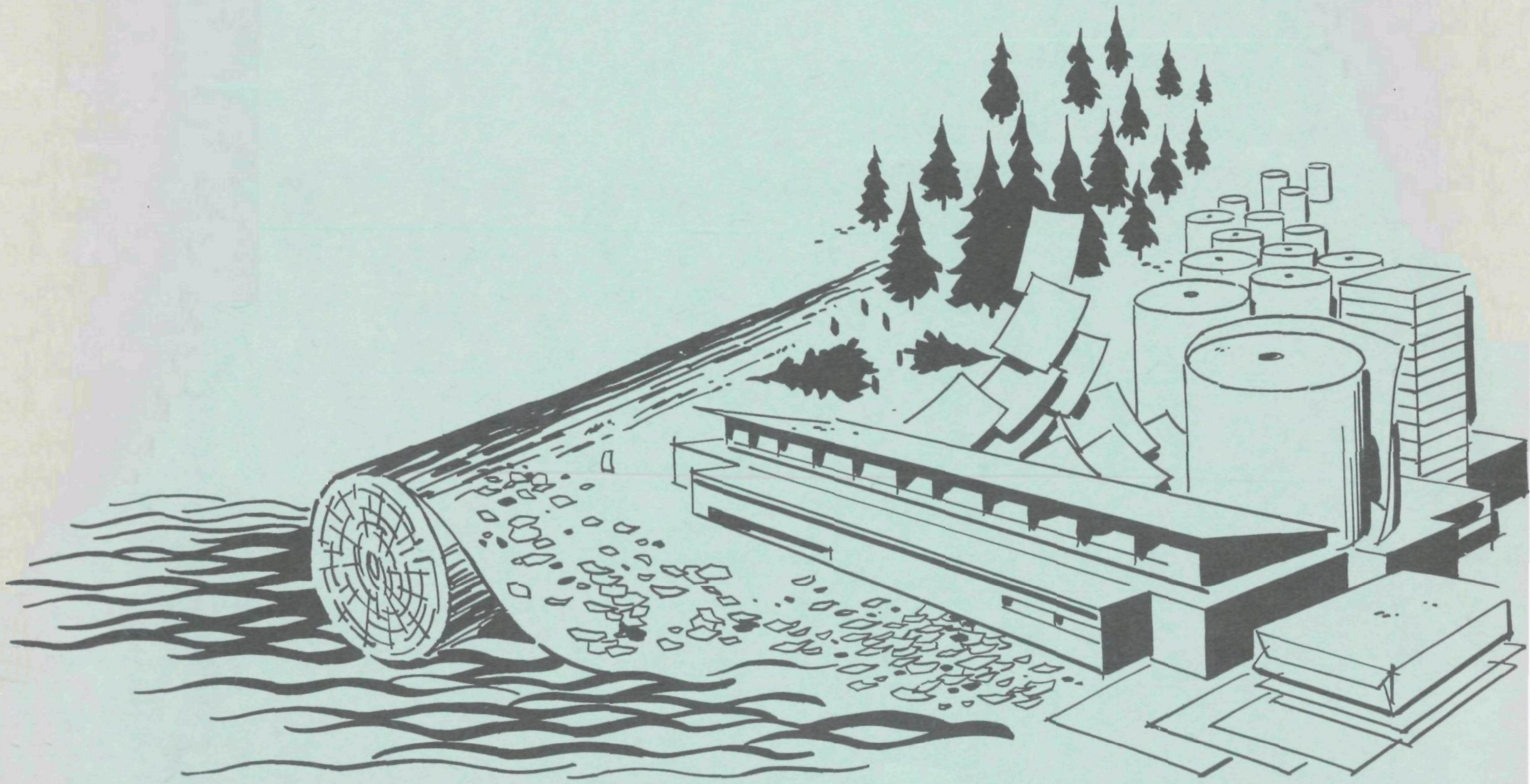
Aerial Photographic Tracing of Pulp Mill Effluent in Marine Waters



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AERIAL PHOTOGRAPHIC TRACING
OF
PULP MILL EFFLUENT IN MARINE WATERS

by

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for the

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ABSTRACT

Aerial photography taken of waste plumes from Kraft pulp mill ocean outfalls was shown to be an effective tool in the study of waste disposal sites. This technique is not limited by sea conditions and permits monitoring and evaluation of outfall sites throughout the year. Photography taken at one instant provides comprehensive information throughout the waste field. Manpower requirements and costs for this method are considerably less than for conventional boat sampling surveys.

Field studies were conducted on the waste plumes from Kraft pulp mill ocean outfalls at Newport and Gardiner, Oregon and Samoa, California. Waste concentrations were measured by conventional boat sampling techniques while aerial photography was taken of the outfall area from altitudes ranging from 3,000 to 11,000 ft. Computerized procedures were used to compute water currents, waste concentrations, toxicity zones and diffusion coefficients from the photography.

The highest concentration measured directly over the outfalls was 2.3 percent waste by volume and the maximum area of influence with concentrations greater than 0.2 percent waste was 155 acres. The maximum concentration determined over the outfall for each field study was generally less than that shown to have a detrimental effect on young salmon for a 14-day exposure.

Surface water current was found to be the dominant factor in the resulting plume pattern. During periods of low current velocities in the receiving water, the hydraulic head created by the effluent source was a significant factor in the resulting plume shape. The steady state form of the Fickian diffusion equation and unidirectional transport velocity was not applicable to the majority of the observations.

Temperature was found not to be an effective tracer for tracking the plume or for estimating waste concentrations since the resulting plume temperature may be greater than, less than or equal to the surrounding ocean temperature.

This report was submitted in fulfillment of Grant WP-00524 under the sponsorship of the Federal Water Quality Control Administration.

Key Words: Kraft waste, marine disposal, ocean outfall, aerial photography, remote sensing, diffusion, water currents, bioassay, water temperature.

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SECTION I

CONCLUSIONS

1. Aerial photography provides comprehensive information on the marine waste disposal process and is an effective tool in monitoring and evaluating ocean outfall sites throughout the year.

2. The maximum concentration measured over the outfall for each field study was generally less than the range of 1.8 to 3.3 percent Kraft pulping waste that has been shown to be detrimental to young salmon for a 14-day exposure. The highest concentration measured during the study was 2.3 percent waste by volume and the maximum area of influence with concentrations greater than 0.2 percent waste was 155 acres.

3. Diffusion coefficients measured ranged from 2.0 to 14 ft^2/sec. The steady state Fickian diffusion equation with a unidirectional transport velocity was not applicable to the majority of the observations.

4. Temperature is not an effective tracer in tracking the plume or for estimating concentrations in the waste field since the resulting plume temperatures may be greater than, less than or equal to the surrounding ocean temperature.

5. Surface water current is the dominant factor in the resulting plume pattern at the three locations observed.

6. Surface spreading of the waste field over the outfall must be considered to adequately explain the resulting plume shape.

SECTION II

RECOMMENDATIONS

It is recommended that observations of the Newport outfall be conducted for a wide range of sea and weather conditions. Field studies made throughout the year using aerial photography with limited boat sampling would provide valuable information for the design and operation of ocean outfalls. Such a study combined with dye drops from the aircraft would indicate seasonal changes in waste disposal conditions, current velocities, diffusion coefficients, plume patterns and foaming tendency. Sufficient data would be available to relate the waste field characteristics to natural parameters such as tide, wind, state of the sea, and river flow. The study would also provide information for sizing the holding ponds for operation of existing outfalls.

While all the photography would not be suitable for automatic computer processing, it would still give information on the current velocities, plume size and pattern and foaming tendency.

It is also recommended that a critical analysis of actual held conditions versus the original design predicitions be made for the several ocean outfalls in Oregon and at Eureka, California. Such a study will indicate areas of design deficiencies and will improve the technology of ocean outfall disposal.

It is recommended that further analysis be made of the area of influence within various concentration zones. This study would compare these data with information now available from the many biological studies which have related Kraft pulp mill effluent concentrations to biological effects.

SECTION III

INTRODUCTION

Pollution of near shore coastal waters and estuaries is a serious problem in the Pacific Northwest since these waters form an integral part of the economy of the region in addition to their high recreational and esthetic value to the people. Sports and commercial fishing combined form a major aspect of the economic and recreational values of the water resources. These uses combined with the other important values of water, make it essential that industrial growth to provide jobs be accomplished without despoiling the environment.

This project on analysis of ocean outfalls from Kraft pulp mills is a part of an overall investigation that has been in progress since 1964. Investigations during the first years of this project included laboratory studies on the development of bioassay methods for assessing water quality impairment from the discharge of Kraft pulp mill wastes into marine waters. Engineering studies on treatment of components of the waste were also undertaken during the first years of this study. Research during the last two years of the project were directed towards investigations of the area and degree of water quality effects from Kraft pulp mill ocean outfalls. This report includes only the work accomplished during the last two years of the project since the previous research has been adequately described in the annual progress reports, published papers, and theses.

Disposal of wastes from the pulp and paper industry presents a serious water quality problem. In the area of Oregon and Washington, lying between the Pacific Ocean and the Cascades, there are now 49 pulp mills producing approximately 17,000 tons of pulp daily (Stanford, 1969). A variety of pulping processes are used including sulfite, Kraft, semi-chemical, and mechanical.

Primarily because it produces a stronger, more versatile pulp at lower cost, the Kraft pulping process has become the dominant method for production of pulp and paper. In 1920 the total production of pulp in the United States was approximately 3.8 million tons annually of which approximately 4.5% was produced utilizing the Kraft process. By 1966 approximately 63% of the nationwide production of paper pulp was produced by the Kraft process.

Growth of Kraft process for pulp manufacturing in Oregon has been similar to that experienced nationwide. In 1939, pulp production capacity in Oregon was approximately 575 tons per day of which 20% was by the Kraft process. By 1969, pulp production in Oregon had risen to more than 7,000 tons per day of which 65% (4,950 T/day) was produced by the Kraft process.

Kraft mills operating in Oregon at the present time include the following:

Boise Cascade Company Mill, St. Helens	625 T/day
Georgia Pacific Corp., Toledo	1,000 T/day
Western Kraft Corp., Albany	575 T/day
Weyerhaeuser Paper Company, Springfield	1,150 T/day
International Paper Company, Gardiner	550 T/day
Crown Zellerback Corp., Wauna	750 T/day
American Can Company, Halsey	300 T/day

The Kraft process of pulp production discharges about 20,000 gallons of liquid waste per ton of pulp, with a population equivalent of about 400 per ton of pulp. Treatment and disposal of waste in a satisfactory manner is a major problem of the pulp and paper industry.

Many of the newer mills have been constructed on or near tidal estuaries or the open coast. Some of the new mills have added to the problems created by many of the older mills which were already located on marine waters. With the addition of new mills and increased production in the older mills, significant volumes of waste are being discharged into marine waters.

One of the primary problems created when Kraft pulp mill effluent is discharged into marine waters is the toxic effect on the biological population. Although numerous investigators have conducted tests on acute toxicity there is little agreement on permissible concentrations. Bioassay results are generally reported in terms of a median tolerance limit for a specified period of exposure to a specific organism. Table 1 shows the results of some of these studies.

Table 1. Bioassays on Kraft Mill Effluent.

Investigator Year	Species	Exposure Hours	TL_m %KME
O'Neal 1966	Bay mussel (Mytilus edulis)	48	2.5
Courtright & Bond 1969	Fluff sculpin (Oligocottus snyderi)	64	9
Howard & Walden 1965	Guppies (L. reticulatus)	48	11
Parrish 1966	Striped sea perch (Phanerodon furcatus)	72	12
Parrish 1966	English sole (Parophrys Vefulus)	72	15

It can be seen from Table 1 that tolerance level varies between test organisms.

O'Neal (1966) found that the toxicity of Kraft waste as measured by bioassays on the bay mussel is biologically degradable but there was no apparent correlation between B.O.D., P.B.I. and toxicity degradation. Sprague and McLeese (1968), in tests with salmon parr and lobster larvae have shown that toxicity degradation rates varied considerably between the two test animals.

While the TL_m is probably the most reproducible statistic from the test and provides valuable information on toxicity; it cannot be applied to actual field problems for determining the permissible concentration in receiving waters since the premise of allowing a stated mortality is unacceptable as a water quality control policy.

The Washington State Department of Fisheries (1960) has conducted extensive tests on the toxicity of Kraft pulp wastes to salmon and trout. The tests were conducted in flowing sea water with a salinity of 35 parts per thousand (ppt) and at temperatures about 50°F. The tests showed that the concentration which produced no obvious harmful effects over a 14-day exposure period was usually between 1.8 percent and 3.3 percent by volume. Longer exposure periods led to somewhat lower levels. Significant mortalities occurred at concentrations greater than 3.3 percent over the 14-day period. This study also indicated that there was little significant difference in the toxicity in wastes between mills producing bleached and unbleached Kraft pulp.

Alderdice and Brett (1957) conducted bioassays to determine the toxic effect of full bleach Kraft effluent on young sockeye salmon. The tests were conducted in 20 ppt salinity sea water and at 18°C. Results indicated that at concentrations below 4.8 percent there was no mortality.

Kraft pulp mill effluent when discharged into marine waters will some times create foam on the water surface. Courtright and Bond (1969) found the foam to be about five times more toxic than the whole mill effluent as measured by bioassays with the mussel larvae (Mytilus edulis). While on the water surface, the foam is unsightly but probably does not create a great threat to marine life. If the foam accumulates on the beach, it can result in lethal concentrations to some marine life in the littoral region.

The maximum concentration of Kraft pulp waste which will not adversely affect marine life is difficult to define when one considers the variable composition of the effluent, possible separation of the waste into fractions upon contact with the sea water, variation in tolerance levels between animals, avoidance reaction of some species and the lack of knowledge on chronic toxicity.

Since 1955 six Kraft pulp mills have been constructed on the Pacific Coast of Oregon, Washington and Northern California. In each case effluent disposal involves the use of ocean outfalls that have been designed and constructed for the purpose of protecting water quality in the near shore environment. The design of these facilities has given consideration to: a) dilution requirements for protection of aquatic resources, b) prevention of objectionable aesthetic conditions on adjacent beaches and the near shore area, and c) the physical circumstances for initial construction and continued protection of the outfall against the ravages of the sea.

The typical outfall extends into the ocean and usually terminates with a diffuser section where the flow is divided into a number of small jets which discharge the waste into the receiving water. The jet of waste is subjected to a momentum force and to a buoyant force which is proportional to the density difference between the effluent and the receiving water. As the jet of waste rises towards the surface, it mixes with the ambient fluid and both its momentum and buoyancy per unit volume decrease. The mixing causes a waste field to be formed either at the surface or submerged below the sea surface depending on the hydrography of the site and the initial jet dilution.

Ocean outfalls along the Pacific coast are in general located on the relatively shallow coastal shelf. The turbulence in this area is usually sufficient to prevent density stratification in the receiving water. Under these conditions the effluent, being less dense than sea water, will generally rise to the surface to form a surface waste field. After the initial dilution due to jet diffusion, the waste is transported from the site by current action and continues to mix and spread by natural turbulence in the ocean.

If density stratification exists in the receiving water and a submerged plume is formed, the waste field is esthetically more pleasing than a surface field but may be potentially more dangerous to the marine life. The submerged plume will create an oxygen sink where the reaeration rates are generally lower than at the surface. Under these conditions less energy from the wind will be available for diffusion. Also concentrations may be higher than for a surface plume as less vertical rise is available for jet diffusion.

Probably the most extreme condition for ocean outfall waste disposal occurs during calm periods when current velocities in the receiving water approach zero. Only the jet diffusion is available for dilution and the waste field forms a pond above the diffusers since only the hydraulic head created by the discharging effluent is available for movement of the waste field. Under these unfavorable conditions, a large waste field can form with nearly uniform concentrations throughout and odor can be a serious problem on the nearby beach.

Once the water quality standards have been set for the receiving water, these can be met through a combination of effluent treatment, outfall location and design, and/or operation of holding ponds to store the waste during adverse disposal conditions.

The purpose of the research included in this report was to study the water quality impairment near existing ocean outfalls. In addition to the area and extent of Kraft pulp mill outfall influence on water quality, this study also includes diffusion analysis of the waste field. Natural conditions which influence mixing, water currents, foaming of the effluent, and the establishment of subsurface plumes are discussed.

SECTION IV

METHODS AND PROCEDURES

In order to study the waste field created by Kraft pulp mill ocean outfall, both aerial photography and boat sampling were utilized. The concentrations determined by boat sampling provided standardization data for the aerial photography. Concentrations throughout the waste plume, water currents and diffusion coefficients were computed from the aerial photography.

Field work was conducted at three outfall locations as shown in Figure 1. These are the Georgia Pacific outfall off Newport, Oregon, the International Paper Company outfall near Gardiner, Oregon, and the Georgia Pacific outfall near Samoa, California. The general procedure employed in the collection of data was to take aerial photography of the waste field and at the same time sample the plume by conventional methods from a boat.

Accurate horizontal control for positioning the boat and orientation of the photography was essential. Shore control was provided by a beach traverse extending between existing control stations at each of the three locations. Horizontal and vertical angles were measured with a Wild T-3 theodolite and the distances along the traverse were measured with either a tellurometer or a geodimeter. Since the geodimeter and tellurometer measure slope distance, the station elevations were determined by reciprocal vertical angles. All positions for this study were computed on the state plane coordinate system so that existing C&GS, GS, and USE control could be used when available. Since most published maps and charts include a state plane coordinate grid, this system provides a common base for positioning.

Traverse stations were permanently marked with steel markers. In order to identify the control stations on the photography, the beach stations were also marked with white or black cloth. Details of the beach traverses are given in appendix A.

In addition to shore control, horizontal control was required in the water for photo orientation. This was accomplished by the use of marker buoys which were set from the survey boat and their position determined by triangulation from the shore stations.

During the 1968 field season ten buoys were permanently anchored with 500-lb. concrete anchors. However, only three buoys were required during the 1969 season. These temporary buoys were set along the plume each day that field work was conducted. The buoy floats were four feet square, two inches thick polyurthene board which were fiberglassed and painted orange. The 60-lb. anchors were adequate to hold the floats in position for the sea conditions encountered during the field work.

Figure 1. Location of ocean outfalls.

Prior to aerial photography the survey boat would set two four-foot square floats with drogues attached to measure the water currents. The drogues extended from one half foot below the water surface to five feet and were constructed of herculite material fitted over a conduit frame to form a cross banner 4-1/2 ft in length and in width. A ten pound weight was attached to the lower end of the drogue. The positions of the current floats were determined from the aerial photography.

The waste concentrations were determined in the plume by boat sampling. Rhodamine WT dye was metered into the waste discharge pipeline on shore with a positive displacement pump. Arrangements were made with the paper companies to maintain a nearly constant waste discharge rate while field work was in progress. In addition, they provided the project with the flow rate records and a dye injection station on the outfall line near the beach.

Dye concentrations in the waste plume were measured with a Turner III fluorometer aboard the survey boat. The fluorometer was equipped with a flow through door and continuous readings were recorded with a chart recorder. The sample was drawn through the instrument with a pump on the discharge side of the fluorometer. Sample intake ports were located along the length of a vertical sampling probe mounted on the side of the boat. By a sliding valve arrangement in the body of the probe, the sampling depth could be selected from one to ten feet below the water surface. Details of the sampling probe are given in appendix B.

An extra fluorometer was always carried aboard the vessel. The fluorometers were standardized in the laboratory before and after each run and standardized in the boat offshore from the outfall. Power for the fluorometer was provided by a 12 volt generator and a 12 volt d.c. to 115 volt a.c. powercon sine-wave inverter.

While continuous sampling was underway, the fluorometer operator would mark each position, record position number, indicate any fluorometer scale change and any sampling depth change on the chart record. The boat's position was determined at one-minute intervals by triangulation. Simultaneous horizontal angles were measured from two shore stations with Wild T-2 Theodolites. The radio operator aboard the boat would signal the theodolite operators when the position was to be taken.

A Whitney underwater temperature probe was also carried in the survey boat. When operating properly, continuous surface water temperatures were recorded on a chart recorder.

At the time of boat sampling, aerial photography of the waste disposal area was taken with a six-inch aerial mapping camera and two 70 mm Hasselblad cameras mounted as a unit in the baggage compartment of a small high wing aircraft. Normally black and white panchromatic film was used in the mapping camera, either normal or infrared color film in one Hasselblad and infrared black and white film in the second Hasselblad. The nine inch by nine inch pictures from the mapping camera included the area from below the aircraft to the horizon and were used for photographic orientation of the smaller cameras. The coverage of the 70 mm pictures included only the area in the immediate vicinity of the waste field.

The photographic film was developed by project personnel in accordance with the film manufacturer's directions. The aerial film from the mapping camera was 9-1/2 inches wide and 100 ft long, and was processed with a Morse B-5 rewind processor while the 70 mm film was processed with a Nikor reel and tank processor.

A flow diagram for the data processing is shown in Figure 2. The initial step in processing the fluorometer and temperature records from the boat survey was to digitize the strip chart records with an X - Y coordinatograph. The coordinates of the trace were recorded on computer cards. These cards, along with the cards containing the shore angles,

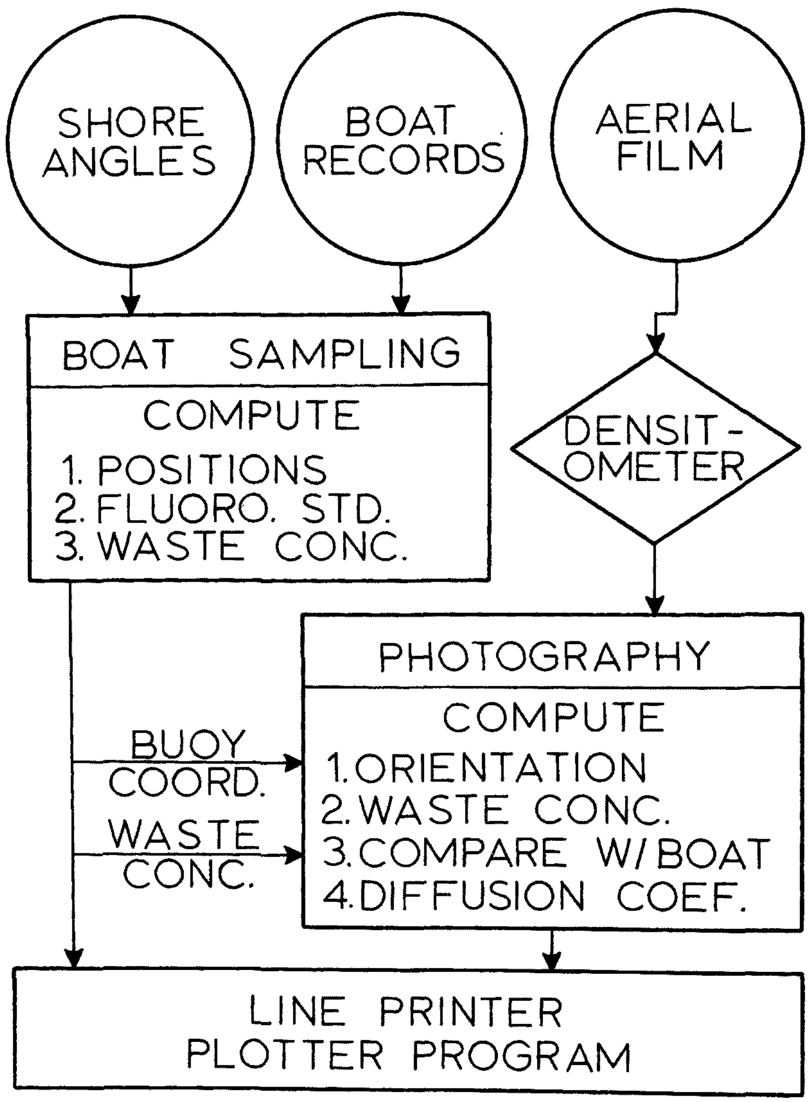


Figure 2. Data processing flow diagram.

were fed into the computer for processing. The digitized strip chart data was reduced to fluorometer readings and the fix number index was shifted to account for the time delay for the sample to pass from the intake port of the sampling probe to the fluorometer. A least square fit was made to the fluorometer standardization data and the fluorometer readings were converted to concentration of the tracer. By knowing the effluent flow rate and the dye injection rate, the tracer concentrations were converted to effluent concentrations.

Angles from the shore stations to the photo control buoys and the boat were reduced to state plane coordinates. Since theodolite sightings were made on the boat's mast, a correction was applied to determine the position of the fluorometer intake ports. The ground coordinates for each digitized point on the chart record was interpolated from the processed shore control data. A detailed description of the procedure used in digitizing the strip chart records and the computer program for processing the data are listed in appendix C.

The results of the boat survey were displayed using a three-dimensional computer plot program. The program draws and labels a state plane coordinate grid, labels a title on the plot and plots the concentrations or temperature. The axes of the plot are rotated so that the Z-axis is not perpendicular to the plane of the paper. The waste concentration or water temperature is represented by the length of a line drawn parallel to the Z-axis. The position of this point can be scaled from the grid to the base of this line.

Laboratory tests were conducted to determine the effect of the Kraft waste on the dye traces. Since the presence of the Kraft effluent in the water does increase the absorption of the exciting and emitted light in the sample cell, the measurable fluoresence of the tracer will be reduced by the waste. Using a tracer to effluent ratio of one to a million, the test showed a reduction of fluoresences of about ten percent for the range of tracer concentration encountered in the field survey. Corrections were not made to the field data for the absorption of the fluoresence by the Kraft waste.

The photographic information was converted to digital data with a McBeth TD-102 photo densitometer modified for automatic scanning. The densitometer is equipped with filters and can measure the film densities of the three layers of a color transparent photograph or the film density of a black and white negative. The aerial film is placed on the scanning table. The scanning table is continuously moving and each time the table changes direction the film is advanced one scan width. The film densities which are recorded as voltage output from the densitometer and the Y photographic coordinate are recorded on computer cards at about one-second intervals while the scanning table is moving. The X photographic coordinate is computed from the number of scans required to digitize the photograph. Details of the scanning equipment are shown in appendix D.

By using this method of analysis, the photographic image can be analyzed and reduced to a symbolic computer image which yields values of concentration and diffusion coefficients. Details of the reduction of the photographic information were given in the progress report on Airphoto Analysis of Ocean Outfall Dispersion (Burgess and James, 1969).

SECTION V

NEWPORT STUDY

The Georgia Pacific pulp and paper plant at Toledo produces about 1000 tons of pulp per day. Following a period of aeration, strong waste from the process is pumped through an eight-mile pipeline to the outfall at Newport. Location of the outfall is shown in Figure 3. The waste disposal area is bounded by Yaquina Head on the north, the north jetty of the harbor entrance on the south, the shore on the east and a reef on the west. The reef extends from the west end of the north jetty to the tip of Yaquina Head. Water depth over the reef varies from about six feet at the south end to 40 feet at the north end. The topographic configuration of the waste disposal area influences the circulation patterns in the receiving water.

The aerial photograph of the Newport-Toledo area shown in Figure 4 was taken looking east with the ocean in the foreground. The location of the outfall in this figure was sketched on the photo and is shown in white. The plant at Toledo is located near the upper center of the photo with the cloud covered Willamette Valley in the background.

Flow rates throught the pipeline vary from about 4000 to 9000 gpm. Figure 5 is a photograph of the plant looking northeast. The strong waste from the plant pass through the aeration lagoons shown in this figure. Holding pond capacity is available for storage of about seven days effluent from the plant. During periods of unfavorable ocean conditions the ponds hold the effluent. Weak wastes from the plant pass through the primary treatment plant shown in Figure 5 near the center of the photograph. Effluent from the primary treatment plant is discharged into the Yaquina River to the left of the bridge.

The 21-inch diameter outfall at Newport was rebuilt and extended to 3500 ft offshore in 1965. As shown in Figure 6 the outfall terminates with a wye diffuser in about 40 feet of water at low tide. Thirteen outlet ports are located at 20-foot intervals on each branch of the wye diffuser. The ports are three inches in diameter and discharge horizontally into the sea. They are oriented so that consecutive ports discharge on opposite sides of the header. As explained by Baumgartner, James, O'Neal (1969) the theoretical jet dilution for this outfall design under normal conditions is about 100. This would represent a waste concentration by volume of one percent or ten ml/L.

Field work was conducted at Newport during the summers of 1968 and 1969. Table 2 includes a list of dates when sampling was successfully conducted. Sampling was attempted on nine days other than those listed, but work was not accomplished due to rough seas, fog or rain.

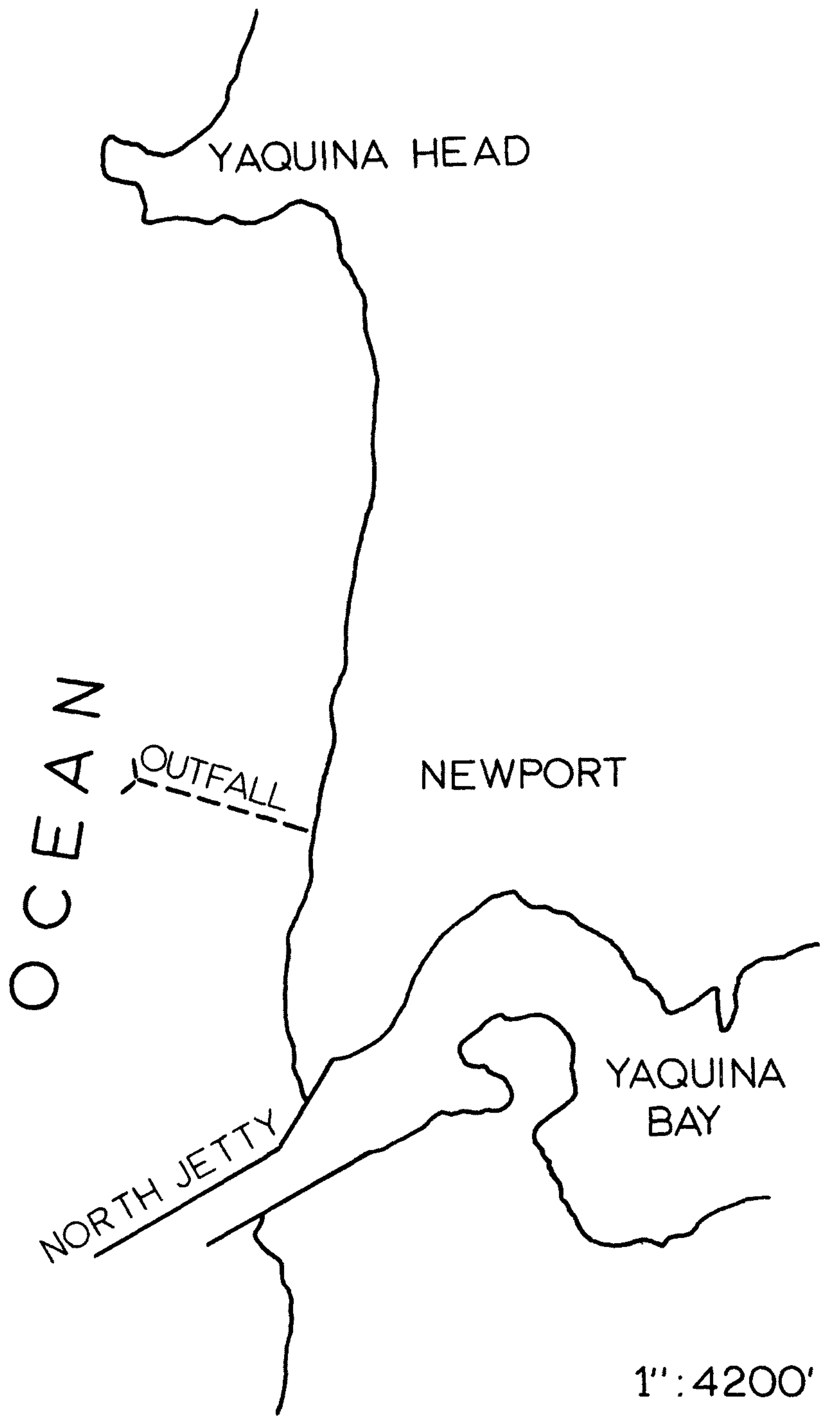


Figure 3. Newport outfall location.

Figure 4. Photograph of the Newport area.

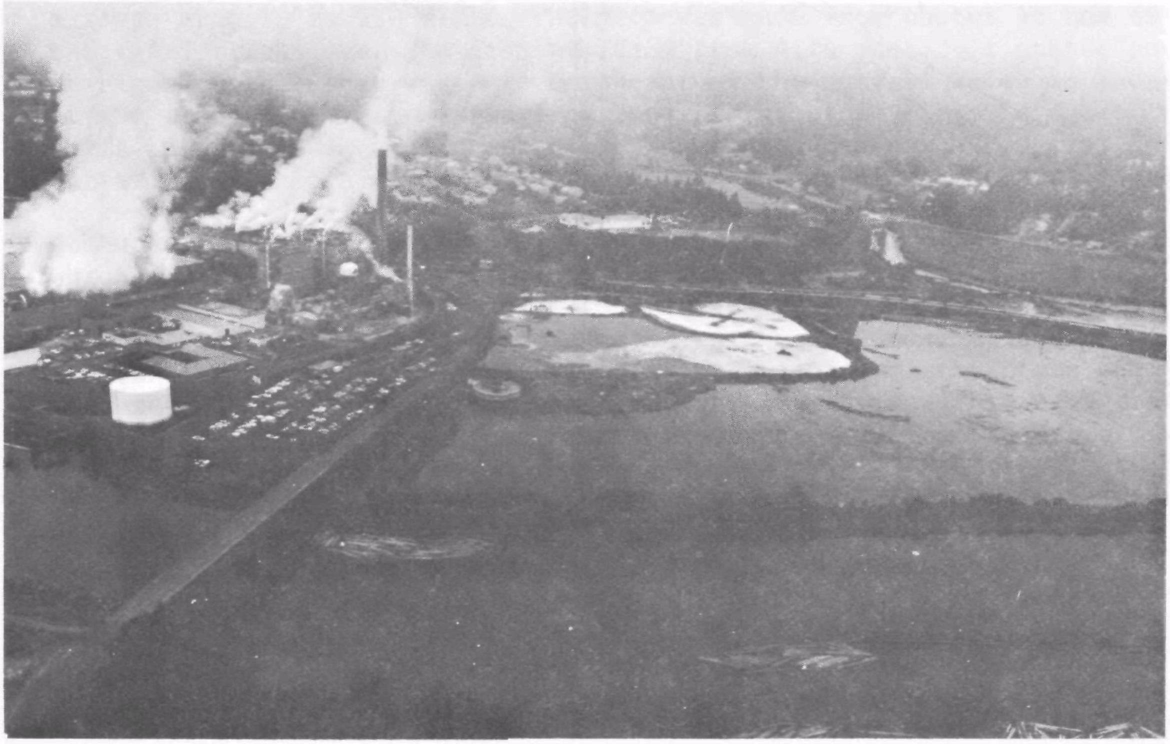


Figure 5. Photograph of the Georgia Pacific plant at Toledo.

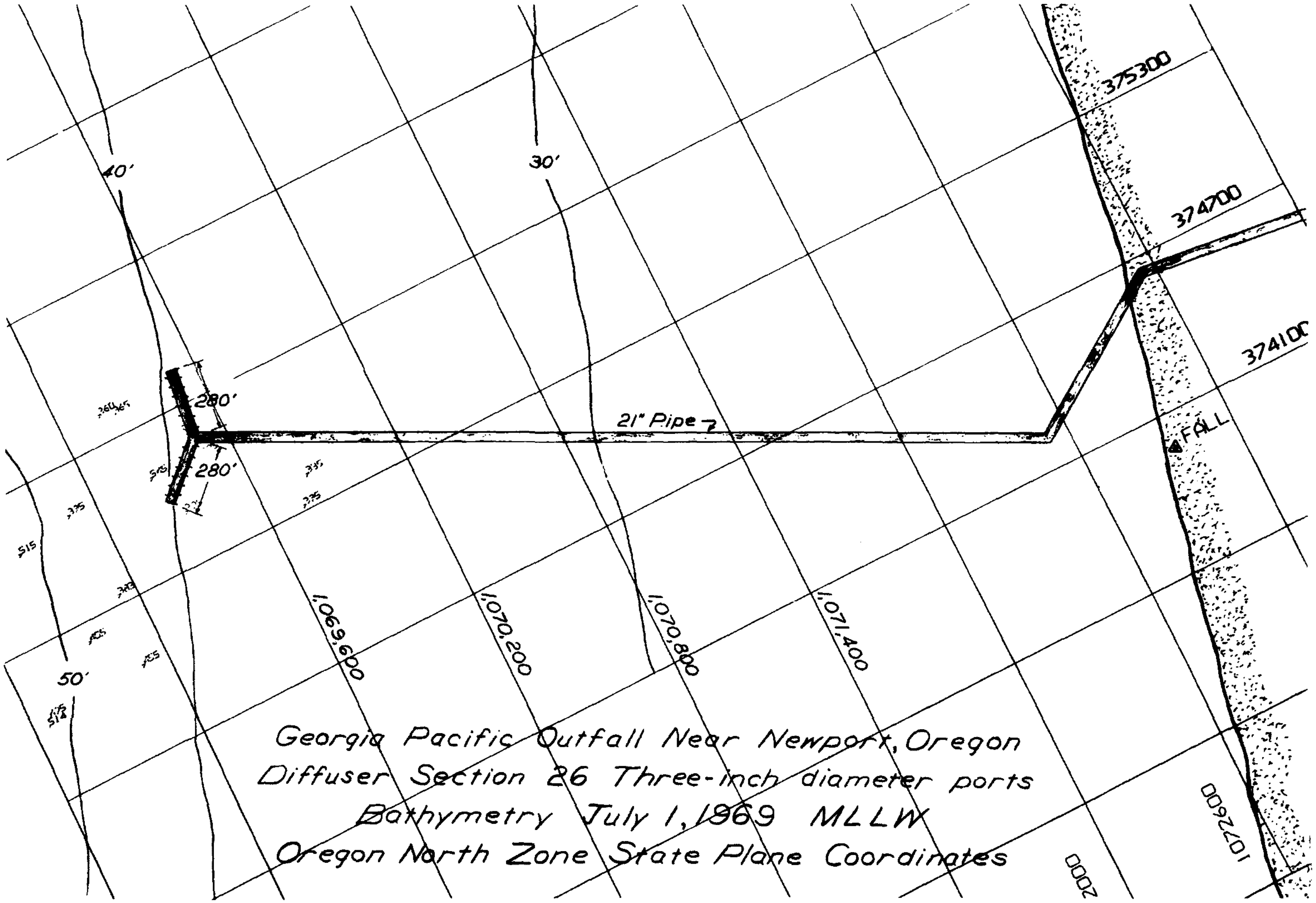


Figure 6. Sketch of the Newport outfall.

Aerial photography during the 1968 field season was taken with a single mapping camera mounted vertically. As sunlight reflection on the water surface was a major problem in processing the data, oblique photography was used during the 1969 field season. See appendix D for description of the cameras. A discussion of the results from the various days of sampling follows.

August 8, 1968

Figure 7 shows the results of the boat sampling on August 8, 1968. The outfall is located in the upper right and the plume extends southwest or to the left. From the appearance of the boat's track which is shown as a solid line on the plot, it is obvious that the location of the waste field was not evident from the boat. Maximum concentration over the outfall was 15 ml/L. Boat sampling was conducted from 16:06 until 18:09. The wind was from the NE 10-20 mph with a four-ft swell. The sea surface was choppy with white caps from the wind; however, no foam from the waste was observed.

Aerial photography was taken on August 8, 1968 with a mapping camera mounted vertically using ektachrome 8442 film. The photography was digitized and processed with the computer. A symbolic plot of the waste field from the line printer is shown in Figure 8. Each character on the plot represents a 30 by 30 ft area in the sea. Symbols on this plot represent different ranges in concentration with the darkest representing a concentration range of 10-15 ml/L and the lightest representing a range from 1. to 2.0 ml/L. The plot was made from photos 18 and 19 of the third flight over the area at 17:30 from 4125 feet. It can be seen in Figure 8 that some waste is northeast of the outfall which is located at the upper tip of the darkest portion of the plot. This is due to a shift in ocean currents in which the plume extended northward from the outfall in the morning while in the afternoon the plume extended southwestward (213° Az). The data shown in Figure 8 was also plotted with a computerized calcomp plotter using an adapted contour plotting program which plots iso-concentration lines as contours. This plot is shown in Figure 7. By comparing the plots in Figures 8 and 9, it can be seen that the line printer plot is distorted as the longitudinal scale is greater than the lateral scale. The overall length of the plume was 4600 ft and the width a maximum of 3100 ft. The area within each concentration range as determined from photography is listed in Table 3.

The average current velocity in the waste plume was 0.26 ft/sec and the average steady state diffusion coefficient was 31 ft^2/sec. A discussion of the diffusion computation is given in appendix E.

Table 2. Newport sampling summary.

Date	Effluent Flow Rate gpm	Rodamin WT Flow Rate ml/min	Remarks
8-8-68	5550	100	
8-14-68	7600	28	cloudy no photography
8-16-68	7550	16	
8-21-68	7400	32	
9-10-68	7450	-a	submerged plume
9-11-68	8950	-a	submerged plume
9-12-68	6750	37	
6-30-69	8100	36	submerged plume
7-1-69	8100	32	submerged plume
7-7-69	9000	38	submerged plume
7-8-69	9000	40	
8-12-69	8300	37	
9-8-69	8400	33	

a - Dye slugs injected into pipeline.

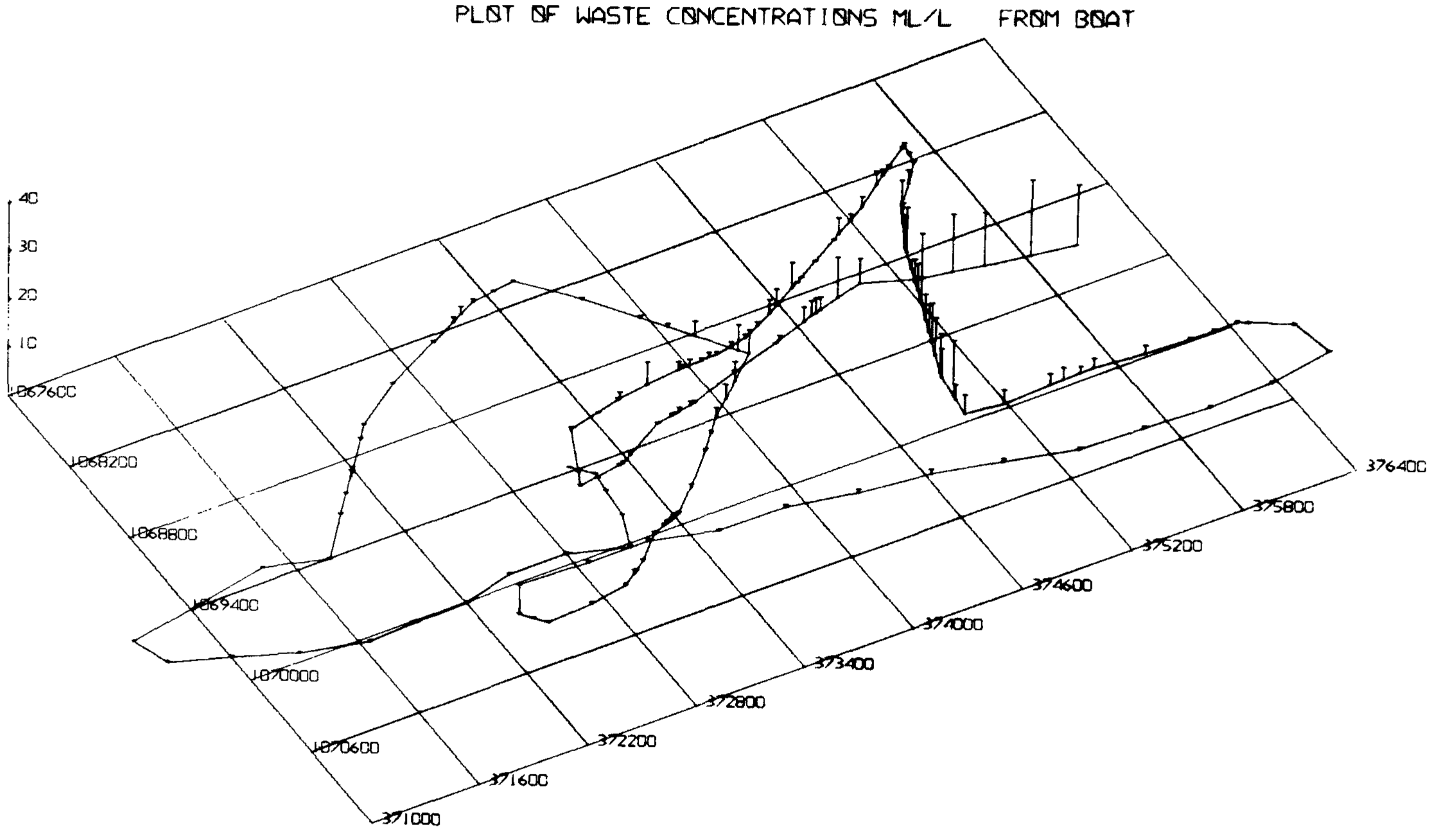


Figure 7. Waste concentrations measured by boat sampling on August 8, 1968.

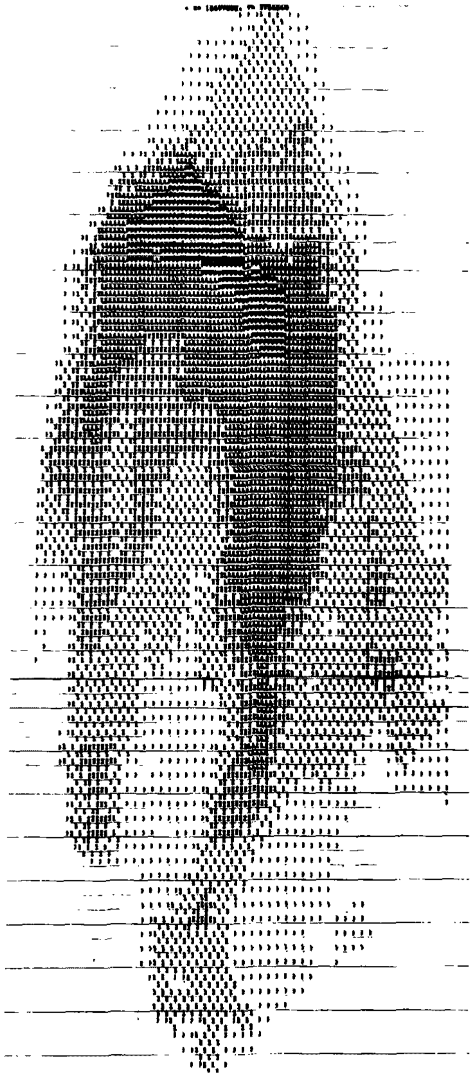


Figure 8. Symbolic plot of waste field on August 8, 1968 from flight 3.

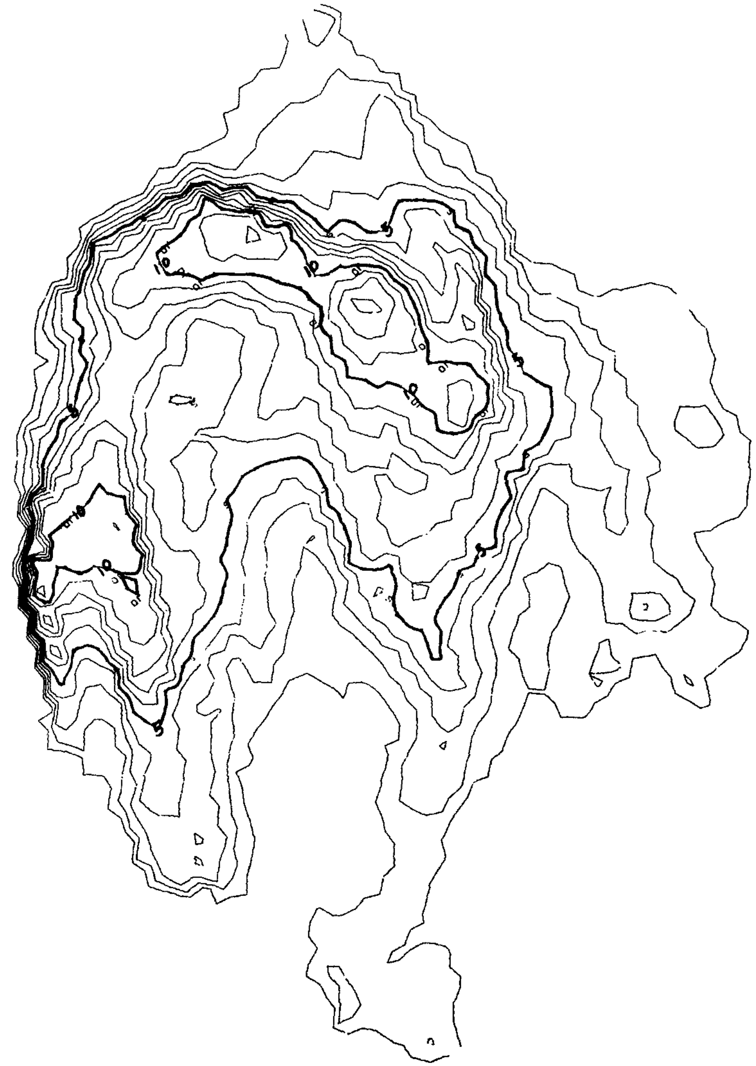


Figure 9. Isoconcentration plot of waste field on August 8, 1968, from flight 3.

Table 3. Area within each concentration range on August 8, 1968.

Concentration range ml/L	Area Sq ft
1 - 2	2.48×10^6
2 - 4	1.62×10^6
4 - 6	9.04×10^5
6 - 10	1.61×10^6
10 - 15	2.38×10^5
Total	6.85×10^6
	= 157 acres

August 14, 1968

On August 14, 1968 boat sampling was conducted; however, clouds prevented aerial photography. Results of the boat sampling, plotted on the Oregon State plane coordinate grid system (north zone), are shown in Figure 10. The outfall is located near the high concentration values at the upper left in the plot and the plume extends northeast towards the beach. Sampling was conducted from 10:24 to 11:40 when the wind was 5 to 10 mph from the southwest and the swell height was 4 to 6 feet. It can be seen from figure 10 that the diffusion coefficients are low as the concentrations 2000 ft northeast of the outfall are about the same as those directly over the outfall. A light foam streak several hundred feet long was observed over the outfall while conducting the boat sampling.

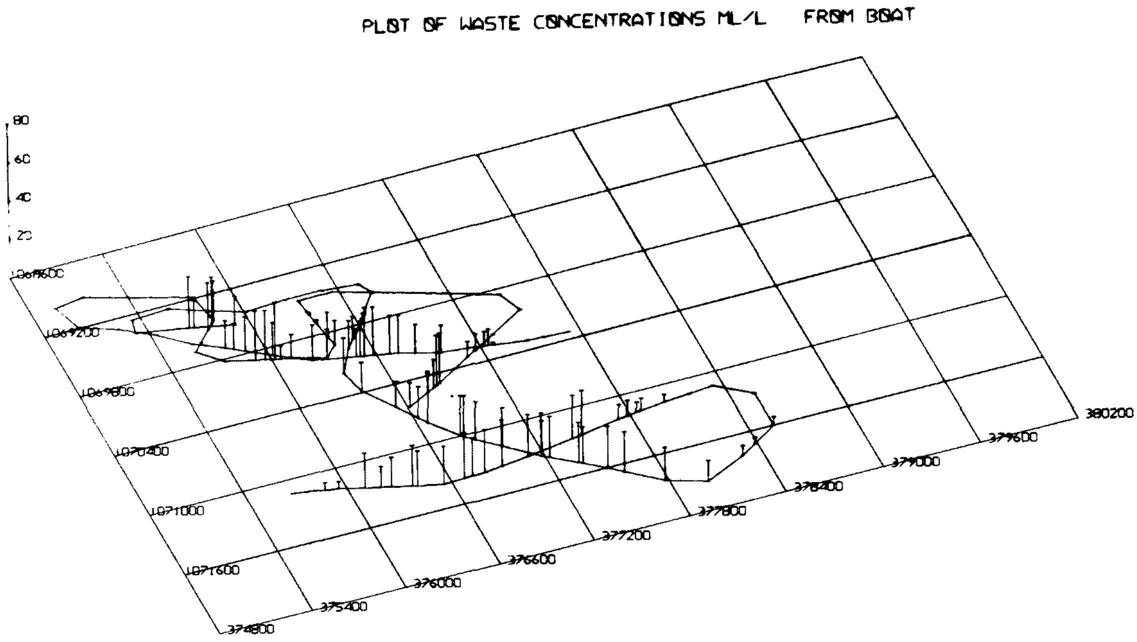


Figure 10. Waste Concentration measured August 14, 1968.

<u>August 16, 1968</u>

On August 16, 1968, the plume was long and narrow and extended northward from the outfall. The waste field was 600 to 1200 ft wide and about 7000 feet long. Photography was taken with a vertical mapping camera using ektachrome type 8442 film. Symbolic plots of the waste field made from photos 3 and 4 of flight one from 8400 ft and from photos 17, 18 and 19 of flight three from 4200 ft are shown in Figure 11. The plot in Figure 12 was made by subtracting the concentrations of the left plume in Figure 11 from those shown in the right plume. Areas where the concentration difference exceeds six units have been cross hatched. The mean concentration difference in comparing 2485 points inside the plume of either flight was 1.8 units. From the outline of the plume it can be seen that plume changed considerably during the 22-minutes between flights. The data shown on the left of Figure 11 was plotted with the contour plot program and is shown in Figure 13.

Areas of different waste concentration ranges within the plume are listed in Table 4. These values were computed from flight three. The average current velocity was 0.42 ft/sec with a mean diffusion coefficient of two ft^2/sec. The photo of the plume over the outfall shown in Figure 14 was made from photo three of flight one with a red filter. It can be seen that the addition of 17 cfs of effluent to the receiving water moving at 0.42 ft/sec did not cause appreciable spreading of the plume; whereas, on August 8 the addition of 12.4 cfs of effluent to the receiving water moving at 0.26 ft/sec did cause spreading of the plume and the plume was half-moon shaped.

The wind of 10 to 15 mph from the southwest was not sufficient to create a choppy water surface. A large swell of six to eight ft did not contribute much to the diffusion of the waste.

Table 4. Area within each concentration range on August 16, 1968.

Concentration range ml/L	Area Sq ft
1 - 2	1.12×10^6
2 - 4	1.01×10^6
4 - 6	7.27×10^5
6 - 10	1.30×10^6
10 - 15	1.63×10^6
15 - 20	1.46×10^6
20 - 25	4.32×10^4
Total	7.29×10^6 = 167 acres

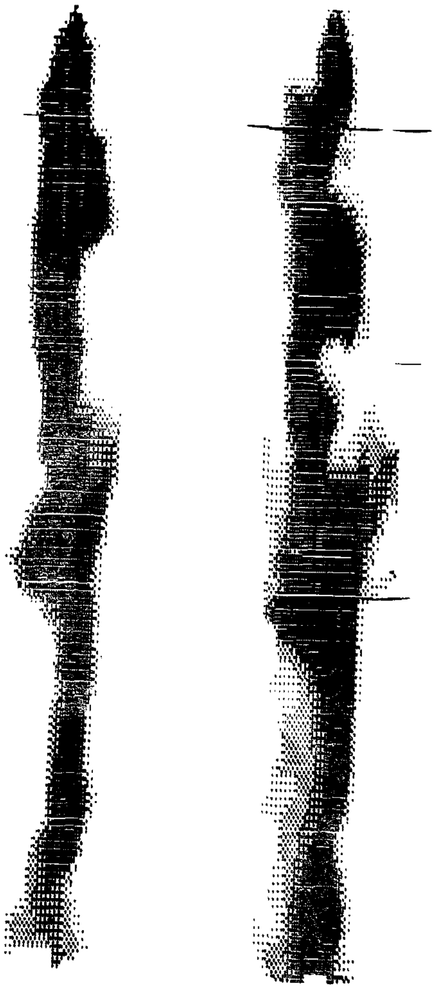


Figure 11. Symbolic plots flights 1 and 3 August 16, 1968.

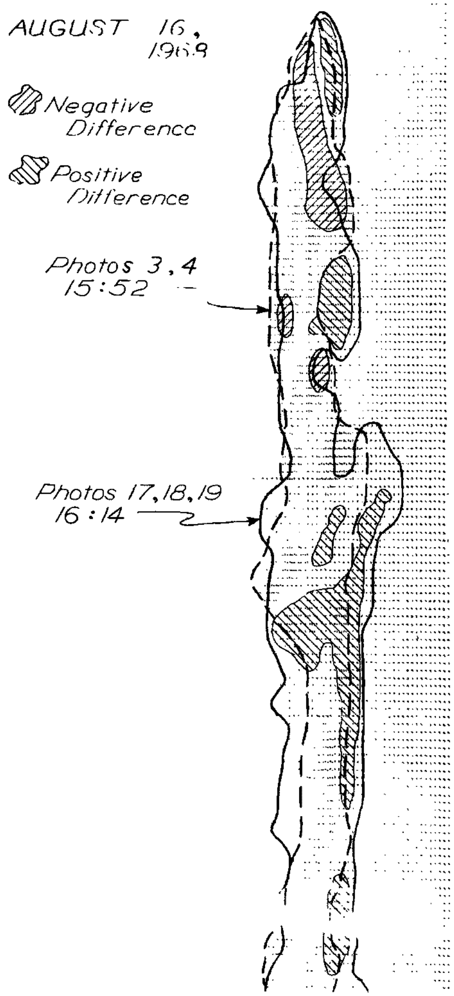


Figure 12. Concentration difference flights 1 and 3 August 16, 1968.

Figure 13. Iso-concentration plot flight 1, August 16, 1968.

Figure 14. Photo of plume over the outfall on August 16, 1968.

The results of the boat sampling conducted from 14:25 until 16:53 are shown in Figure 15. The plume extends from the lower left of the plot to the upper right. Maximum concentrations measured over the outfall were about 23 ml/L with one irregularly high value near the head of the plume.

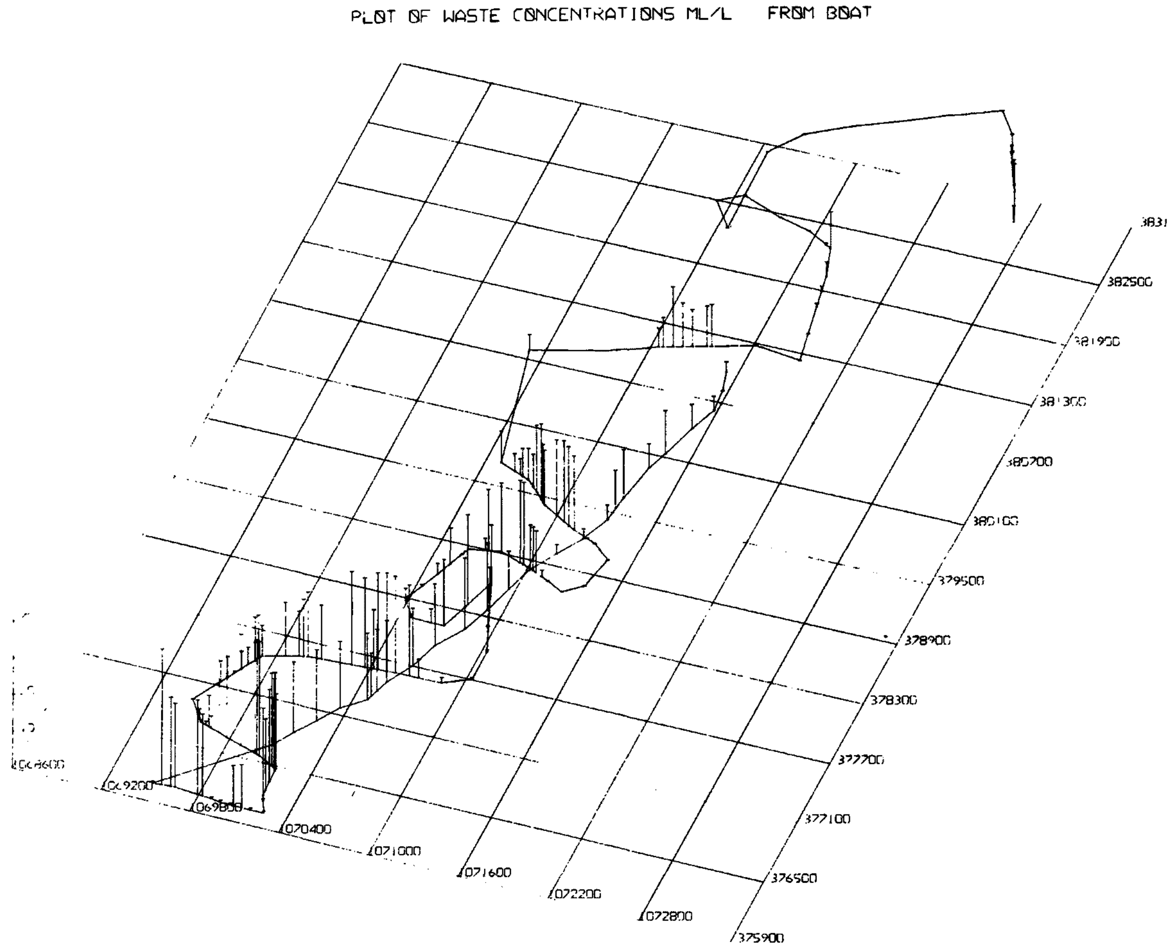


Figure 15. Boat sampling conducted on August 16, 1968.

August 21, 1968

On the morning of August 21, 1968 the swell was ten feet and breaking on the reef offshore from the outfall. Boat sampling was delayed until the afternoon. The wind was zero to five mph from the southwest, but by mid afternoon had changed to 10 to 15 mph from the northwest. The boat sampling was conducted from 12:10 until 13:41 and is shown in Figure 16. The outfall is located in the lower left of the plot and the plume extends northward. The plume was approximately

7500 ft long, 800 ft wide near the outfall and 2000 ft wide at the end of the plume. Maximum concentration over the outfall was 20 ml/L.

Vertical aerial photography was taken using Ansco D-200 film. As this was the photographic firm's first experience with the film, the film was under exposed about one stop. This combined with scattered clouds rendered the photographic results of questionable value.

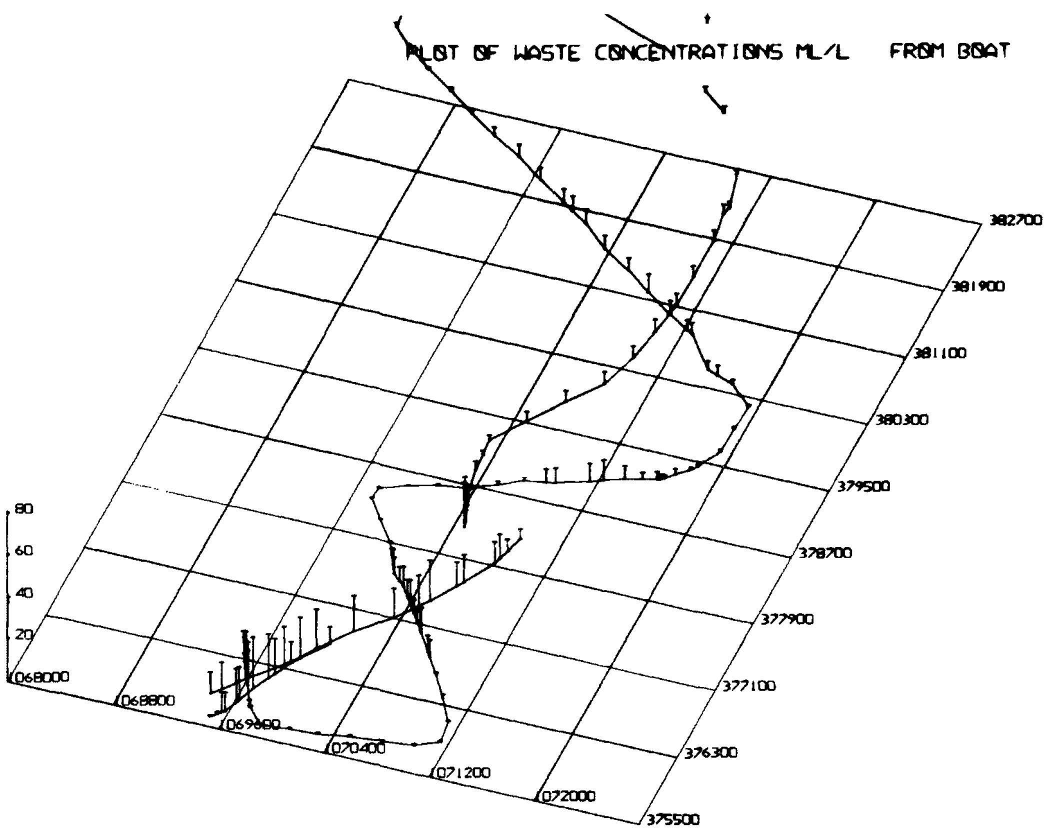


Figure 16. Waste concentrations from boat sampling on August 21, 1968.

September 10, 1968

On September 10, dye slugs were introduced into the pipeline. Because of density stratification, the waste field and dye slugs were submerged. There was no wind on this day and the swell height was one to two ft. The dye slugs did not move away from the outfall in discrete patches as planned but accumulated about the outfall area below the water surface. The boat sampling showed measurable dye concentrations only directly over the outfall.

Aerial photography was taken using Ansco D-200 film. A copy of one of the vertical photos over the outfall is shown in Figure 17. It can be seen that there was considerable foaming of the effluent. The photograph is oriented so that north is to the right and the outfall is located near the upper center of the photo. Foam extends both west then north and northeast from the outfall. The submerged plume can be seen in the photo where not obstructed by the foam as the light area to the south and east of the outfall. This photo covers an area 3400 by 4600 ft.

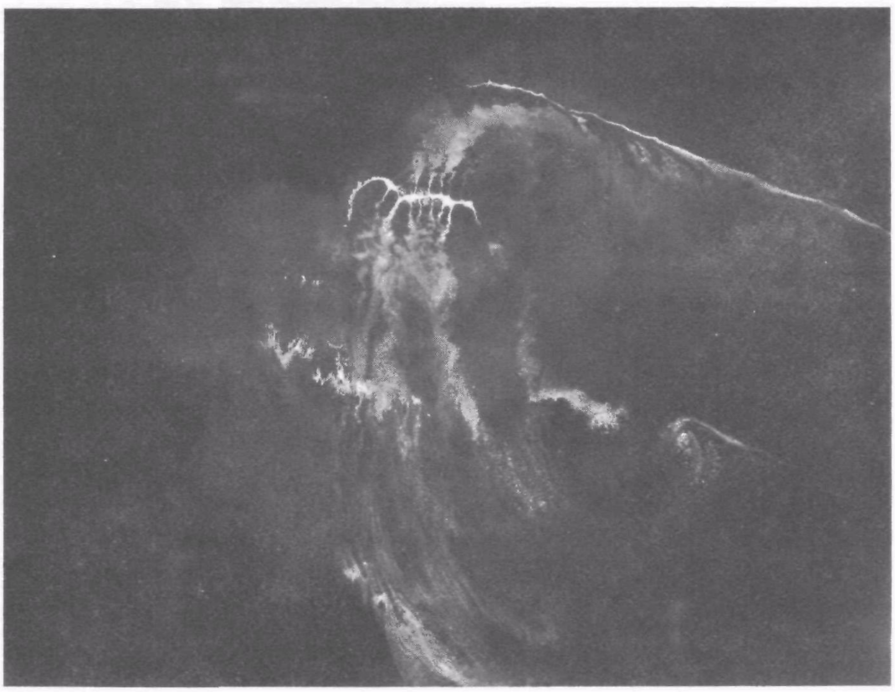


Figure 17. Photograph of the outfall area, September 10, 1968.

September 11, 1968

The weather conditions were about the same as on the 10th except that clouds covered the area and there was a 0-5 mph east wind. The plume was still submerged but the individual boils over the outfall could be seen from the boat. Two foam streaks extended westward from the outfall for about a half mile. Dye slugs were injected into the pipeline; however, dye concentrations were only detectable directly over the outfall.

September 12, 1968

Weather conditions remained calm until about 2 p.m. when a 15-20 mph wind from the northwest began. The plume was submerged in the morning but came to the surface after the wind began blowing. Waste concentrations measured by boat sampling from 15:49 until 17:11 are shown on the Oregon State plane coordinate (north zone) grid in Figure 18.

The outfall is located near the center of the plot and the plume extends southward. Maximum concentration over the outfall was about 10 ml/L. Detectable concentration were measured 3000 ft from the outfall.

Vertical aerial photography was taken of the plume using a 6-inch focal length camera. The interference caused by sunlight reflection on the choppy water surface made the photography impossible to process.

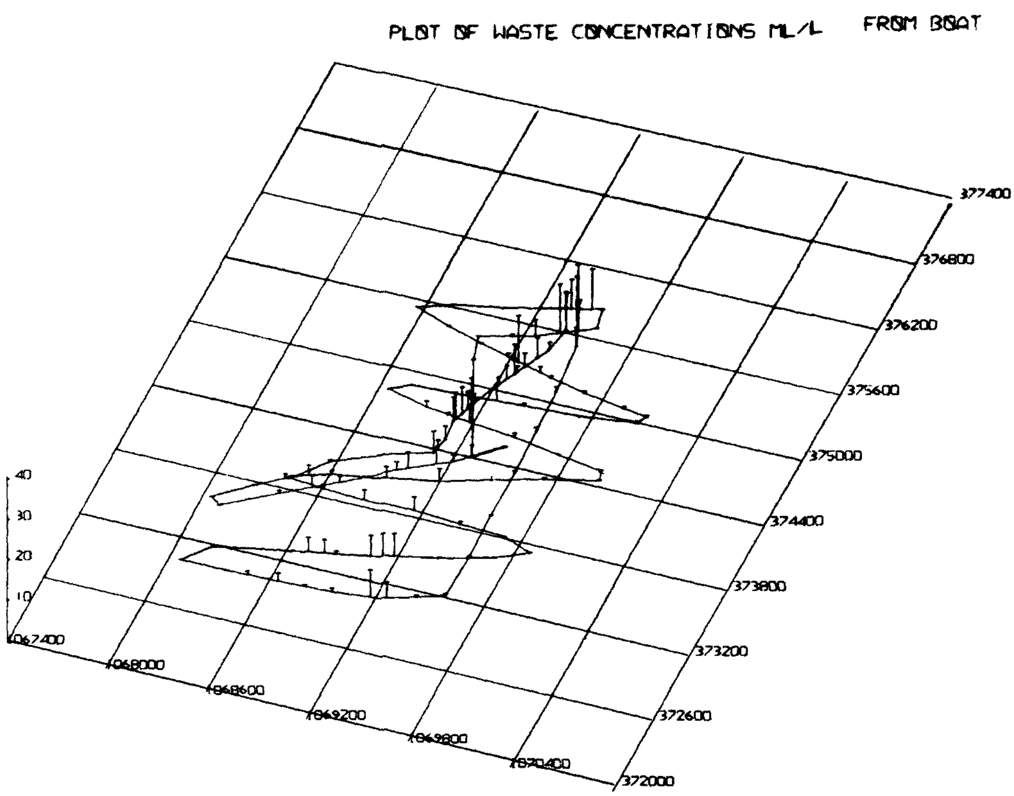


Figure 18. Waste concentrations measured by boat sampling, September 12, 1968.

June 30 and July 1, 1969

On June 30 and July 1 the plume was submerged below the sea surface. There was a light breeze of about five mph from the east in the morning shifting to 5-10 mph from the north in the afternoon with a one to two ft swell on June 30th. Aerial photography was taken of the outfall area but there was no evidence of the waste field from either the photography or the boat sampling.

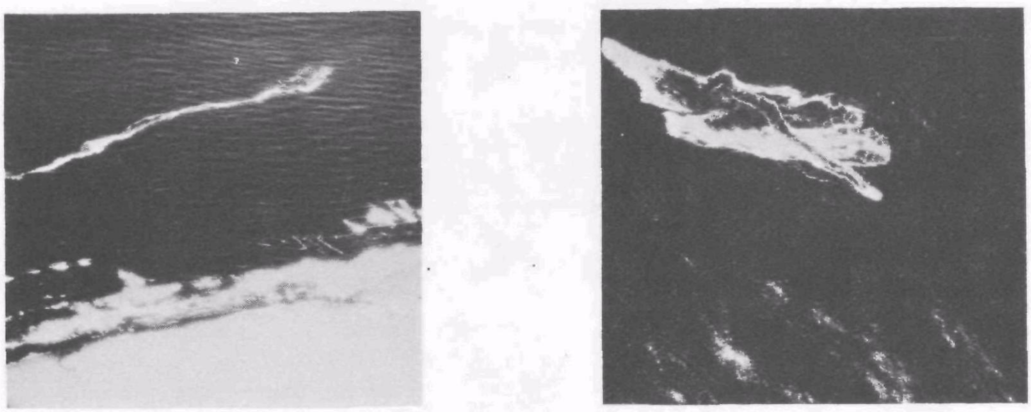
The weather remained calm with a two to four ft swell on July 1st. The photo of the outfall area shown in Figure 19 was taken from 600 ft with the camera oriented 45 degrees from vertical towards the west. Four buoys can be seen about the outfall but all that is visible of the waste field is a small amount of surface foam which covers an area approximately 200 by 300 ft. The sky was overcast and surface light reflection can be seen in the upper part of the photograph.

Figure 19. Aerial photo of the outfall area on July 1, 1969.

July 7 and 8, 1969

On both days the wind was from the north and a foam streak extended southward from the outfall for approximately 1.3 miles. On July 7th the surface plume was narrow and extended only a few hundred feet from the outfall. The wind on the 7th increased from 5 mph at 8:00 to 12 mph at 20:00.

The infrared black and white photos in Figure 20 show the foam on July 7th. Infrared photography does not indicate temperature differences. The photo in Figure 20A was taken in a northwest direction with the shore in the foreground and the foam extending southward from the outfall. The photo in Figure 20B was taken over the outfall in a westward direction with the foam streak extending upwards and to the left. The survey vessel was crossing over the outfall in Figure 20B.



A B

Figure 20. Photographs of the foam on July 7, 1969.

On July 8th the wind was stronger and increased from 6 mph at 8:00 a.m. to 15 mph at 15:00. Photos in Figures 21 and 22 show the plume on July 8 at 15:21 and 15:56. The photos were taken from 4000 ft with the camera tilted 45 degrees from vertical towards the east. A foam streak can be observed extending from the outfall on the left. The foam and the plume do not coincide as the plume is to the right of the foam. In Figure 22 dark upwelled water can be seen below (west) the plume. Measurements from the temperature probe indicated that this water was approximately two degrees C warmer than the inshore water. The upwelled water appears to move over the plume with limited mixing between the two masses. The upper or nearshore edge of the plume did not change position between photos.

Results of the boat sampling are shown in Figure 23. The outfall is located near the center of the grid and the plume extends southward or towards the left. The sampling was conducted from 15:00 until 16:16 and the maximum concentration measured over the outfall was 10 ml/L.

Three photographic flights over the outfall were processed. Ektachrome type 8442 film was used in the mapping camera while the two 70 mm cameras were used with infrared color type 8443 and infrared black and white type 5424. Symbolic plots for the three flights are shown in Figure 24. In order to have the longitudinal and lateral scales approximately equal, each symbol on the remaining symbolic plots in this report represent an area of 20 ft across the plume and 30 ft along the plume. The plots shown in Figure 24 were from flights taken at times 15:15, 15:21 and 15:56 and from 3000, 4000 and 4000 ft, respectively. They include only the first 2300 ft of the plume so that the change in plume shape between flights can be seen. Measurable concentrations extended 5500 ft from the outfall.

The average steady state diffusion coefficient for flights one and two was 14 ft^2/sec while the average diffusion coefficient from flight three was 9 ft^2/sec. The average current velocity was 0.5 ft/sec. Area within the different concentration ranges as computed from flight three are listed in Table 5.

Table 5. Waste field area on July 8, 1969.

Concentration range ml/L	Area Sq ft
1 - 2	1.05×10^6
2 - 4	1.62×10^6
4 - 6	2.06×10^6
6 - 10	4.10×10^5
Total	5.14×10^6
	= 117 acres

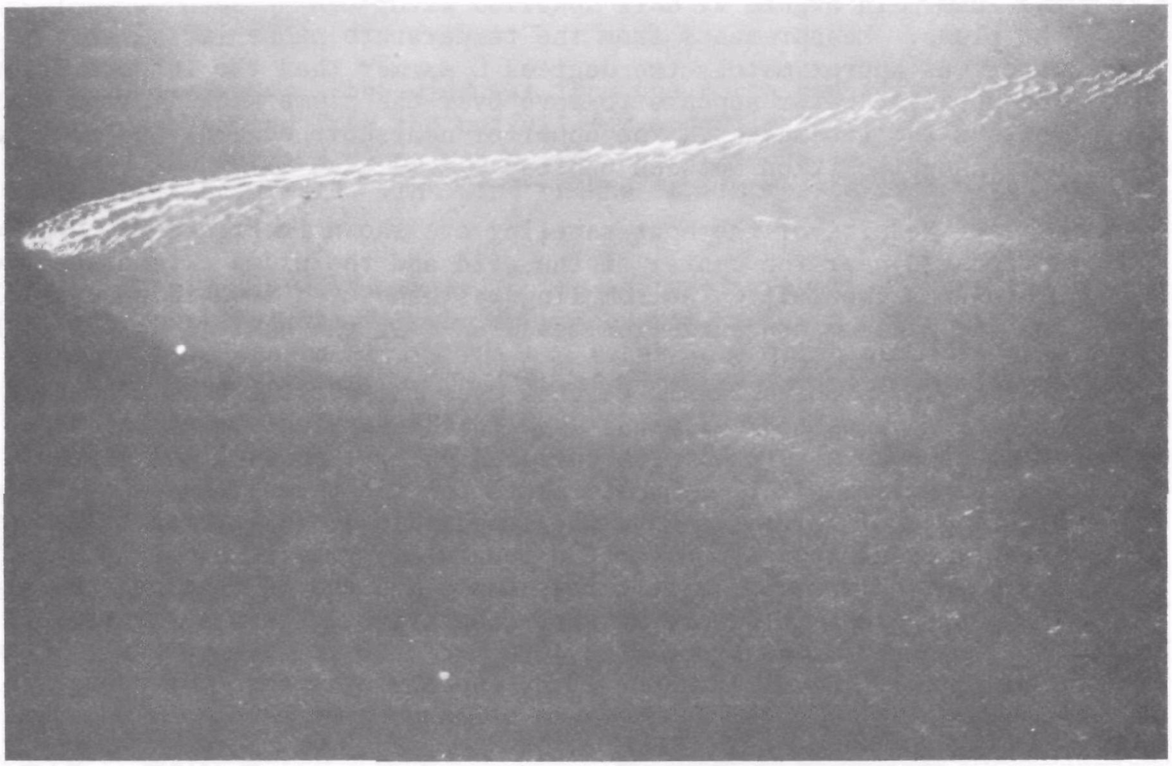


Figure 21. Photo of the plume on July 8, 1969 at 15:21.

Figure 22. Photo of the plume on July 8, 1969 at 15:56.

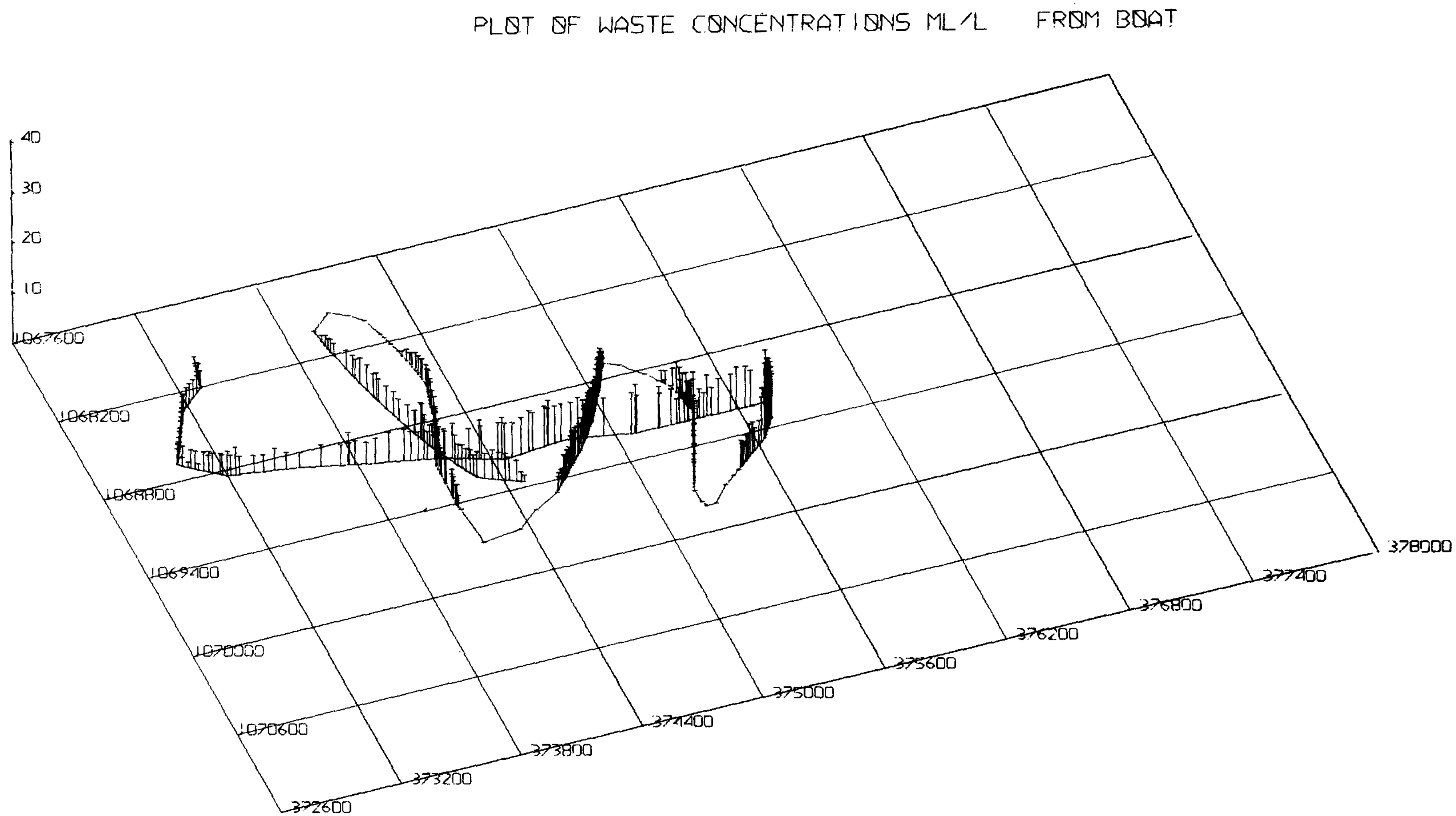


Figure 23. Waste concentrations measured by boat sampling on July 8, 1969.

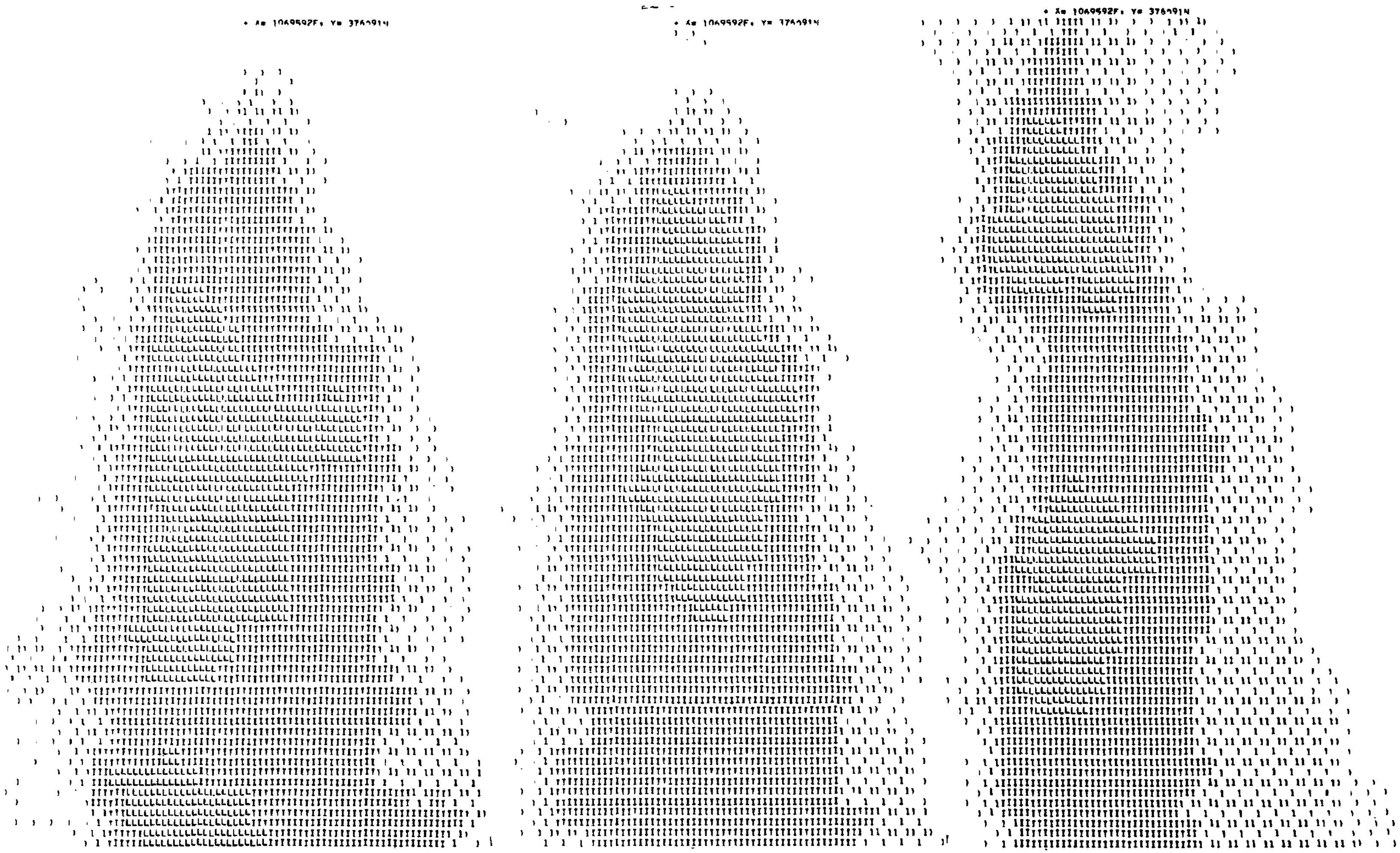


Figure 24. Symbolic plots from flights 1, 2, and 3 on July 8, 1969.

August 12, 1969

Both aerial photography and boat sampling were successfully conducted on August 12, 1969. Waste concentrations determined from boat sampling from 12:44 until 13:46 are shown in Figure 25. The outfall is located near the center of the grid and the plume extends northwest or upward and to the right.

Surface water temperatures measured from the boat are shown in Figure 26. The height of a vertical line on the plot represents the water temperature in degrees C. minus nine degrees. This method of plotting was used so that a small difference in water temperature would be apparent as it is easier to see a difference in lengths of lines that are one and two units long than lines that are ten and eleven units long. It can be seen in the plot that the water temperature over the outfall was about two degrees colder than in the upper right of the plot where the waste concentration is zero. Although the effluent in the pipeline is about 40°C. it mixes with the subsurface water and the resulting mixture on the surface in this example was colder than the surrounding surface water.

The oblique photo of the plume shown in Figure 27 was taken with the camera pointed northward from 4,000 ft. In the immediate vicinity of the outfall the foam extends both east and west of the outfall then northward. This foam pattern is similar to that on September 10, 1968. The waste field extends in all directions from the outfall but primarily northwest. The wind was three mph from the east in the morning but changed to five mph from the west in the afternoon.

One current float set to the west of the outfall moved northwest while the other current float set to the east of the outfall moved northeast. The average current velocity was 0.1 ft/sec. It appears that under these relatively calm conditions, that the hydraulic head created by the effluent has a measurable influence on the shape of the waste field.

A symbolic plot of the waste field is shown in Figure 28. While three flights were processed, the photographic results were essentially the same in each case. The hole or blank area in the plume was in the foam over the outfall where concentrations could not be computed. The plot shows a large waste field with nearly uniform concentration of 6 to 10 ml/L throughout. The azimuth from north of the centerline of the plot in Figure 27 is 340°. Area within the different concentration ranges are listed in Table 6.

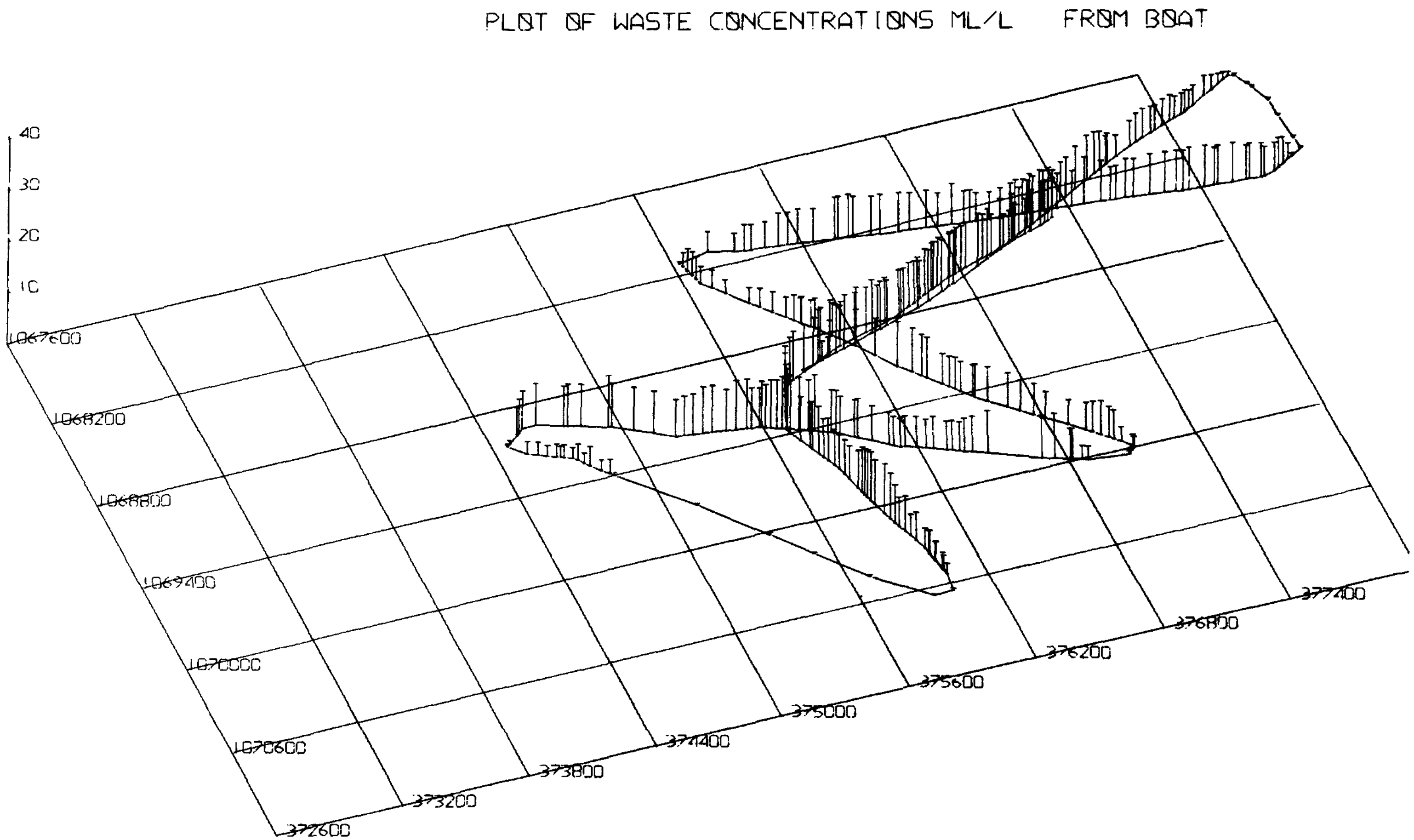


Figure 25. Waste concentrations from boat sampling on August 12, 1969.

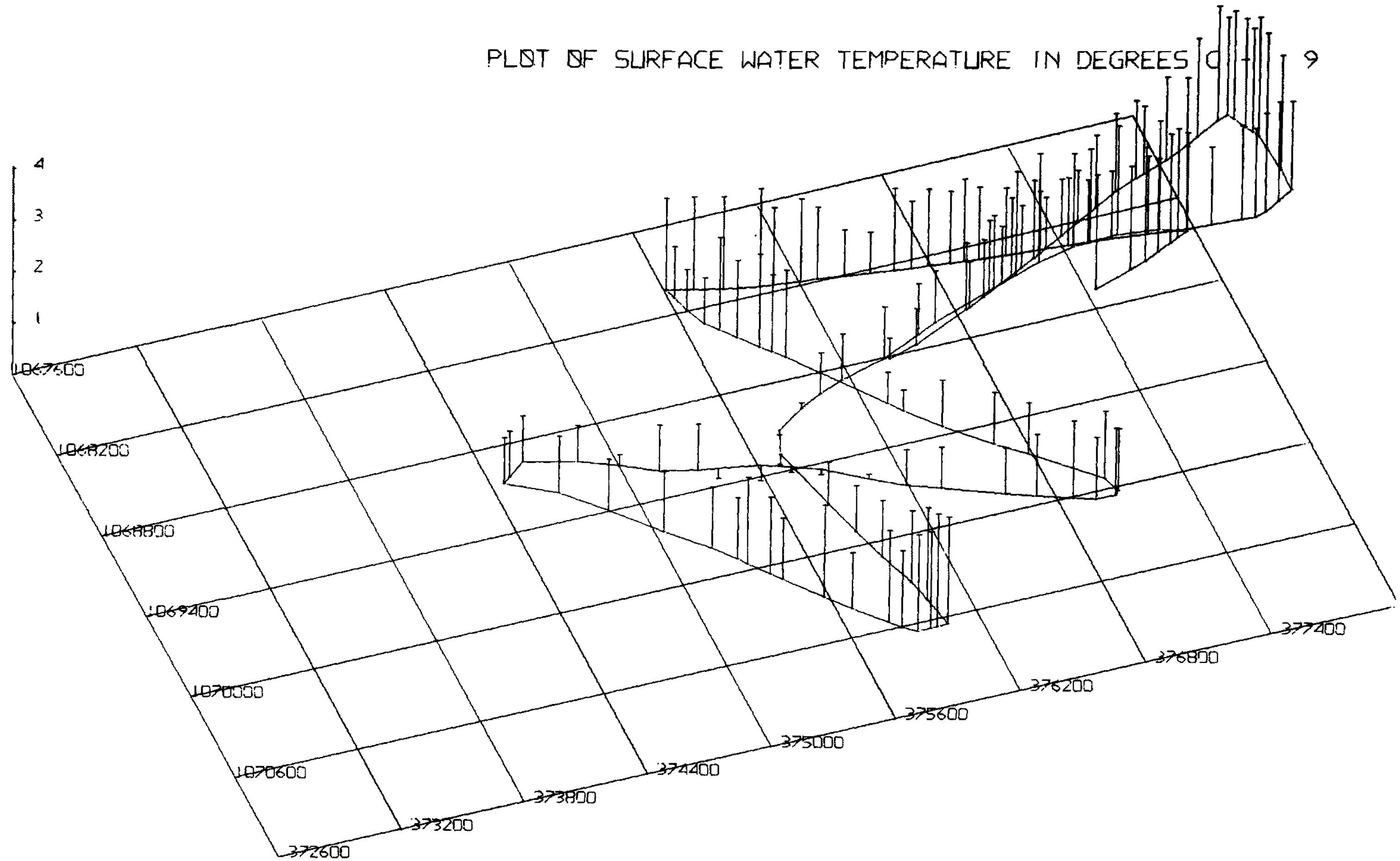


Figure 26. Surface water temperature on August 12, 1969.

Figure 27. Photograph of the waste field on August 12, 1969.

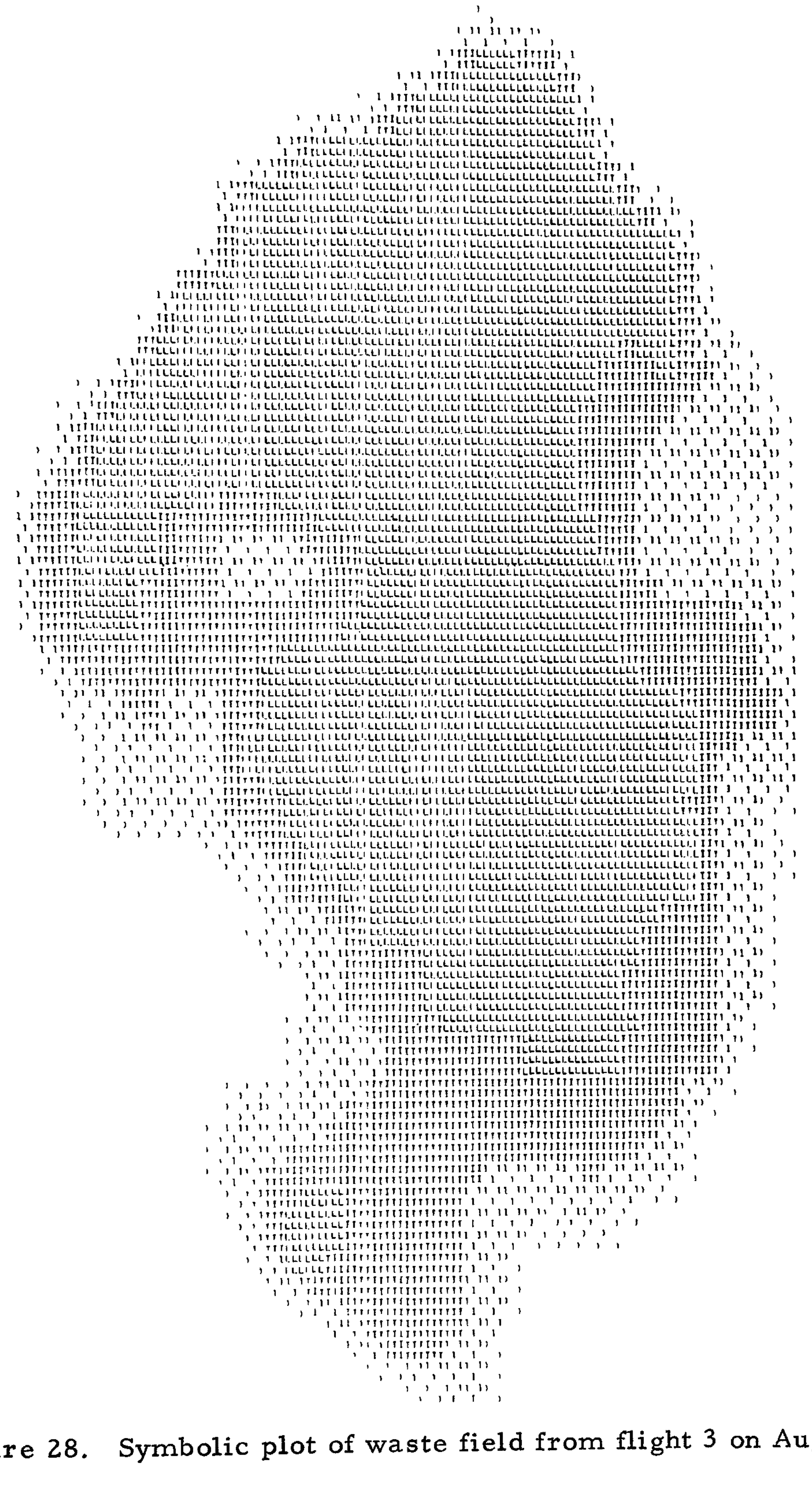


Figure 28. Symbolic plot of waste field from flight 3 on August 12, 1969.

Table 6. Waste field area - August 12, 1969.

Concentration range ml/L	Area Sq ft
1 - 2	4.86×10^5
2 - 4	1.03×10^6
4 - 6	1.50×10^6
6 - 10	3.00×10^6
Total	6.02×10^6
	= 137 acres

September 8, 1969

The photograph of the plume shown in Figure 29 was taken from 8,000 ft looking north. The surface plume was small and extended northward from the outfall. A small amount of surface foam can be seen about the outfall. The location of the plume was not obvious from the boat while sampling; however, a large subsurface plume could be seen from the aircraft extending northeast from the outfall. The wind was from the southwest at 5 mph with a four-foot swell.

Data for the symbolic plot of the waste field, shown in Figure 30 was from the 70 mm infrared color photography taken from 3,000 ft. The current velocity was 0.2 ft/sec. Area within the different concentration ranges are listed in Table 7. Results of the boat sampling are shown in Figure 31.

Table 7. Waste field area - September 8, 1969.

Concentration range ml/L	Area Sq ft
1 - 2	1.87×10^5
2 - 4	3.10×10^5
4 - 6	2.41×10^5
6 - 10	1.07×10^6
10 - 15	6.84×10^4
Total	1.87×10^6
	= 43 acres

Figure 29. Aerial photo of waste field on September 8, 1969.

VOLUMETRIC WASTE CONCENTRATION IN ML/LITER

SWITCH ON 60 - FT GRID

DIRECTION OF PLUME .01 RADIANS

FLIGHT NO. 1 DATE 9/ 8/69

CONCENTRATION CODE IN ML/L

))	1 - 2	1 1 1	2 - 4
III III	4 - 6	LLL LLL	6 - 10
PPP PPP	10 - 15	RRR RRR	15 - 20
MMM MMM	20 - 25	*** ***	GT 25

+ X= 1069512E, Y= 374947N

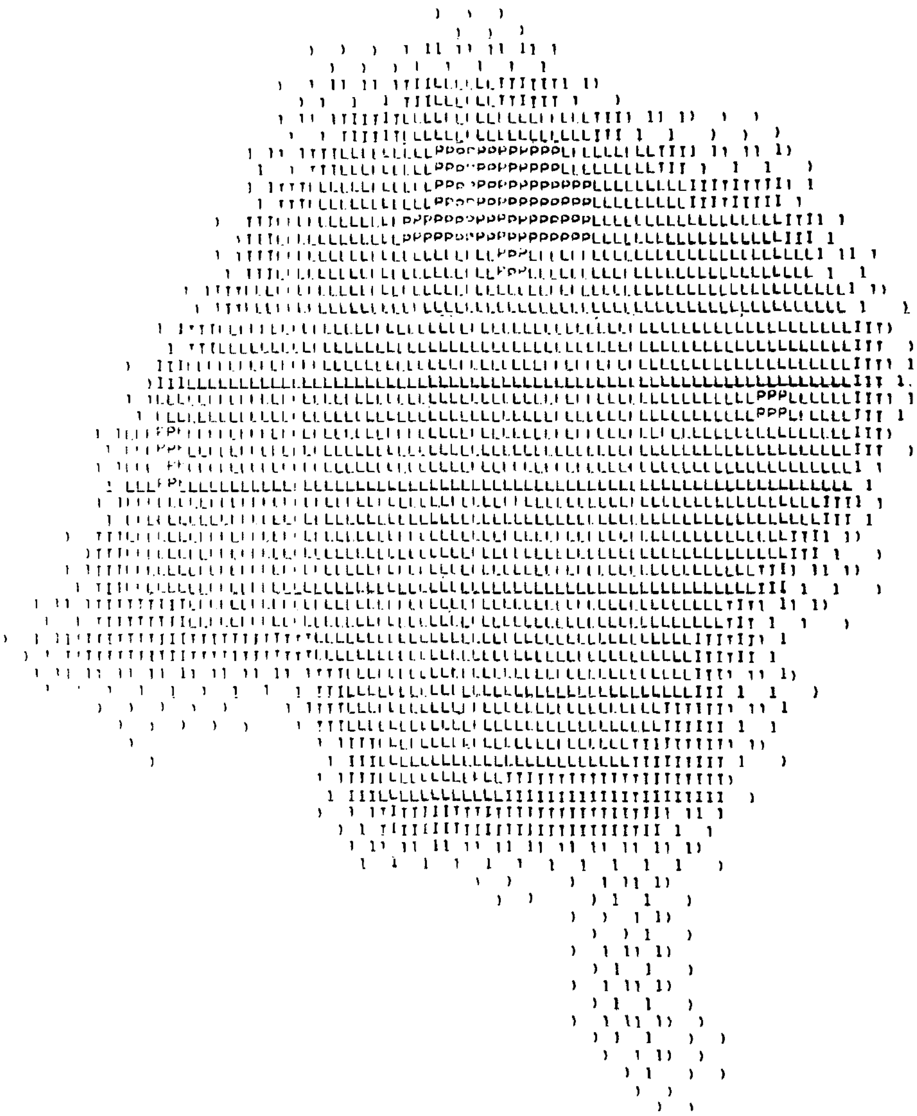


Figure 30. Symbolic plot of waste field from flight 1 on September 8, 1969

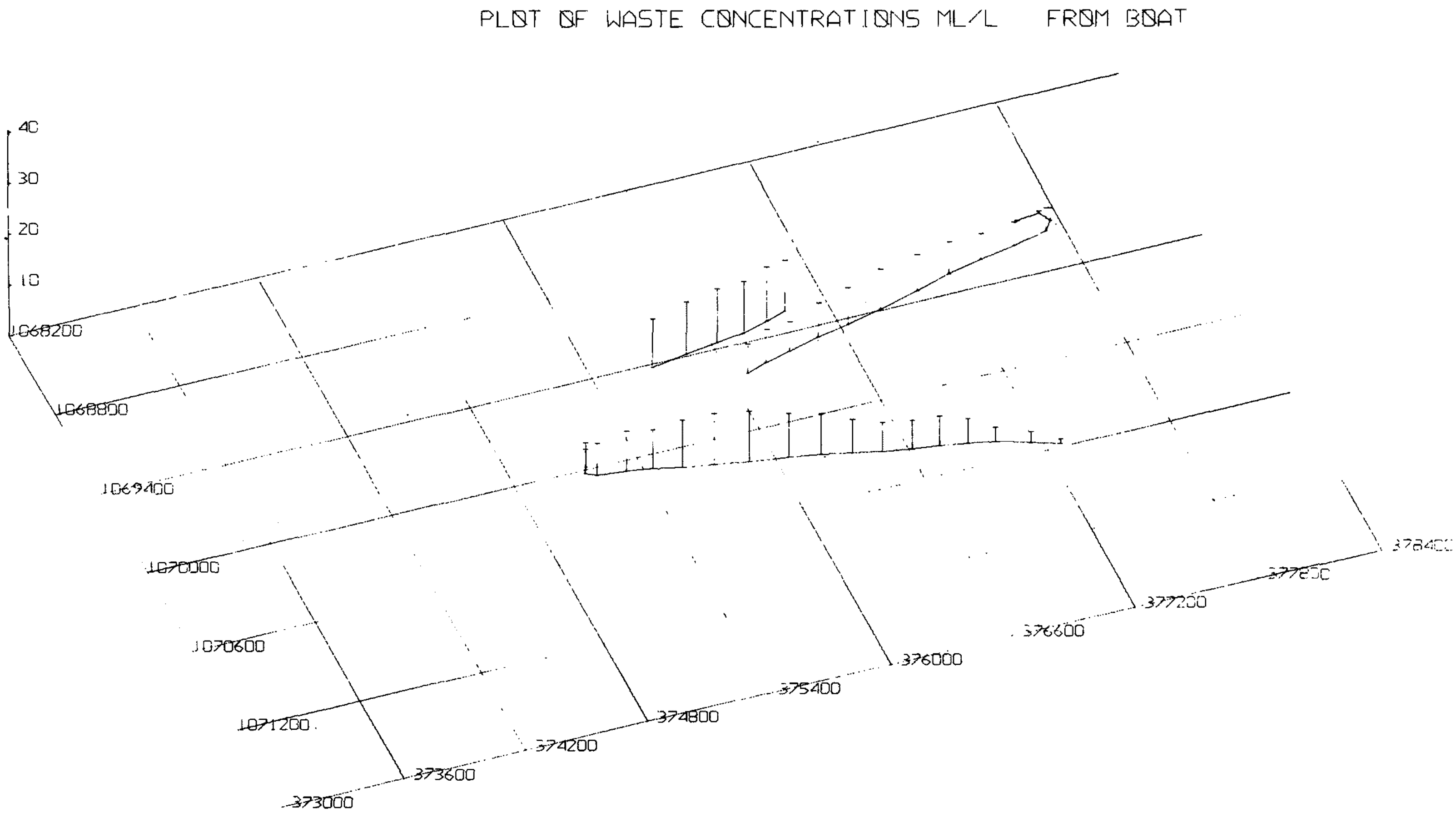


Figure 31. Waste concentrations from boat sampling on September 8, 1969.

SECTION VI

GARDINER STUDY

The International Paper Plant at Gardiner produces approximately 550 tons per day of pulp and discharges about 10,000 gpm of liquid waste into the ocean. The ocean outfall is located 5-1/2 miles north of the mouth of the Umpqua River. A straight shoreline extends both north and south of the outfall and the shore near the outfall is a gently sloping sandy beach. The location of the outfall is shown in Figure 32. The plant is located about a mile north of Gardiner and discharges its wastes through a three-mile pipeline to the ocean.

The photograph in Figure 33 was taken looking northeast. The location of the outfall was sketched on the photo and is shown in white. It can be seen that there is no residential development on the shore near the outfall. During low tides, three to six vehicles were parked near the beach on the access road to the outfall while the occupants were digging clams. The plant is located near the bend in the Umpqua River to the right of the picture. Dark upwelled water can be seen in the lower left of the photograph.

A photo of the International Paper Plant is shown in Figure 34. Liquid waste from the process are discharged into the pond shown on the left of the figure. A pumping station located to the left of the pond pumps the waste over the hills to the ocean. The 36-inch outfall extends about 3,000 feet offshore and terminates in about 25 ft of water. As shown in Figure 35, the diffuser section consists of 24 five-inch diameter ports spaced 7.5 ft apart. The ports are oriented horizontally and alternately discharge on opposite sides of the pipeline. Shifting sands partially cover the diffuser section and it was not known how many of the ports were open at the time of sampling.

Boat sampling was conducted with the charter boat "Sea Hawk" from Winchester Bay on July 15 and 16, and August 19 and 20, 1969. In addition the Northwest Regional Office and the Pacific Northwest Water Laboratory of the Federal Water Quality Administration conducted a survey of the outfall during the week of January 20, 1969. Measurements of a dye tracer released during the survey produced a minimum dilution of 1:27 over the outfall. An extension of the centerline of the plume during this study would have intersected the beach approximately one mile south of the outfall. In addition, a biological survey conducted during the study showed that more organisms and more species were observed over the outfall than at other surrounding locations. Description of the sampling by dates follow.

July 15 and 16, 1969

On July 15 and 16 the wind was 10 to 18 mph from the NNW during the sampling period. The swell on the 15th was four ft, and two to three ft on the 16th.

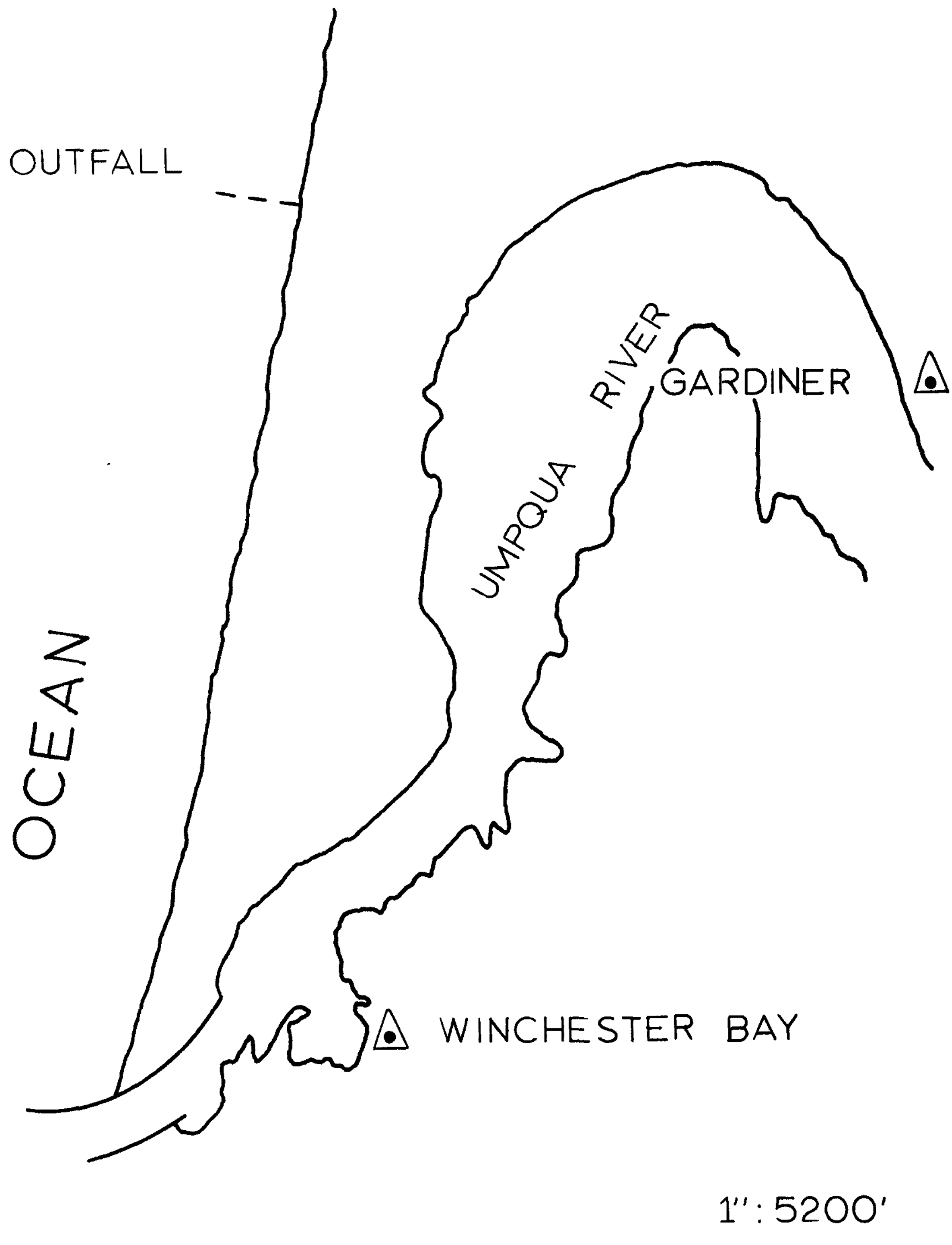


Figure 32. Gardiner outfall location map.

Figure 33. Photograph of the Gardiner outfall area.

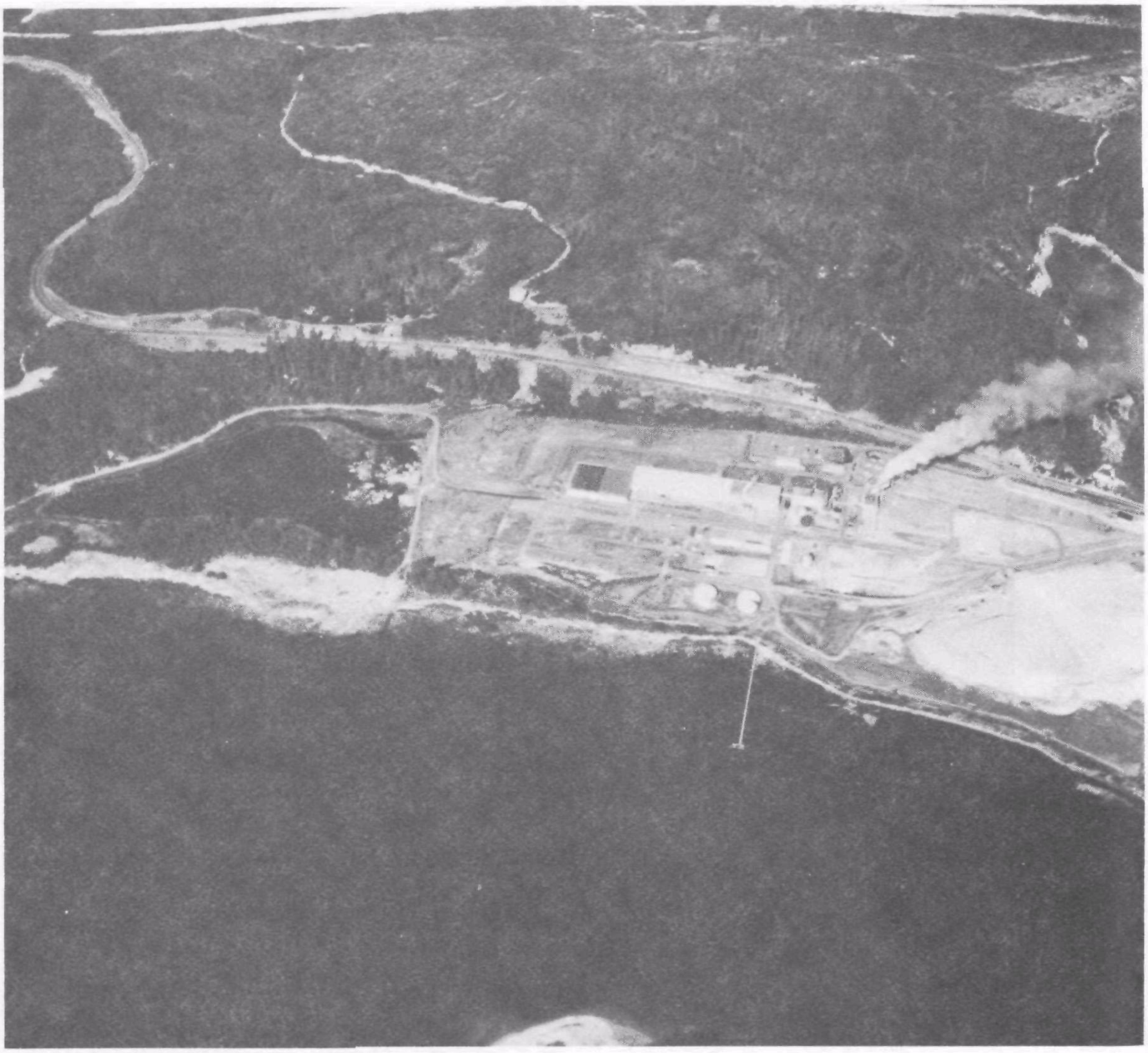


Figure 34. Photograph of the International paper plant.

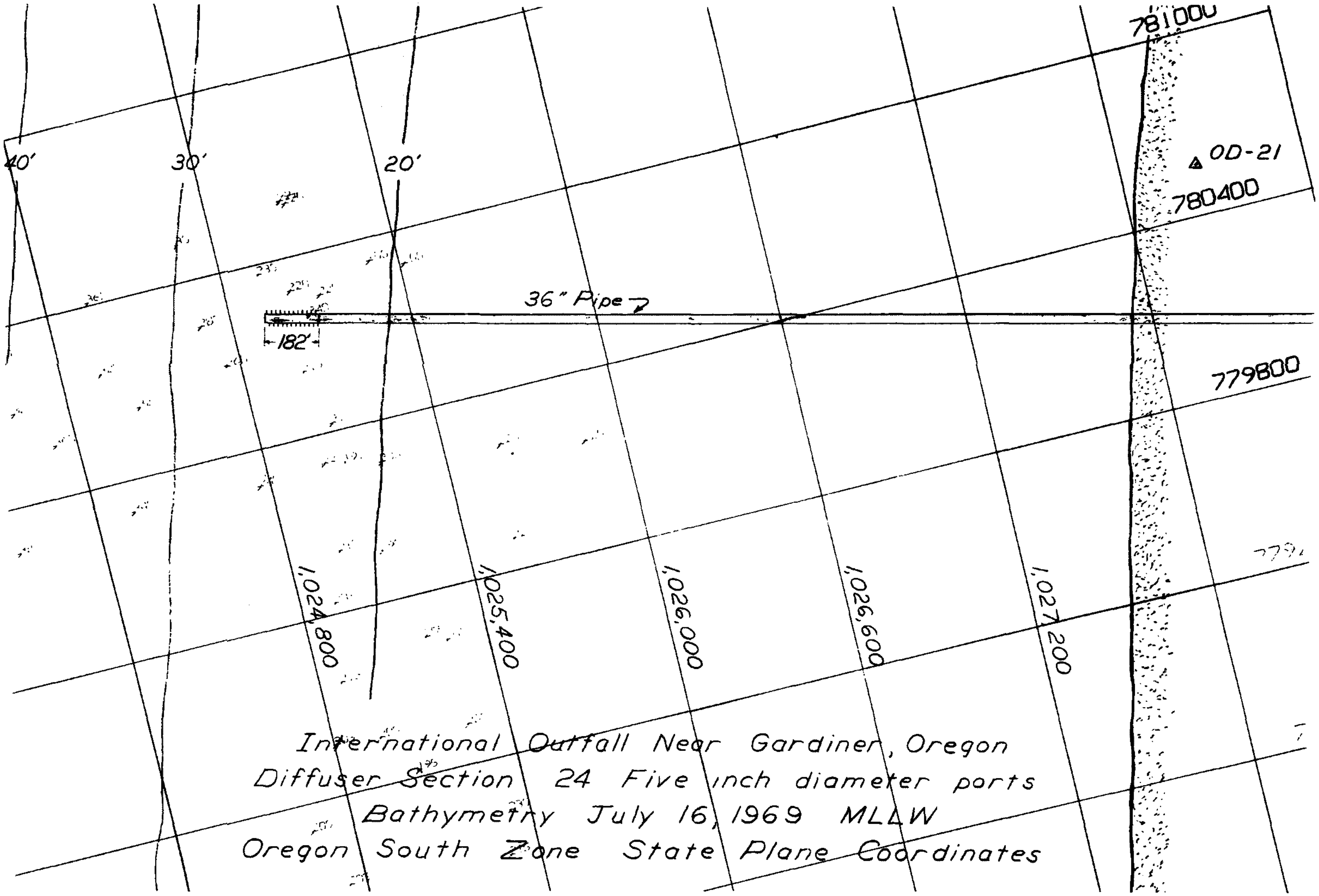


Figure 35. International Paper Company outfall near Gardiner, Oregon.

Air bubbles in the fluorometer intake lines rendered the results of the boat sampling of little value on July 15. The plume configurations were similar on both days and the results of the boat sampling on July 16 are shown in Figures 36 and 37. The first sampling run shown in Figure 36 was conducted from 12:39 until 13:35 while the second run shown in Figure 37 was conducted from 14:45 until 15:36. The plume extended southward (left) from the outfall with a maximum concentration of 23 ml/L over the outfall.

While the survey boat was headed westward, direct sunlight was on the instrument. Since the sunlight caused interference with the fluorometer readings, these sections of the sampling record were not processed and discontinuous boat track is shown in Figures 36 and 37.

Aerial views of the plume are shown in Figures 38A and 38B. The photos which were taken at 15:05 are 45 degree oblique views from 4000 ft. The outfall in Figure 38A is located at the center of the photograph and the plume extends to the right. One area of relatively high waste concentration extends south from the outfall while a second area of high concentration extends southwestward. The dye patch located near the lower left of center on 38A was dropped at 14:20. The dye patch shown in lower right of Figure 38B was dropped at 12:14. The plume in Figure 38B is shown in the upper left of the photo.

Three photographic flights over the outfall area were processed. The iso-concentration plot shown in Figure 39 was from the first flight over the outfall at 14:50. The concentration interval on this plot is 2 ml/L with the outside contour representing 2 ml/L. The symbolic plot of the waste field shown in Figure 40 was made from the second flight over the area from 5000 ft at 15:03. Infrared color film and infrared black and white film were processed from the 70 mm cameras. The large mapping camera was used for orientation and current float position computations.

The plume on July 16, 1969, is similar to that for August 8, 1968, at Newport. It appears that the addition of 22.4 cfs of waste to the receiving water moving at 0.26 ft/sec caused surface spreading of the plume near the outfall. Two current floats were set above the outfall. One float moved downstream in the waste field but the second float set on the centerline of the plume remained stationary just upstream from the outfall. Since there was no kelp in the area, to hold the float, it may have been set at the stagnation point created by a source in a uniformly flowing stream.

The average steady state diffusion coefficient was 9 ft^2/sec. Areas within the different ranges in waste concentration as determined from flight 2, are listed in Table 8.

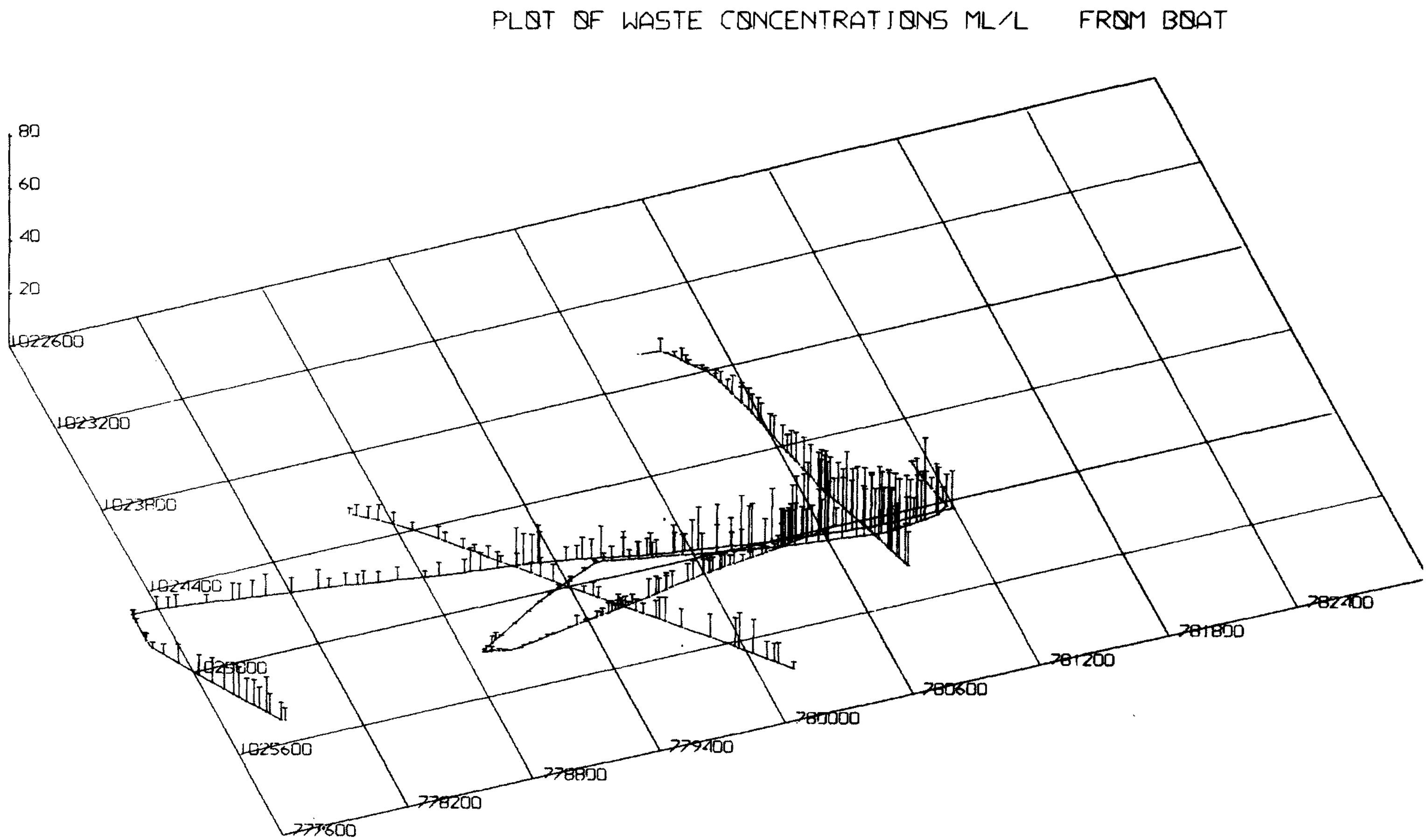


Figure 36. Waste concentrations measured by boat sampling July 16, 1969, run 1.

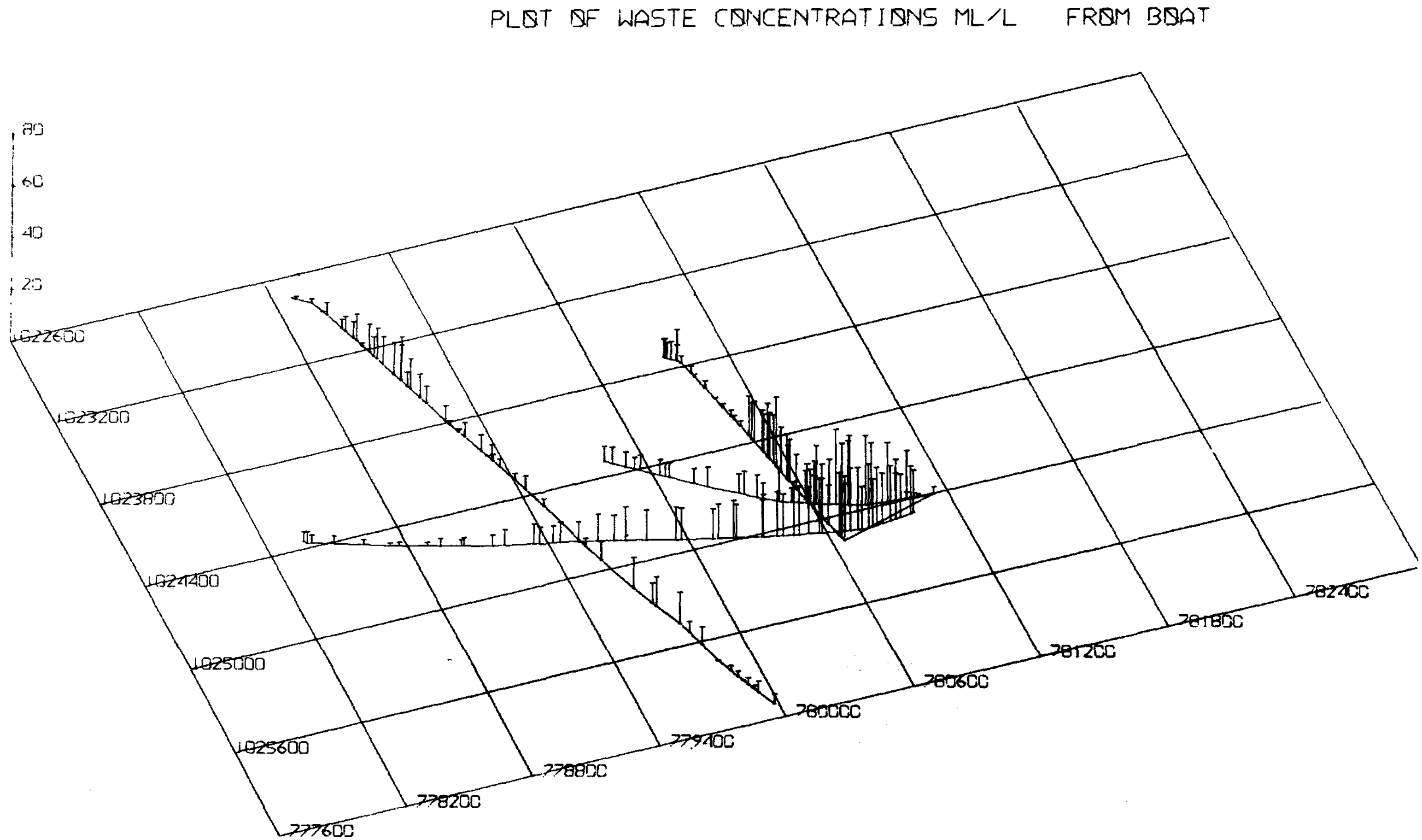


Figure 37. Waste concentrations measured by boat sampling July 16, 1969, run 2.

A

B

Figure 38. Plume and dye patch on August 16, 1969.

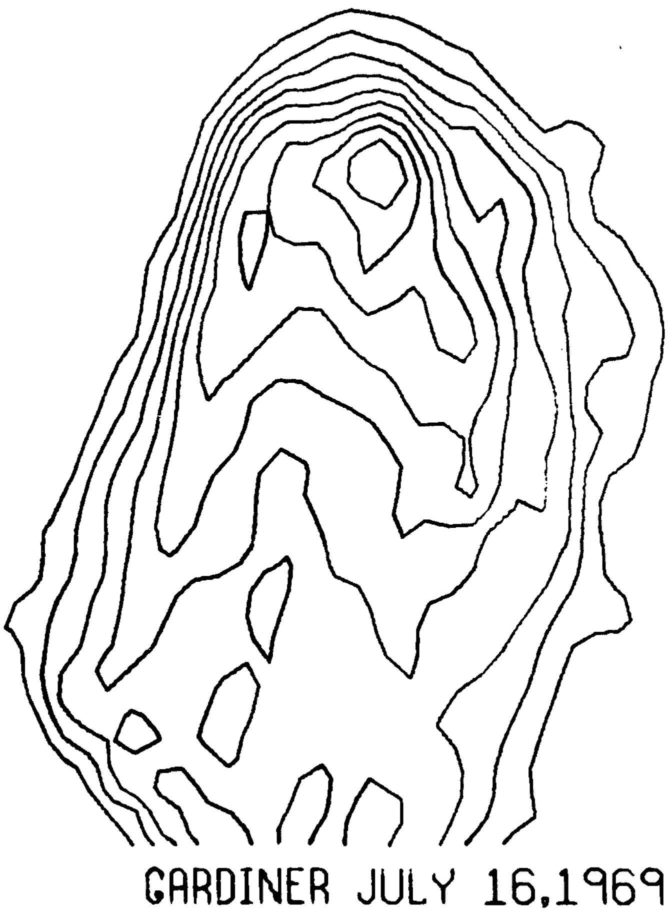


Figure 39. Iso-concentration plot from flight 1.

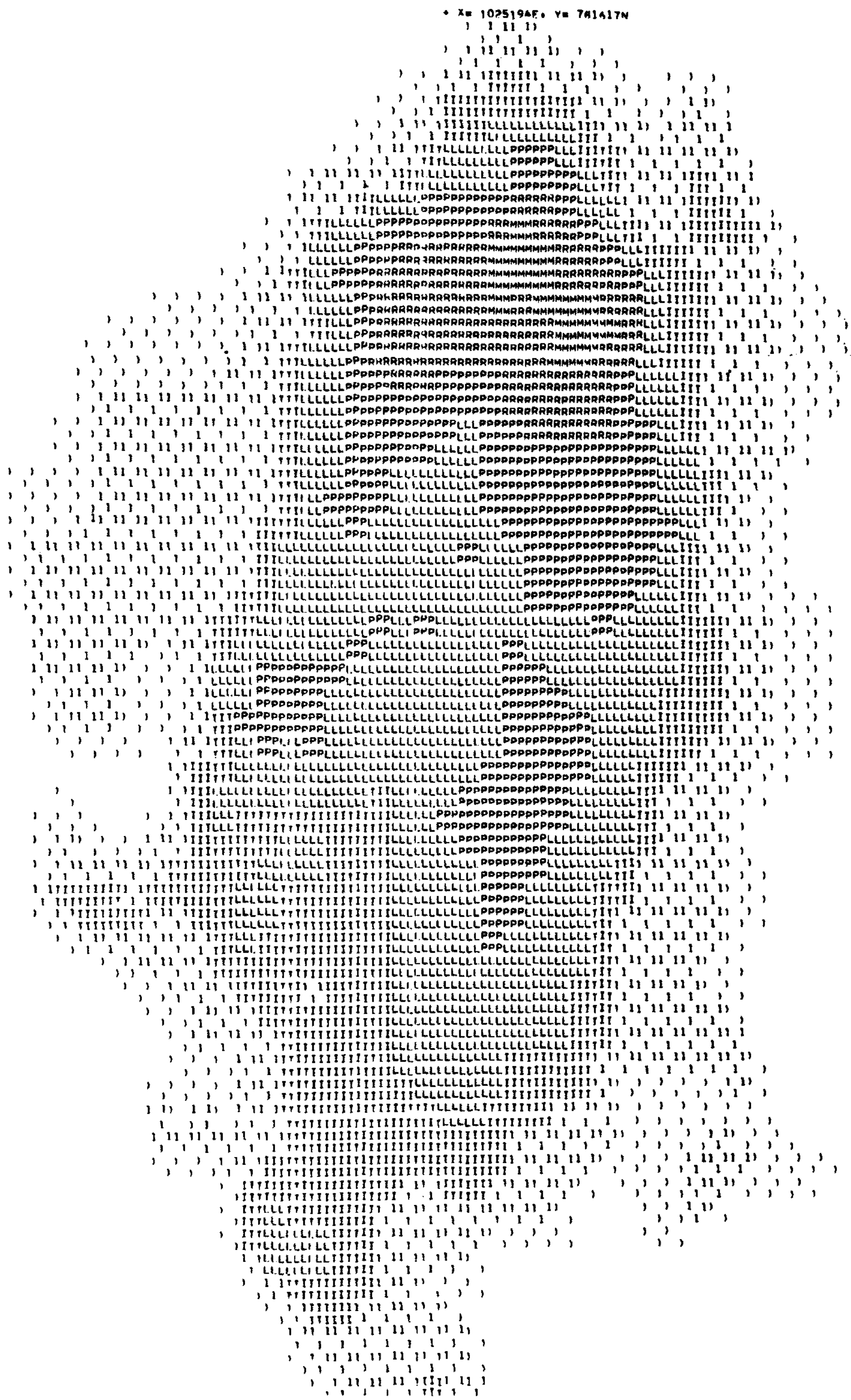


Figure 40. Symbolic plot of waste concentrations from flight 2 on August 16, 1969.

Table 8. Area within each concentration range on July 16, 1969.

Concentration range ml/L	Area Sq ft
1 - 2	1.21×10^6
2 - 4	1.53×10^6
4 - 6	9.00×10^5
6 - 10	1.18×10^6
10 - 15	6.01×10^5
15 - 20	2.23×10^5
20 - 25	5.76×10^4
Total	5.70×10^6
	= 130 acres

August 19 and 20, 1969

The swell height was four to five feet on both sampling days with a light wind of zero to five mph from the west. The fog did not lift until noon on the 19th but was clear at 11 o'clock the next day.

Waste concentrations determined from the boat samplings are shown in Figures 41 through 43. Maximum concentration over the outfall was 22 ml/L. The boat sampling shown in Figure 41 was conducted from 15:16 until 15:39 on August 19, 1969. The sampling period was short because of generator trouble and the plume in Figure 41 is not well defined. On August 20 the first sampling period was from 11:33 until 12:04 and the second sampling period was from 15:05 until 15:34.

Surface water temperature measured during the two sampling periods on August 20 are shown in Figures 44 and 45. In general the water temperature over the outfall was one to two degrees colder than the surrounding water temperature.

The plume changed shape and location while sampling on both August 19th and 20th. Low tide on the 19th was at 10:20 and high tide was at 16:50. The oblique view of the plume in Figure 46 was taken from

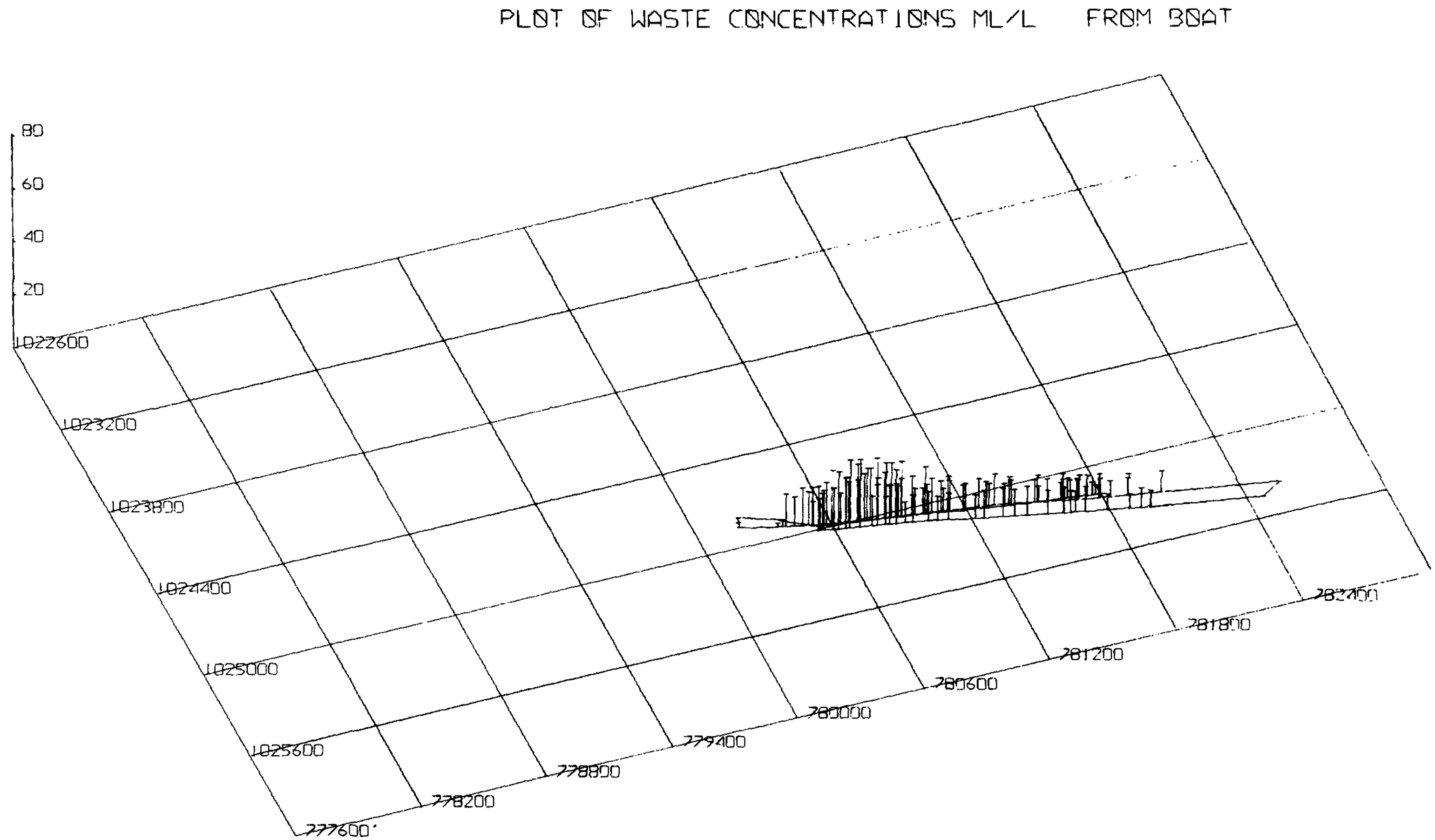


Figure 41. Waste concentrations measured by boat sampling on August 19, 1969.

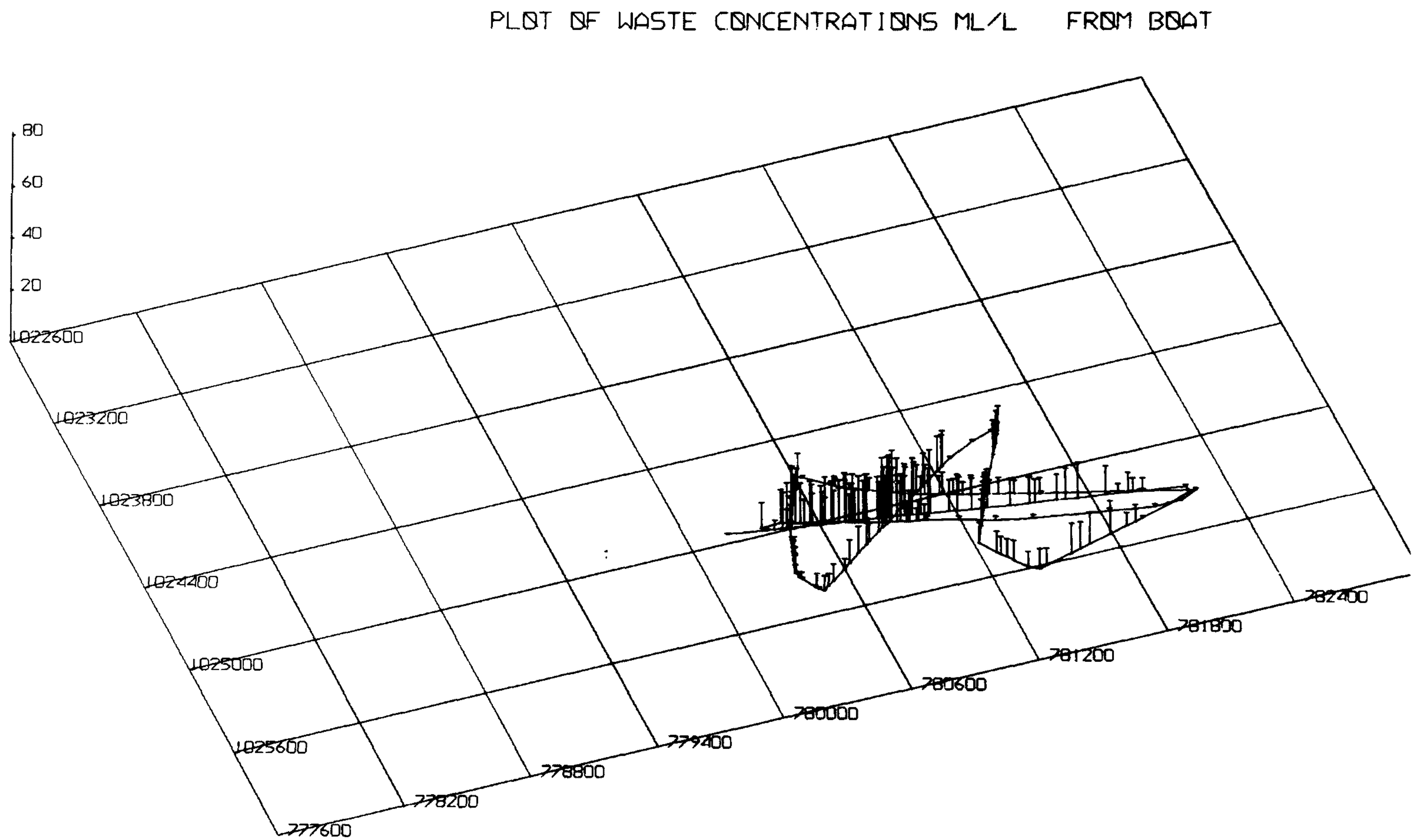


Figure 42. Waste concentrations from boat sampling on August 20, 1969, run 1.

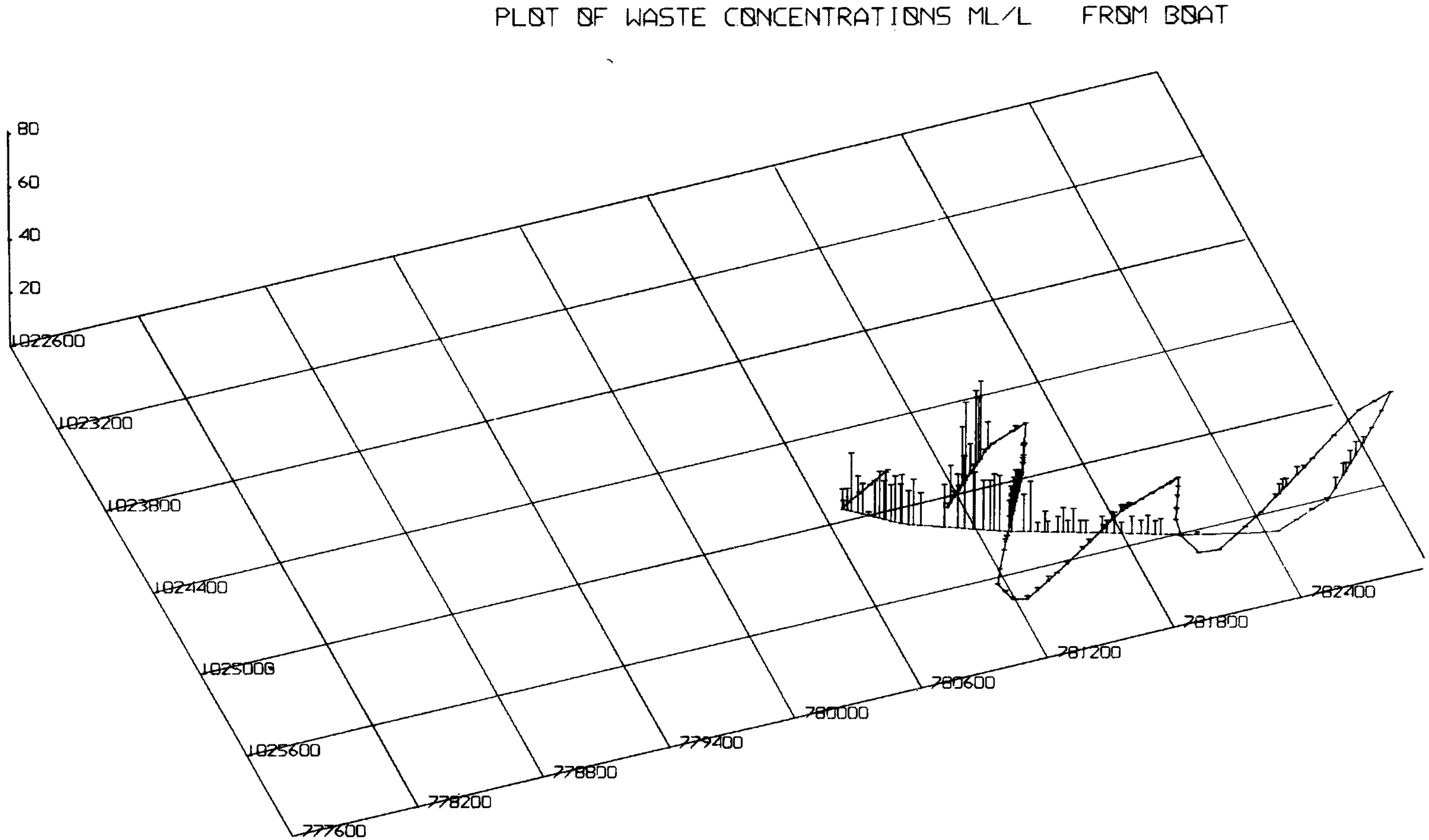


Figure 43. Waste concentrations from boat sampling on August 20, 1969, run 2.

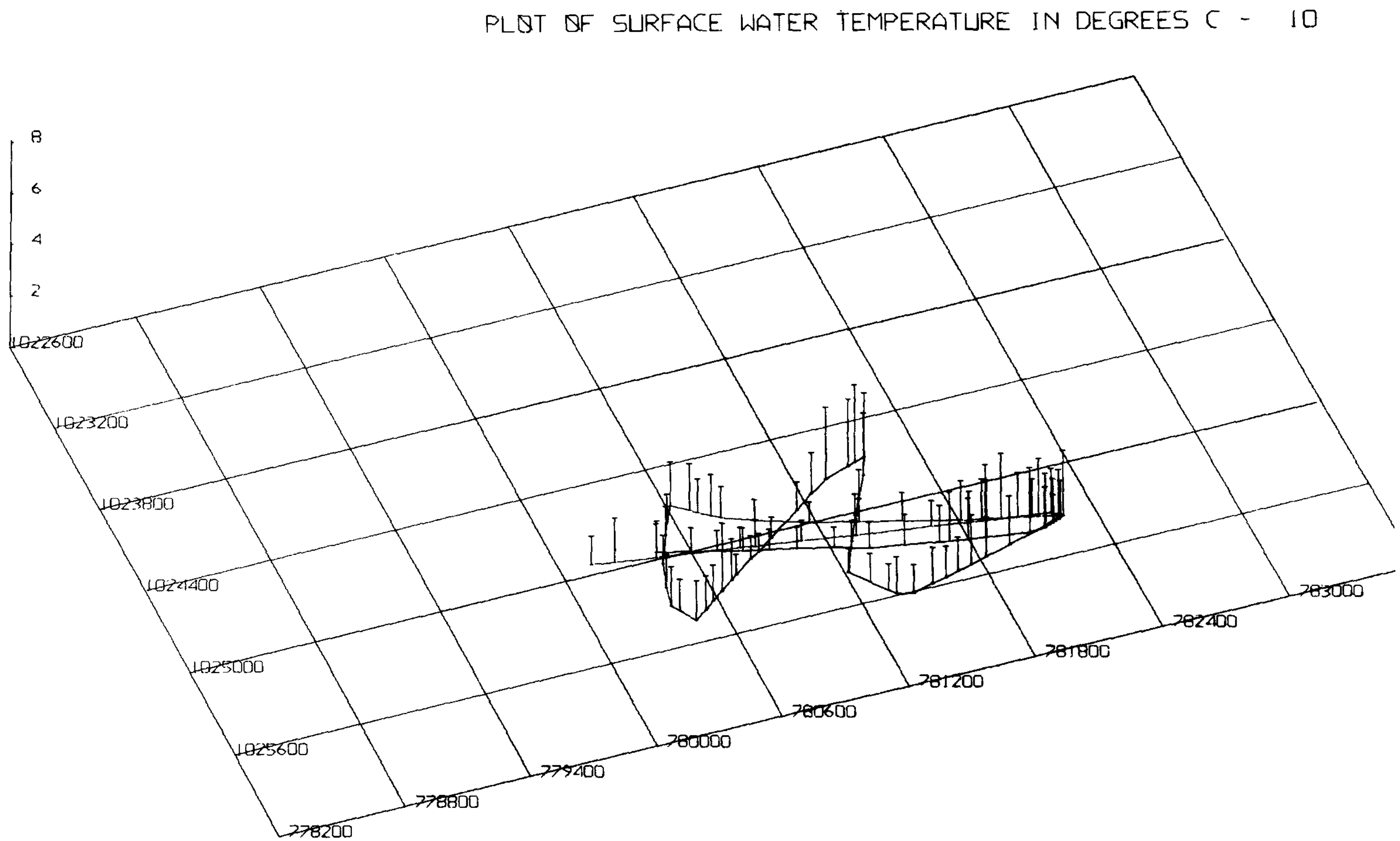


Figure 44. Surface water temperatures measured August 20, 1969, run 1.

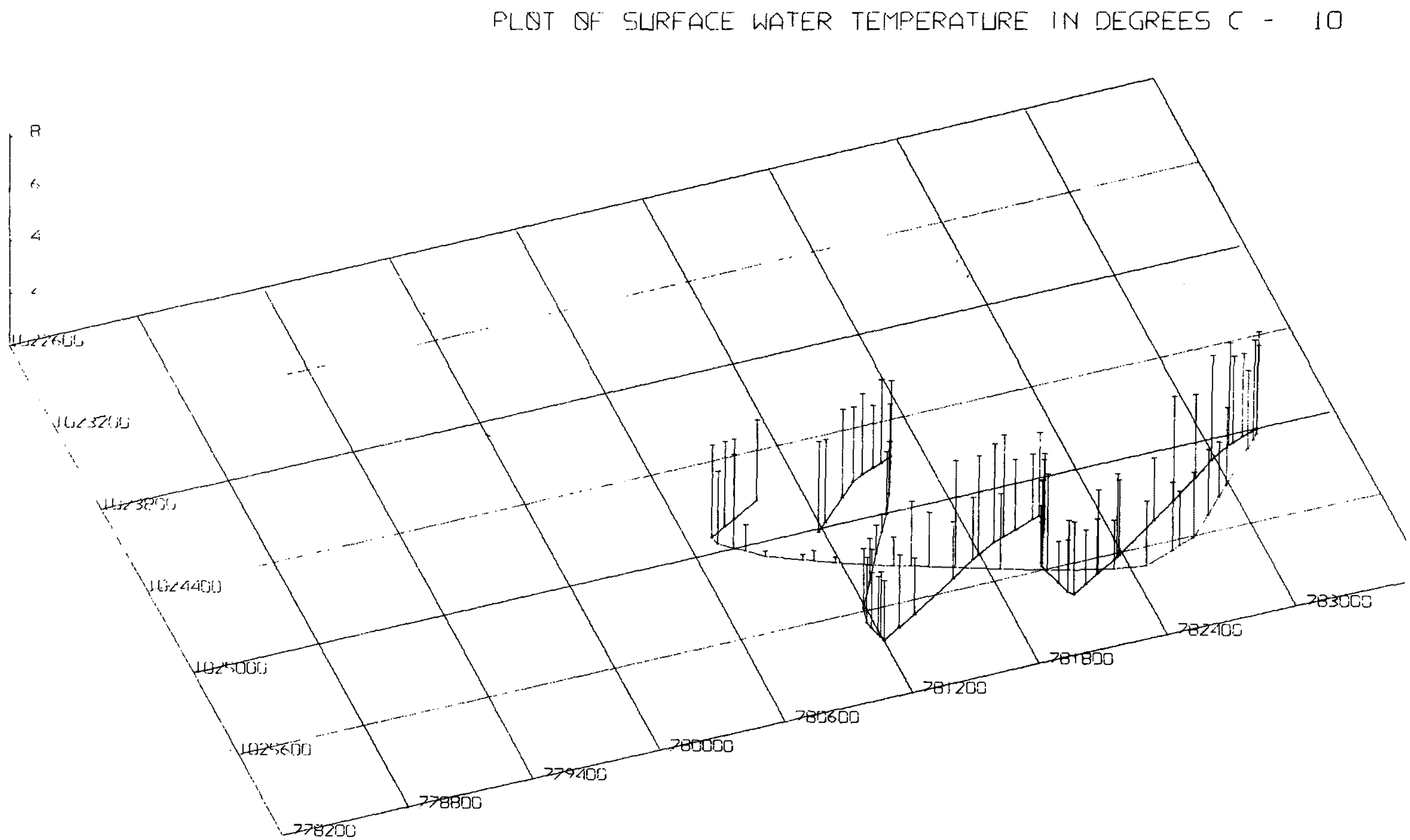


Figure 45. Surface water temperatures measured August 20, 1969, run 2.

4000 ft at 12:39, August 19, using panchromatic black and white film with a 25A filter. The outfall is located in the lower right and the plume extends upward to the left along the surf zone. A tide rip can be seen extending through the surf zone in the upper left and a dye patch can be seen offshore from the plume on the left.

The two 70 mm photos in Figure 47 were taken in the same flight with infrared black and white film with an 89B filter. The boat in Figure 47A appears as a white spot in the center of the picture. Infrared photography of the plume requires about three stops more exposure than land detail. The dye patch in Figure 47A is just visible on the IR film. As the photos were scanned automatically, the infrared band was used to distinguish the dye from the waste field in the computer processing. Figure 47B was taken over the outfall.

The variation in film density in the infrared photograph is greater than that in Figure 46. Ninety percent of the light return in the infrared band is from the upper two feet of the water; whereas, in the red band ninety percent of the light return is from the upper seven feet.

The photos of the plume in Figures 48 and 49 were taken at 13:53 from 6000 ft and at 16:28 from 4000 ft, respectively. The plume in Figure 48 extends upward and to the left from the outfall located near the lower right of the photo. The dye patch can be seen as a narrow streak oriented approximately perpendicular to the beach at the left of Figure 48. At 16:28 the plume extended directly towards shore from the outfall.

The 70 mm color photo of the waste field in Figure 50 was taken at the same time as that shown in Figure 49. The variation in grey on the print represents the change in blue film density of the original transparency. The surf is visible in the upper right as the dark area. Near the upper center of the photo is gray area which is suspended sand from the turbulent surf zone and relatively free of waste. The differentiation between the plume and the suspended sand is not possible in Figure 49 which was taken with panchromatic film and a red filter. The blue band was useful distinguishing the suspended sand from the plume in the processing of the photographic data.

On the morning of August 20th the waste plume extended from the outfall northeast into the surf. The photos of the plume shown in Figures 51 and 52 were taken at 11:27 from 4000 ft and 11:41 from 5000 ft, respectively. The survey boat can be seen sampling the waste field. The outfall is located about a half inch below the boat in Figure 52. The shape of the plume about the outfall is mainly a result of surface spreading of the waste caused by a 17 cfs source in a relatively calm receiving body. Apparently the water currents carry the waste northeastward from the outfall and the swell is moving the waste into the surf. Swell normally does not have a large forward transport; however, in the nearshore area when the wave peaks, the swell begins to change from an Airy or Stokes wave to a solitary wave with a forward transport

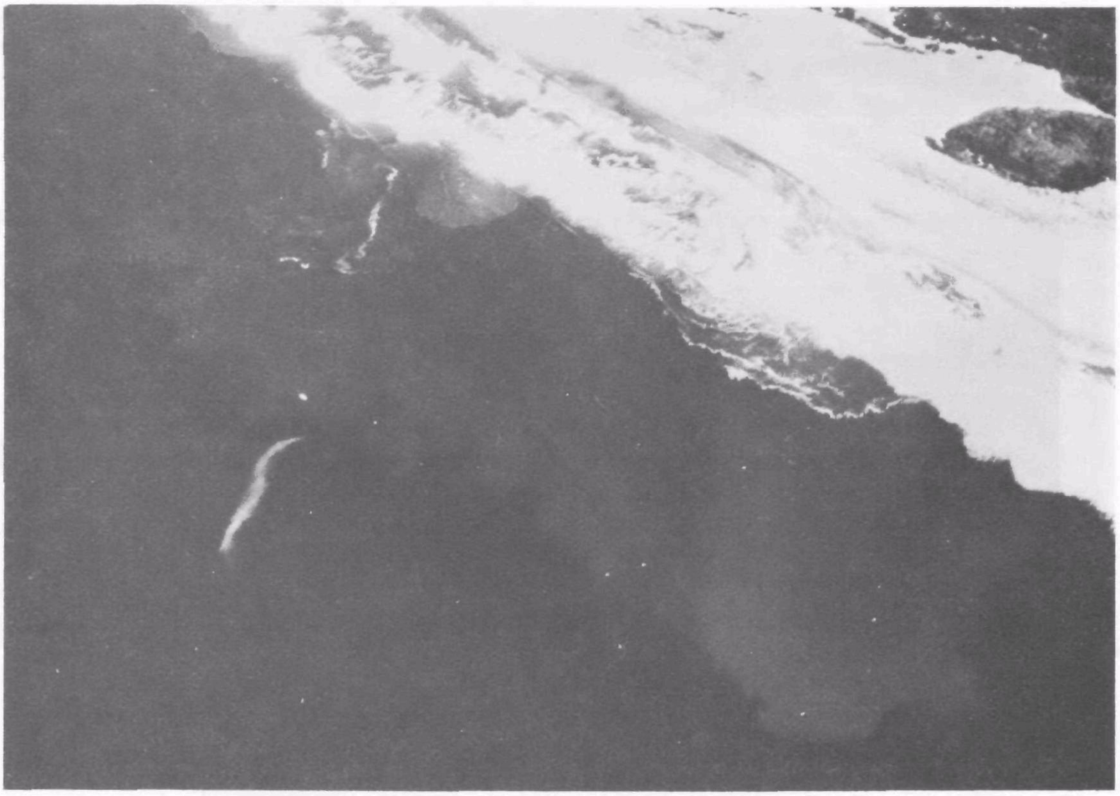
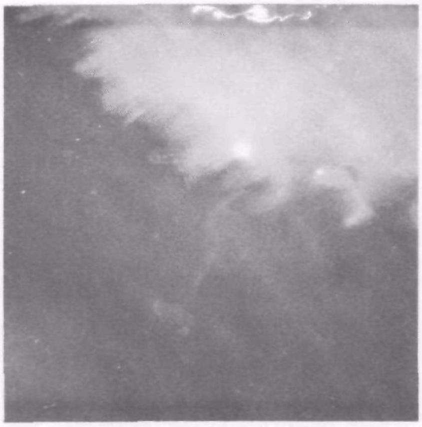
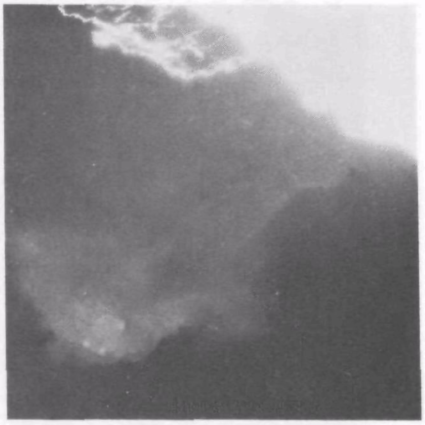


Figure 46. View of waste field at 12:39 on August 19, 1969.



A



B

Figure 47. Infrared photos of the waste field at 12:39 on August 19, 1969.

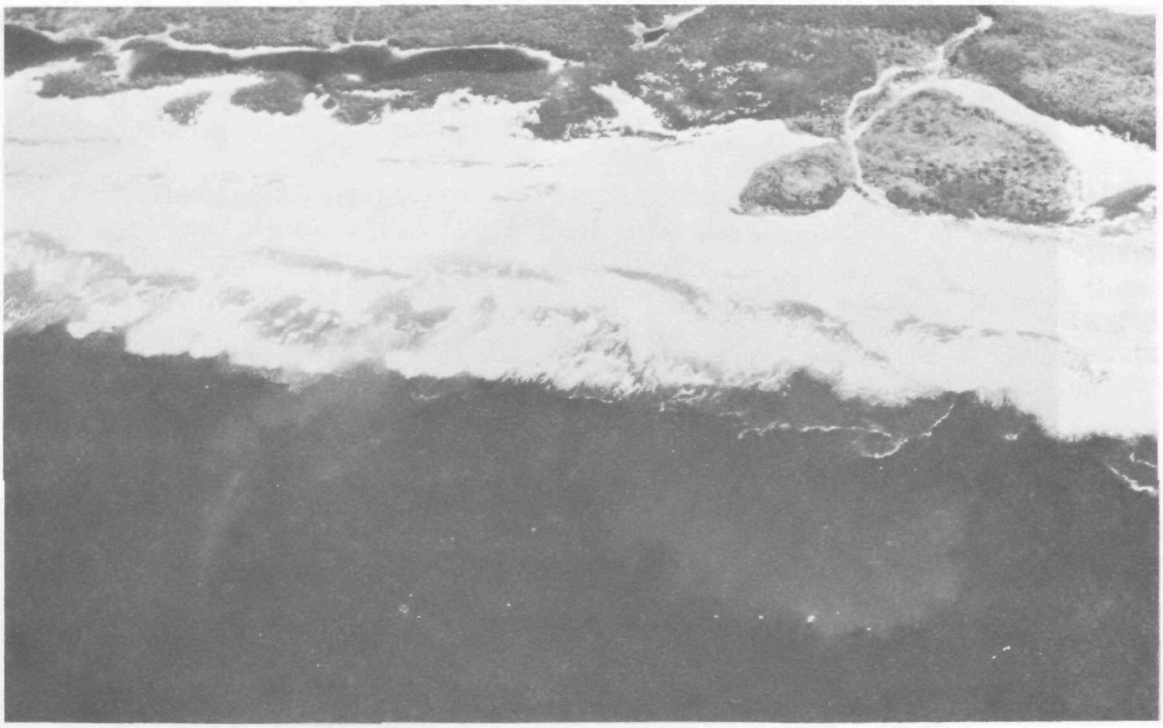


Figure 48. Photo of waste field at 13:53 on August 19, 1969.

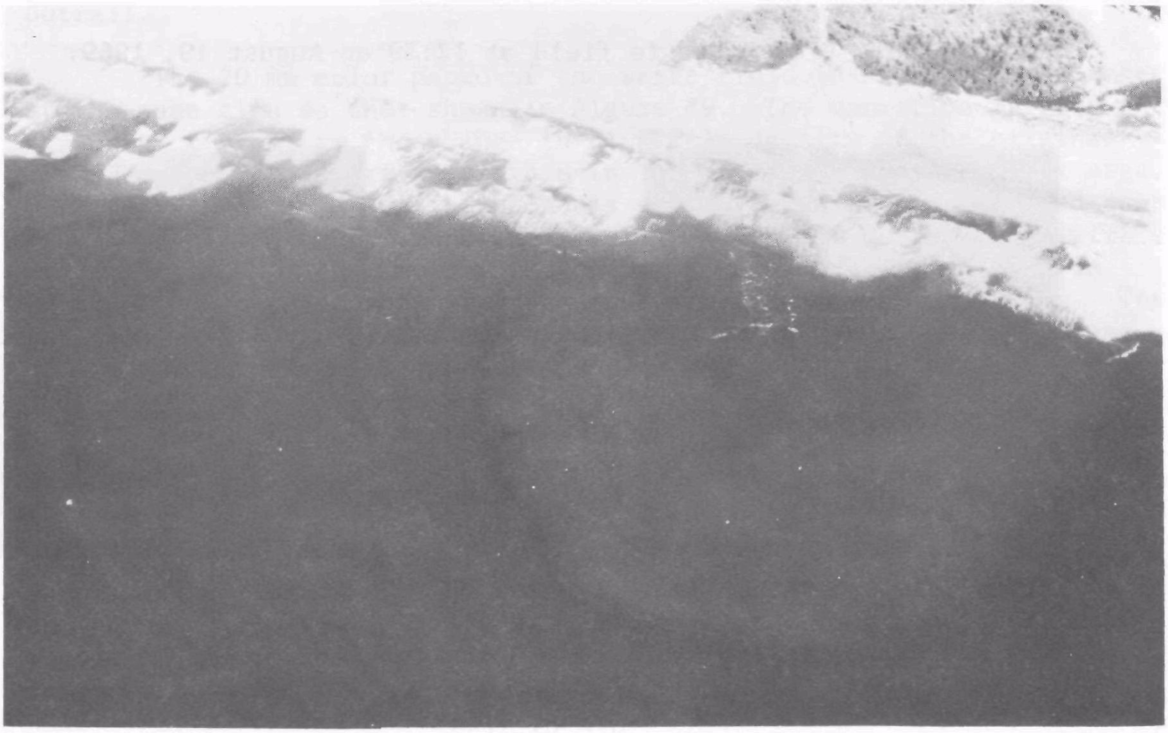


Figure 49. Photo of waste field at 16:28 on August 19, 1969.

Figure 50. Seventy mm photo of waste field at 16:28 on August 19, 1969.

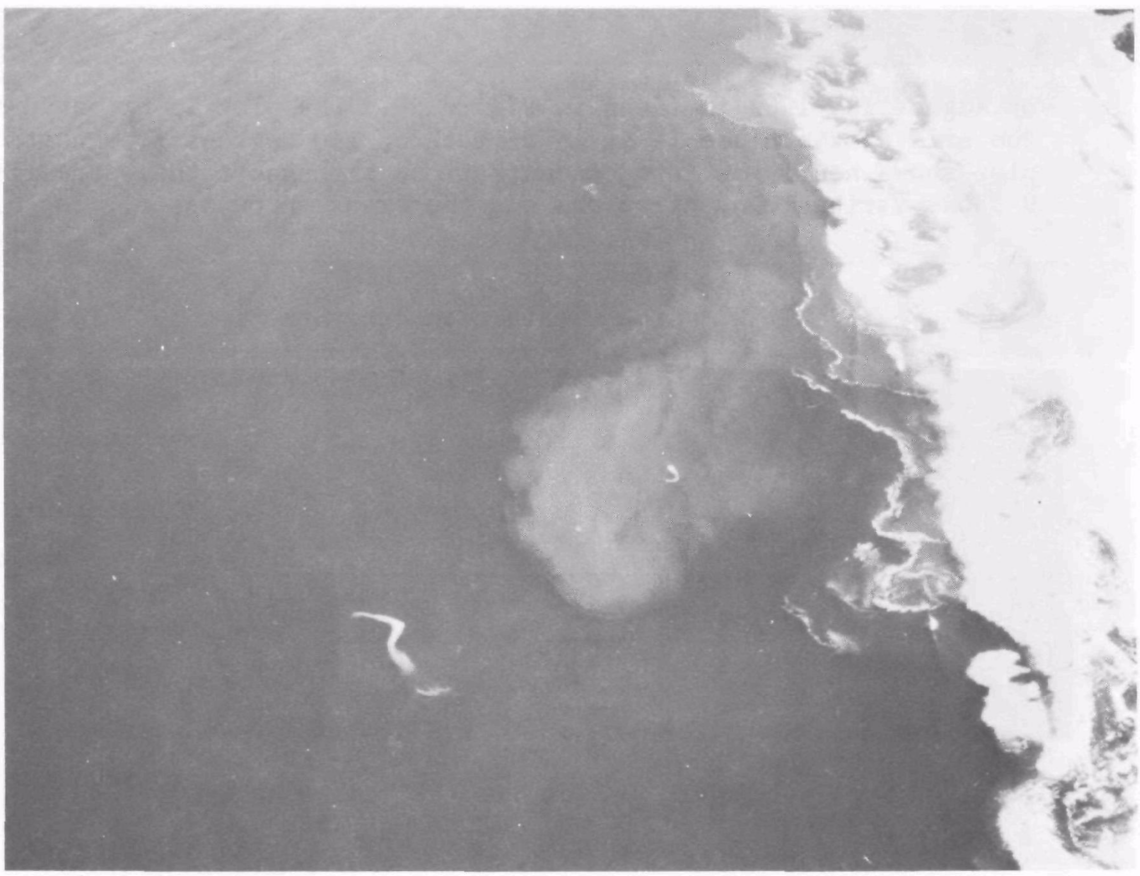


Figure 51. Photo of the waste field at 11:27 on August 20, 1969.

of water near the surface. The dye patch shown in the lower left of Figures 51 and 52 was dropped at 11:03. It can be observed that the dye patch moved northeast towards the outfall several hundred feet between flights. The current velocity was 0.13 ft/sec. Infrared black and white photos of the waste field are shown in Figure 53. The photo in Figure 53A was taken at 11:27 from 4000 ft while the photo in Figure 53B was taken from 8000 ft at 12:15. The boat is the white spot in Figure 53A and the surf is on the right. The three white dots to the left of the plume in Figure 53B are salmon fishing boats.

At 14:30 it appeared that the waste discharge into the ocean had stopped. However, a few minutes later a very dark brownish-red effluent began appearing on the surface. This may have been caused by a sluge deposit slumping into the pump sump in the holding pond. The photograph in Figure 54 was taken at 15:45 from 4000 ft. The new plume can be seen extending from the outfall northward. The old plume has dispersed but some of the waste can be seen north and south of the outfall. A tide rip near the center of the photo extends from the surf. This area appears as light gray and is bounded by a small foam streak. The water in the rip is nearly free of waste but in the red band is not distinguishable from the surrounding water containing waste.

A symbolic plot of the waste field for flight three taken at 16:30 on August 19, 1969 is shown in Figure 55. The plot is oriented so that the axis of the plume is at an azimuth of 110 degrees from north. The plot shows nearly uniform concentrations throughout the waste field. Table 9 shows various concentrations and the areas encompassed.

Table 9. Area within each concentration range on August 19, 1969.

Concentration range ml/L	Area Sq ft
1 - 2	2.05×10^5
2 - 4	4.32×10^5
4 - 6	2.66×10^5
6 - 10	3.24×10^5
10 - 15	1.78×10^6
15 - 20	2.47×10^6
Total	5.48×10^6 = 126 acres

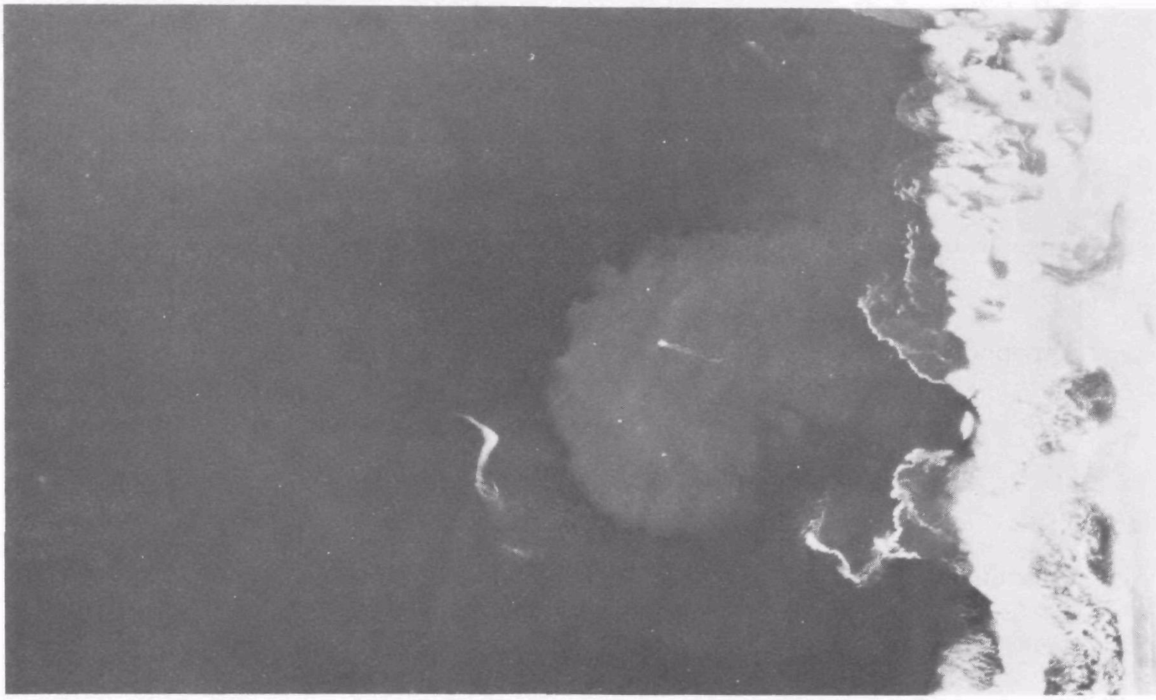
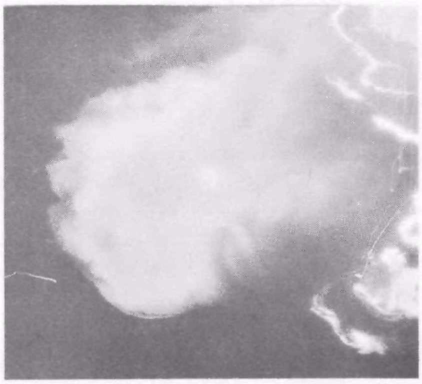


Figure 52. Photo of the waste field at 11:41 on August 20, 1969.



A

B

Figure 53. Infrared photos of the waste field on August 20, 1969.

Figure 54. Photo of the waste field at 15:45 on August 20, 1969.

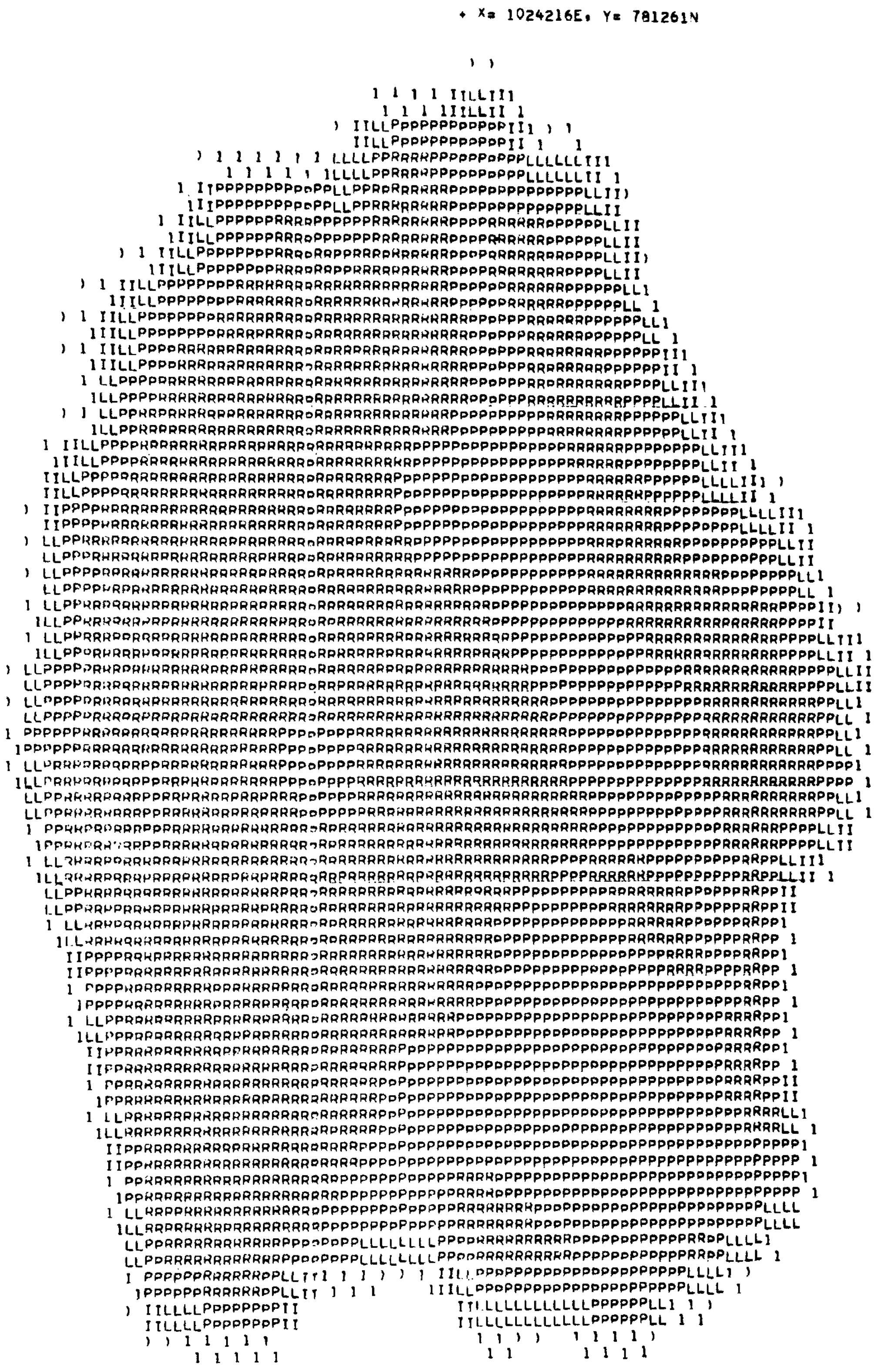


Figure 55. Symbolic plot of the waste field on August 19, 1969.

A symbolic plot of the waste field from flight one on August 20, 1969 at 11:58 is shown in Figure 56. The vertical axis of the plot has an azimuth of 62 degrees from north. The position of outer limit of the surf zone is indicated by the straight line at the bottom of the plot. Area within the different concentration ranges as determined from flight one are listed in Table 10.

Table 10. Area within each concentration range on August 20, 1969.

Concentration range ml/L	Area Sq ft
1 - 2	1.08×10^6
2 - 4	7.60×10^5
4 - 6	3.35×10^5
6 - 10	4.57×10^5
10 - 15	6.80×10^5
15 - 20	1.03×10^6
20 - 25	5.08×10^5
GT 25	7.20×10^3
Total	4.85×10^6 = 111 acres

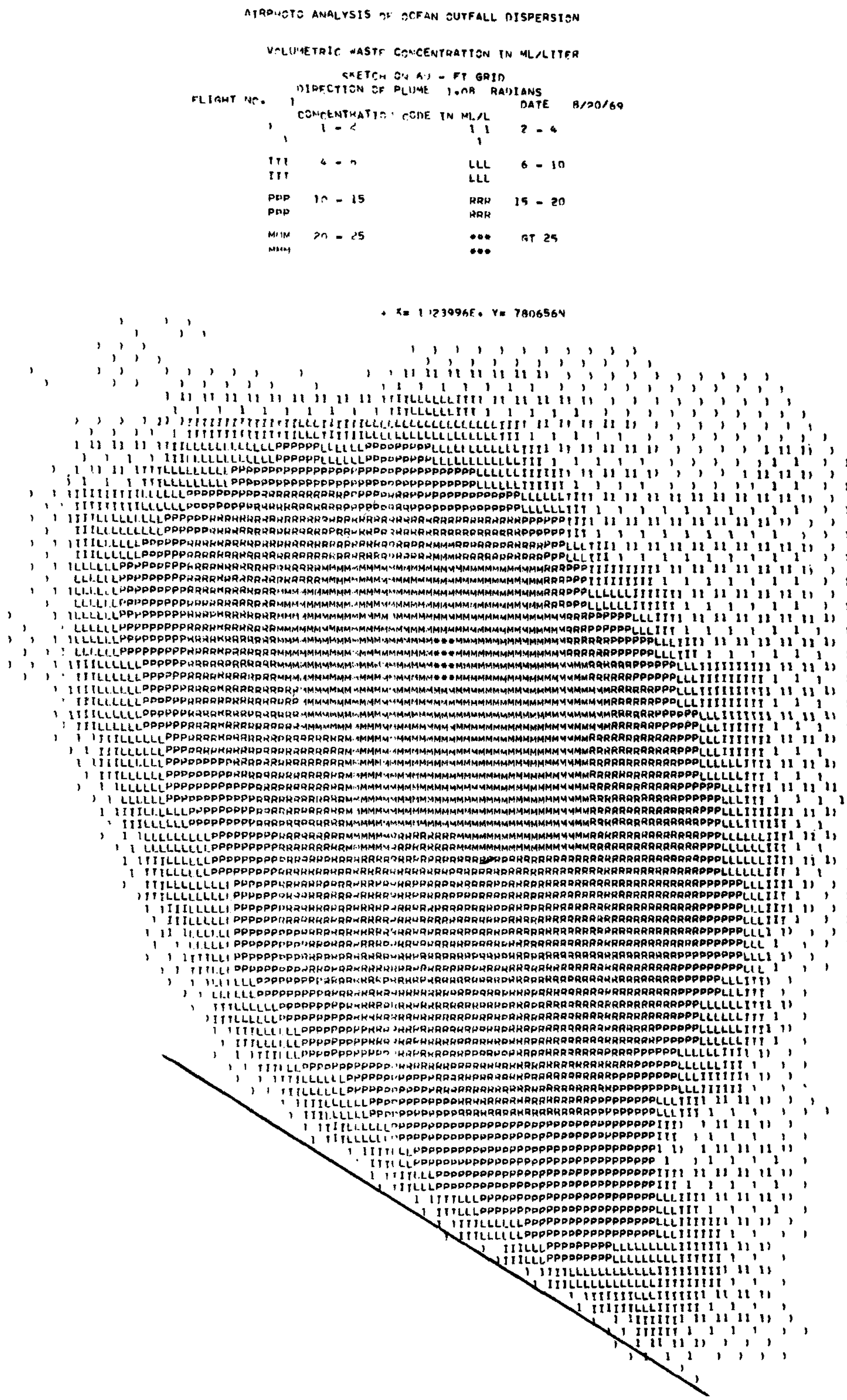


Figure 56. Symbolic plot of waste field on August 20, 1969.

SECTION VII

SAMOA STUDY

The Georgia Pacific Corporation plant of Samoa, California is located on a narrow sand spit one mile west of Eureka as shown in Figure 57. The sand spit is about eight miles long, one mile wide and is bounded on the east by Arcata Bay and on the west by the Pacific Ocean. The Georgia Pacific plant is located approximately four miles north of the entrance to the bay.

Crown-Simpson Company has a plant at Fairhaven which is located on the spit approximately 2-1/2 miles north of the bay entrance. Both plants discharge their liquid wastes into the ocean. During the study period of August 6 and 7, 1969, the Crown-Simpson plant was not in operation. However, they were pumping water from the bay through their outfall in order to prevent sand from covering and plugging the diffuser ports.

The Georgia Pacific plant produces about 500 tons per day of bleached pulp. Liquid waste from the process is discharged through a 48-inch outfall into the ocean. A photograph of the plant is shown in Figure 58. The location of the outfall was sketched on the photograph and is shown as a white line. The outfall extends about 2900 ft into the ocean and terminates in about 40 ft of water. As shown in Figure 59, the diffuser section contains 50 ports spaced ten ft apart. The eight-inch diameter nozzles discharge horizontally and are pointed to alternately discharge on opposite sides of the header. Due to drifting sand, it is not known how many of the nozzles were operating at the time of sampling.

Field work was conducted at Samoa on August 6 and 7, 1969. The Humbolt State College research vessel "Sea Gull" was chartered for the boat work. The swell was three to four feet on these two days and the wind 5-10 mph from the northwest. Fog on both days prevented sampling in the morning.

Waste concentrations determined by boat sampling are shown in Figures 60 through 63. Sampling on August 6 was conducted from 14:21 until 15:01 for run 1 and from 15:59 until 16:49 for run 2. On August 7 the boat sampling was conducted from 12:53 until 14:39 and from 16:00 until 16:26 for runs 1 and 2, respectively.

The outfall is located on the right of the plots and the waste plume extends towards the left or southwest. The state plane coordinate grid was drawn at 800 foot intervals. The plume is bounded on the southeast by the surf zone. Maximum concentrations measured over the outfall were 18 ml/L or a 1.8 percent waste concentration by volume. The effluent flow rates were 18,600 and 16,500 gpm on the two sampling days.

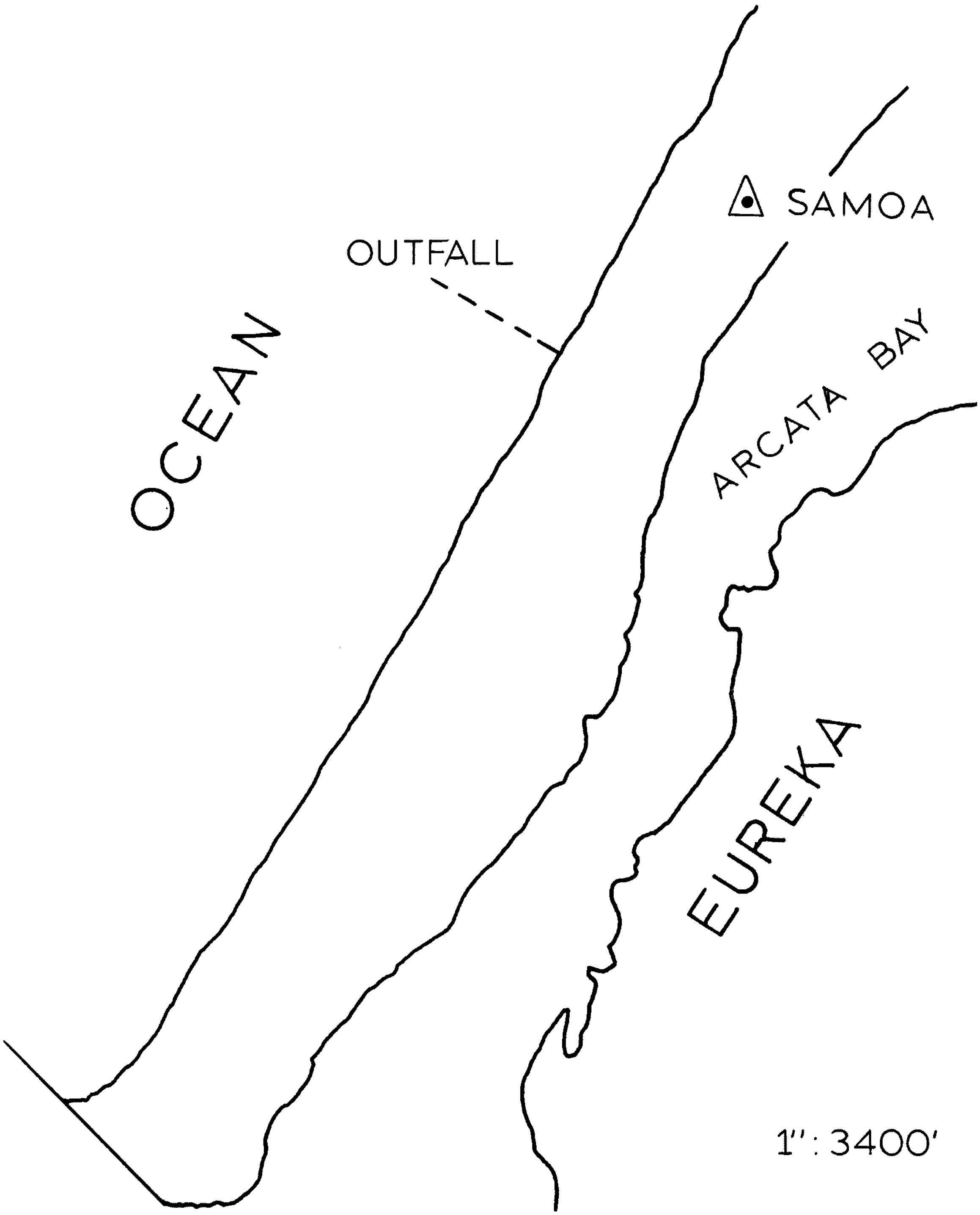


Figure 57. Samoa outfall location map.

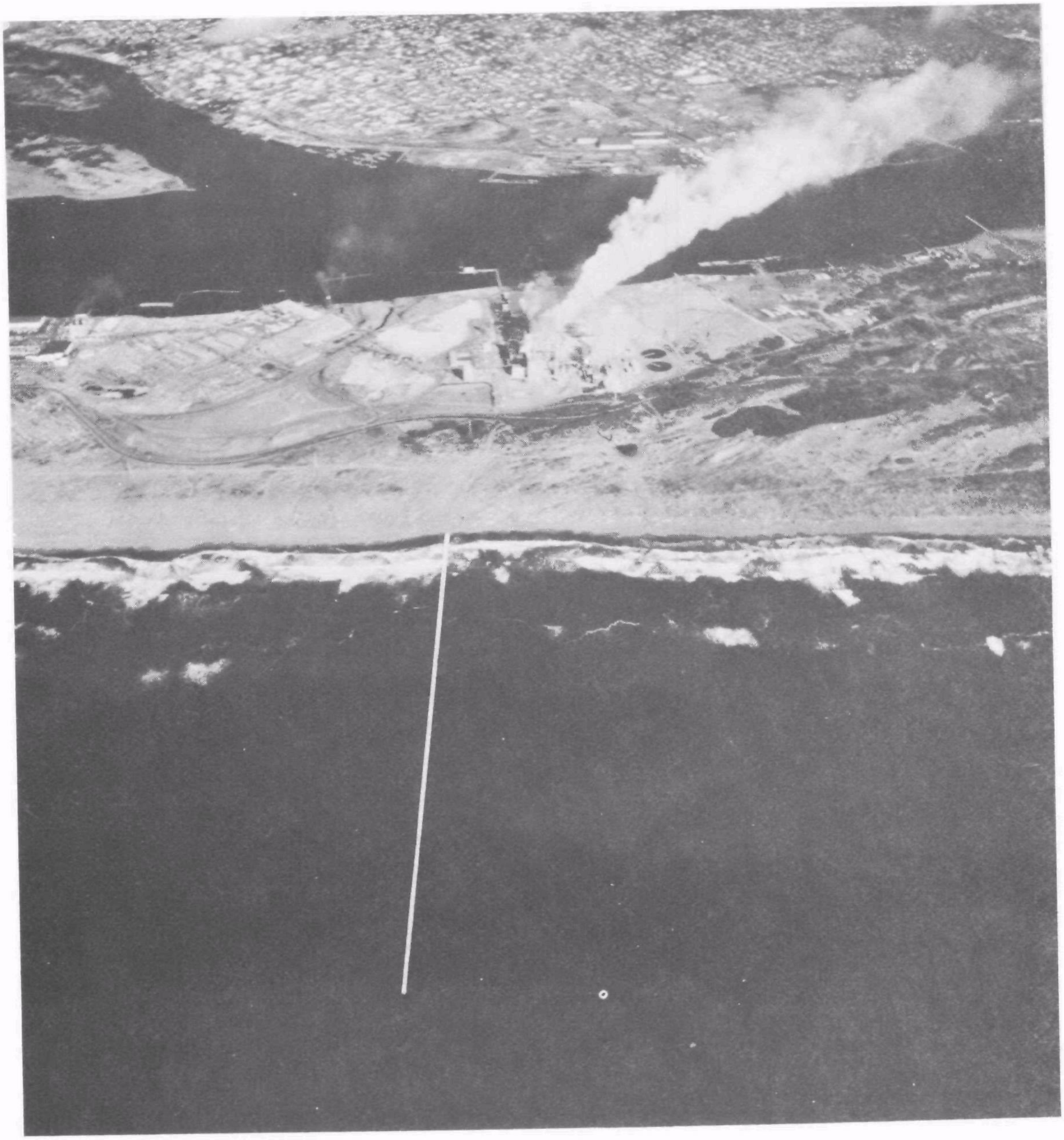


Figure 58. Aerial view of the Georgia Pacific plant near Samoa, California.

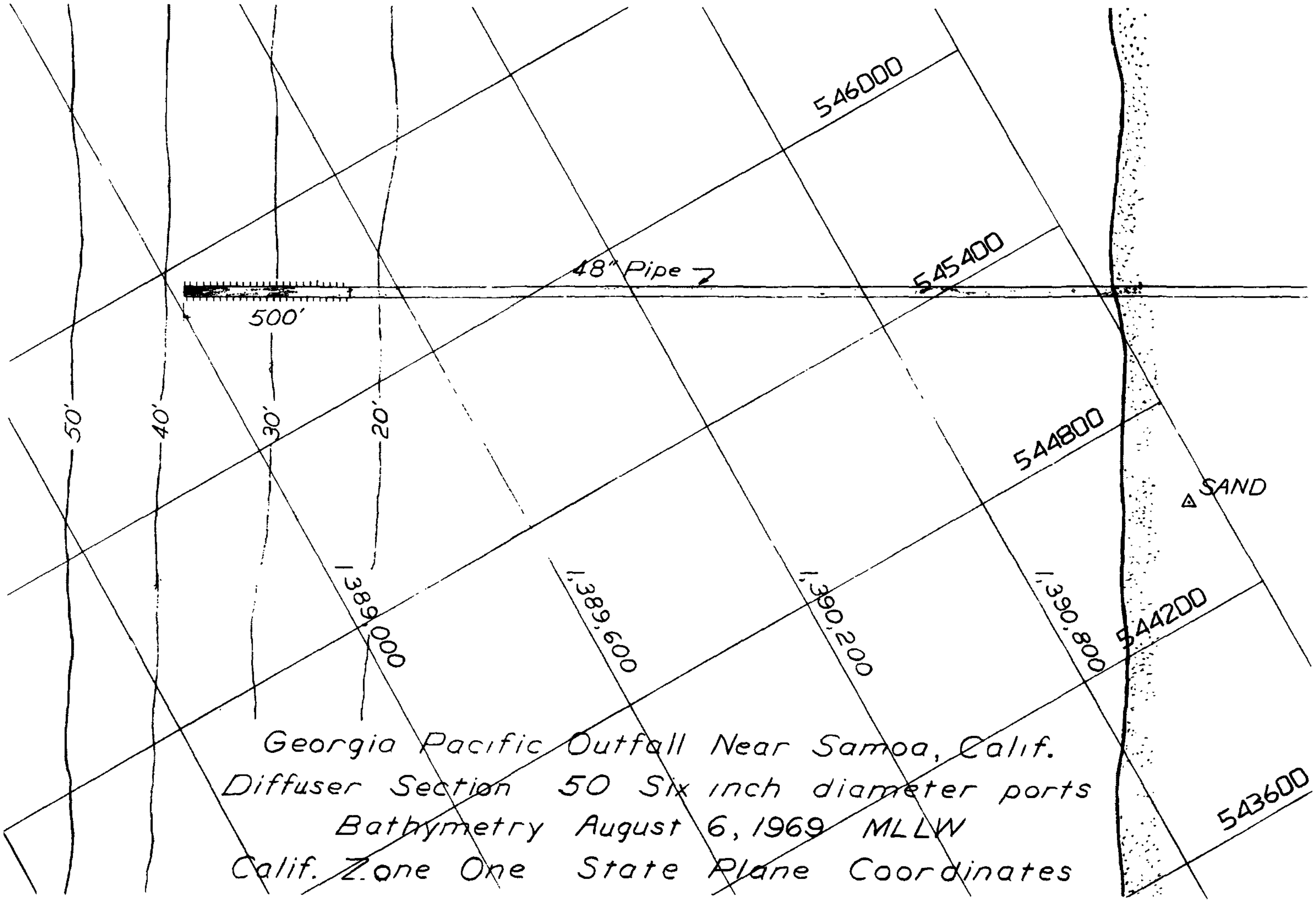


Figure 59. Georgia Pacific outfall near Samoa, California.

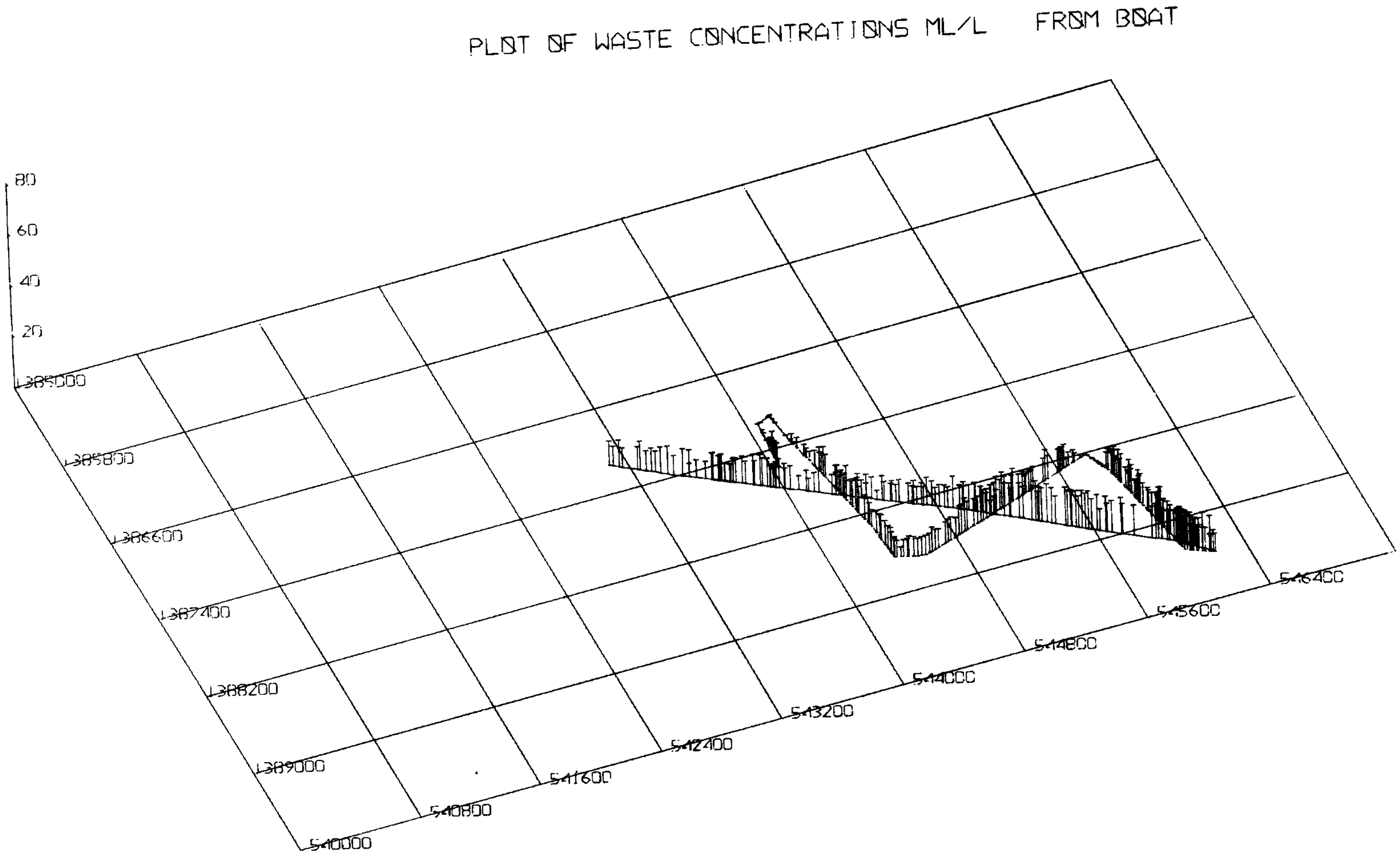


Figure 60. Waste concentrations from boat sampling on August 6, 1969, run 1.

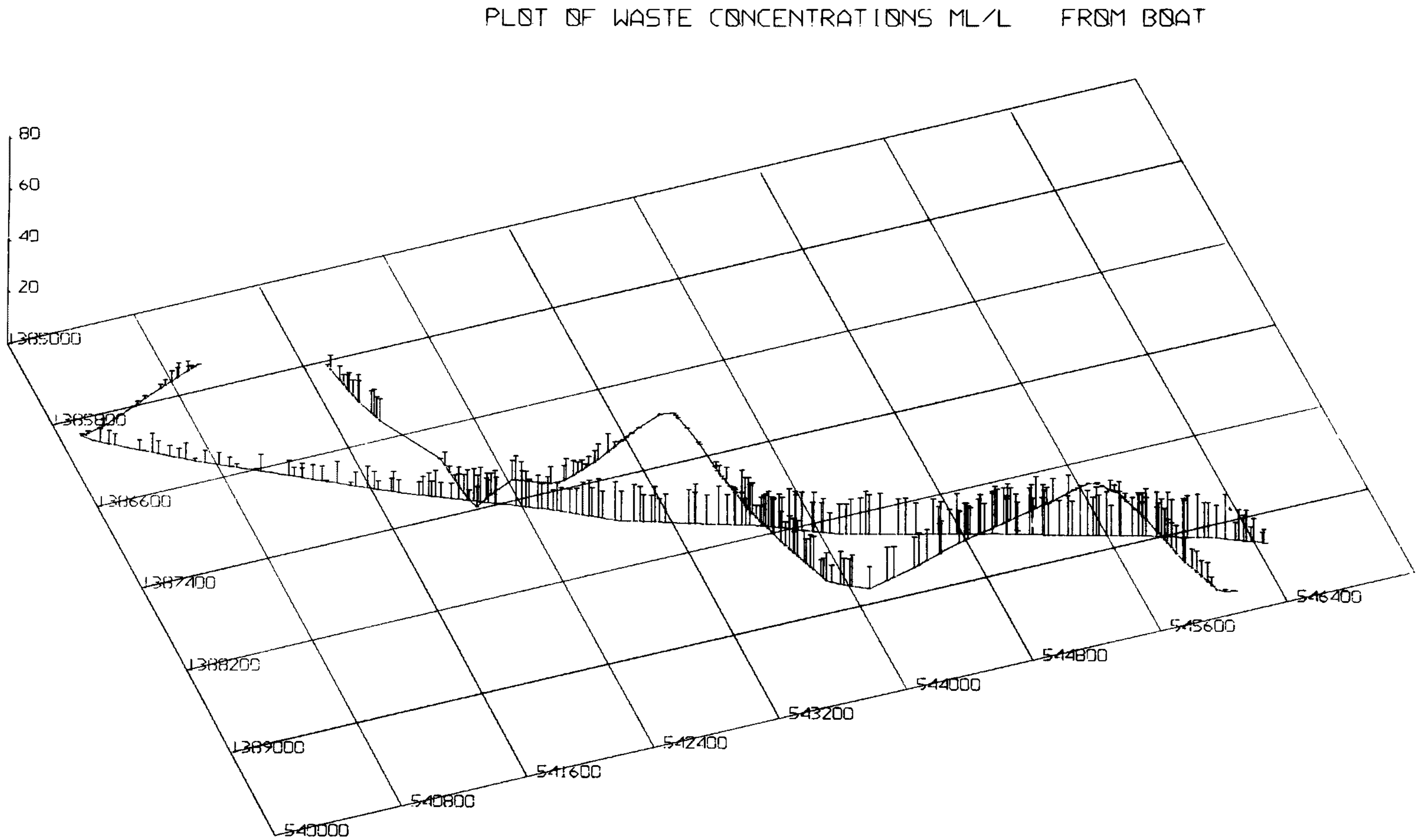


Figure 61. Waste concentrations from boat sampling on August 6, 1969, run 2.

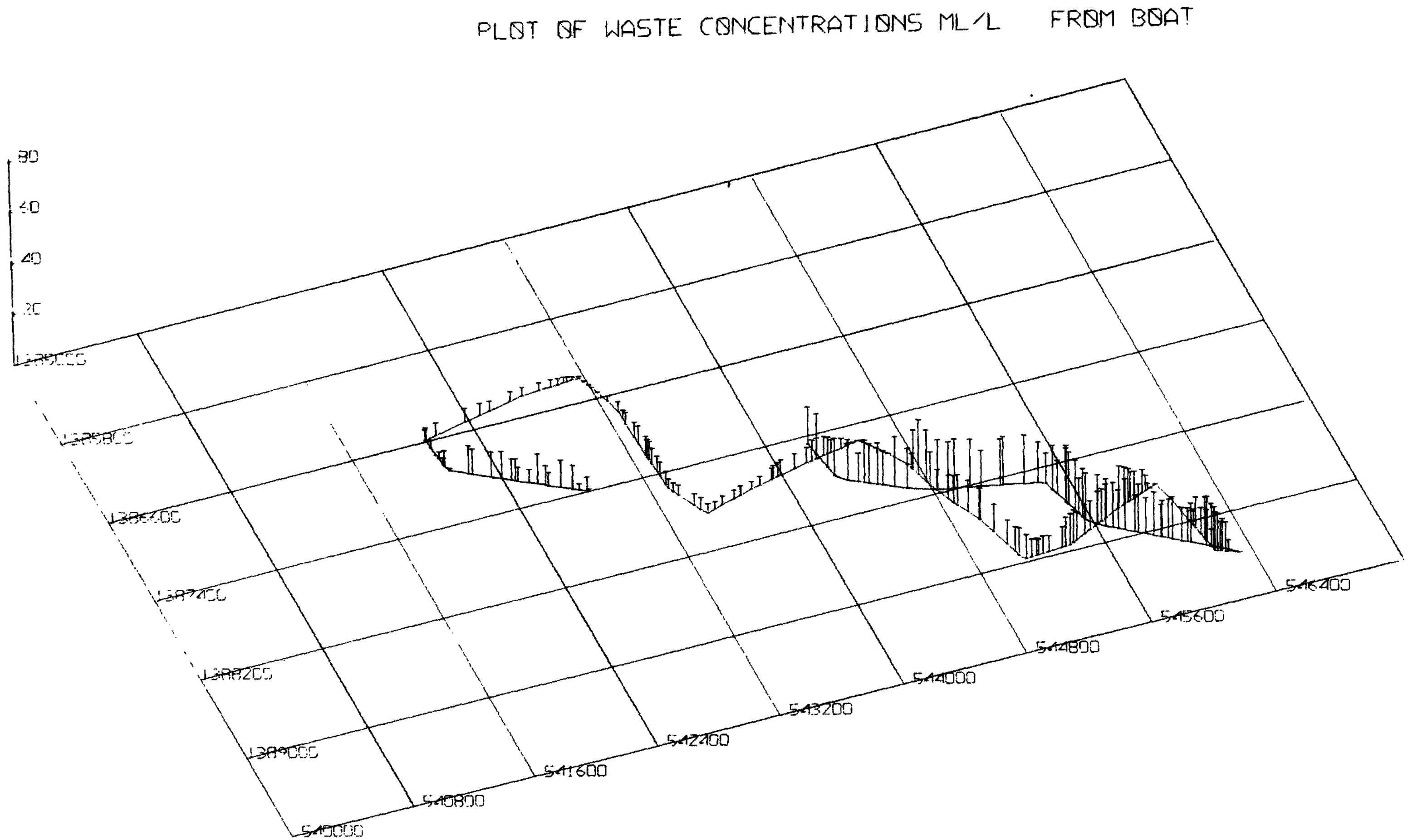


Figure 62. Waste concentration from boat sampling on August 7, 1969, run 1.

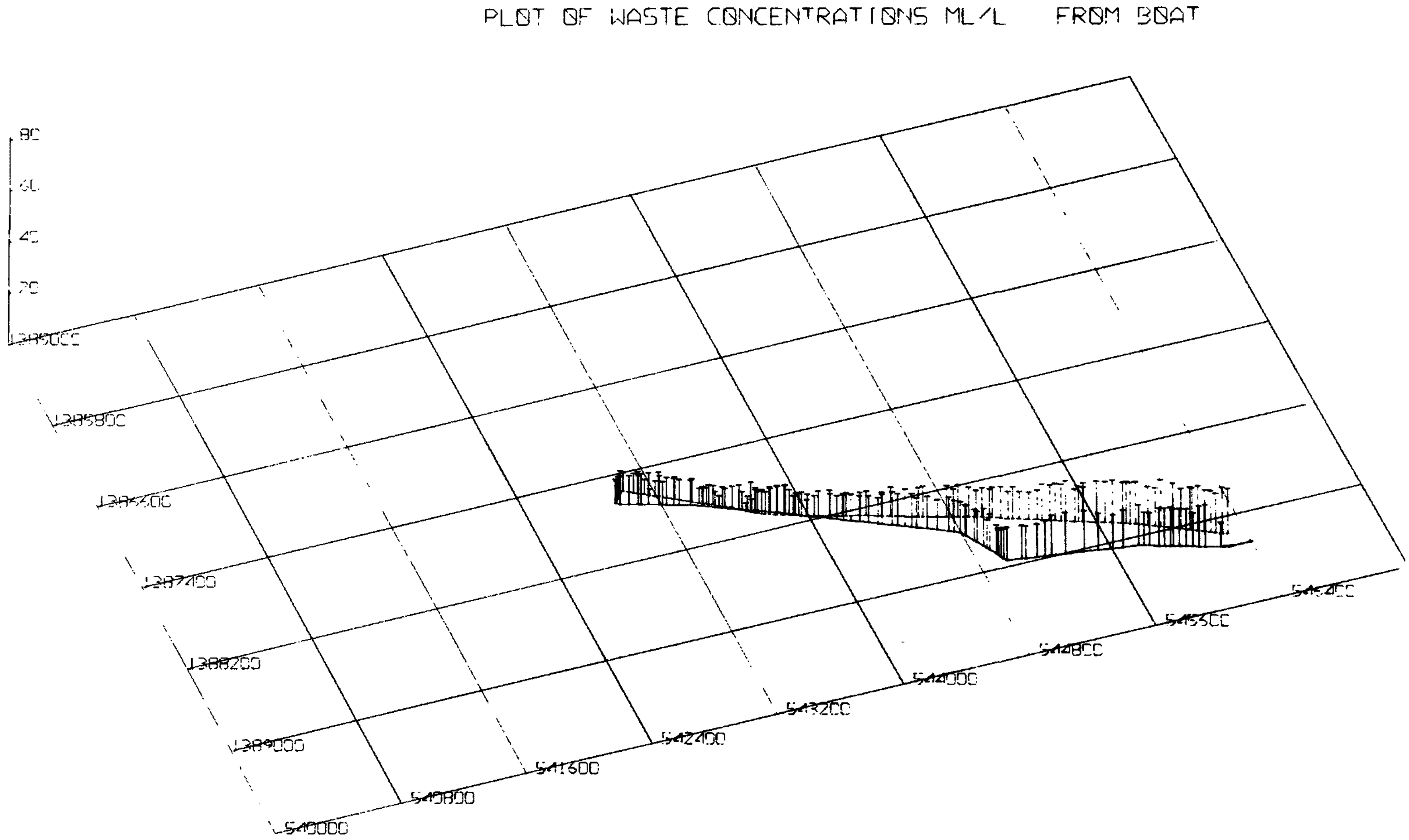


Figure 63. Waste concentrations from boat sampling on August 7, 1969, run 2.

Surface water temperatures minus 10°C. as measured on August 6 and 7 are shown in Figures 64 and 65. It can be seen that there was little temperature variation in the surface water and that the offshore water tended to be slightly warmer than those in the plume or nearshore. The lowest temperature value was located at the south end (left) of the boats track shown in Figure 65. This point was in Crown-Simpson's fresh water plume.

On the aerial photograph of the plume shown in Figure 66, the outline of the Georgia Pacific plume is shown with the broken line while the outline of the Crown-Simpson plume is shown with a solid line. The photo was taken from 5000 ft at 17:09 on August 6, 1969. During the two days of field observations the plume maintained nearly the same size, shape and position. Although, at times the entire plume moved between the shore and the Crown-Simpson plume. The plume was 700 to 1500 ft wide and about 8000 ft long.

A symbolic plot of the waste field is shown in Figure 67. The plot was made from flight one on August 6th. The flight was taken from 3000 ft at 17:27 o'clock. As the first two 70 mm photos did not overlap a blank area is seen near the head of the plume. The total area covered by the plume was 155 acres.

Problems were encountered in the photographic data from Samoa on August 7th. The processing of the photographic data requires that the background light from the open sea be subtracted from the light return in the plume. Because the plume extended to the surf zone, background light measurements were available from only the offshore side of the plume. The large variation in the color of the water perpendicular to the shore rendered the photographic results of questionable value.

The mosaic strip in Figure 68 shows the plume at 16:20 on August 7th. The negative prints were made from 70 mm infrared color photographs from 6000 ft. The dark area in the upper part of the strip is caused by suspended sands near the surf zone. The Georgia Pacific plume extending from left to right in the mosaic is almost entirely inshore of the Crown-Simpson plume shown near the right of the figure. Numerous fishing boats can be seen about the outfall area. The light area in the lower portion of the negative prints is caused by dark upwelled water. A dark narrow band can be seen along the lower (west) edge of the plume.

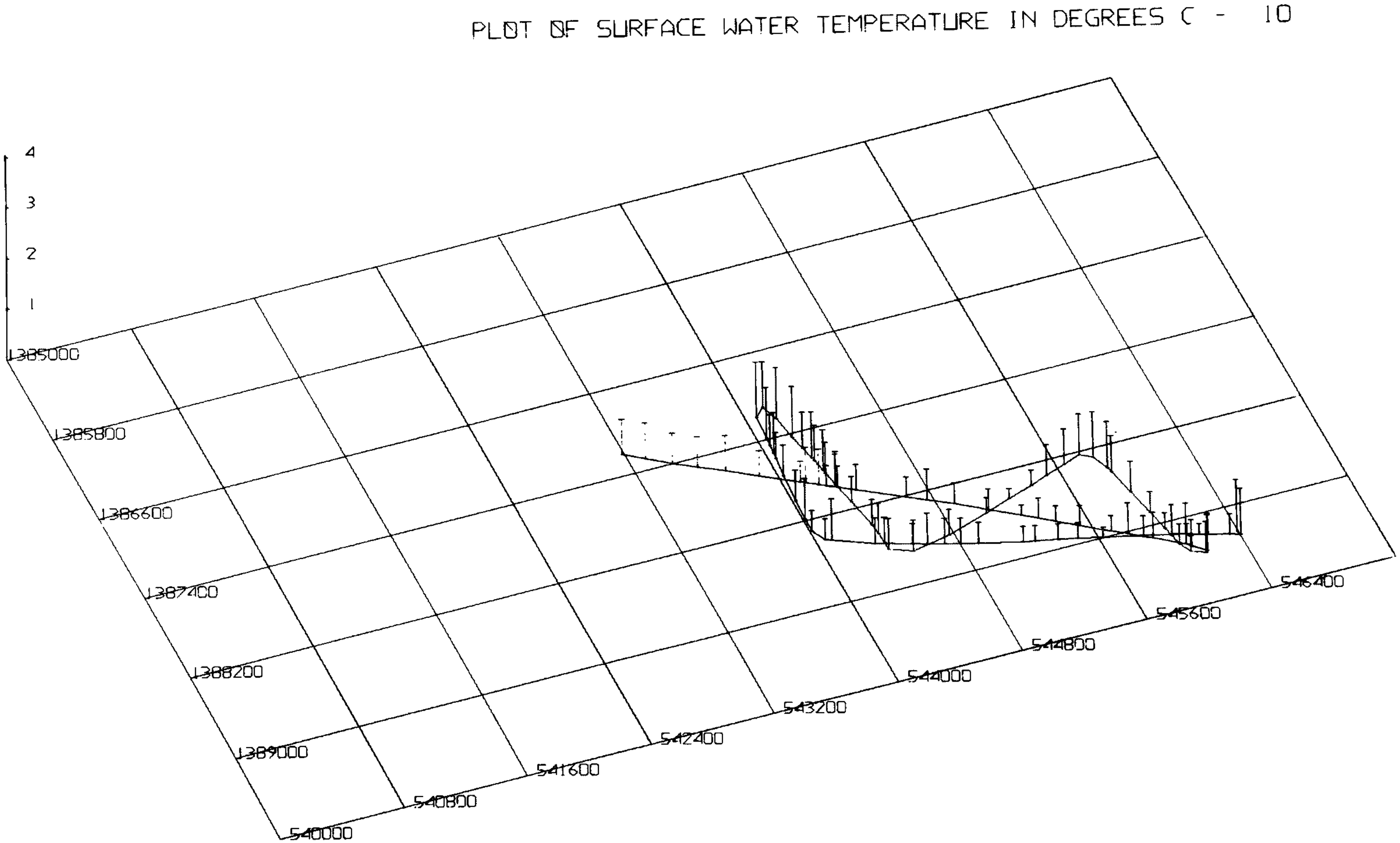


Figure 64. Surface water temperatures on August 6, 1969, run 1.

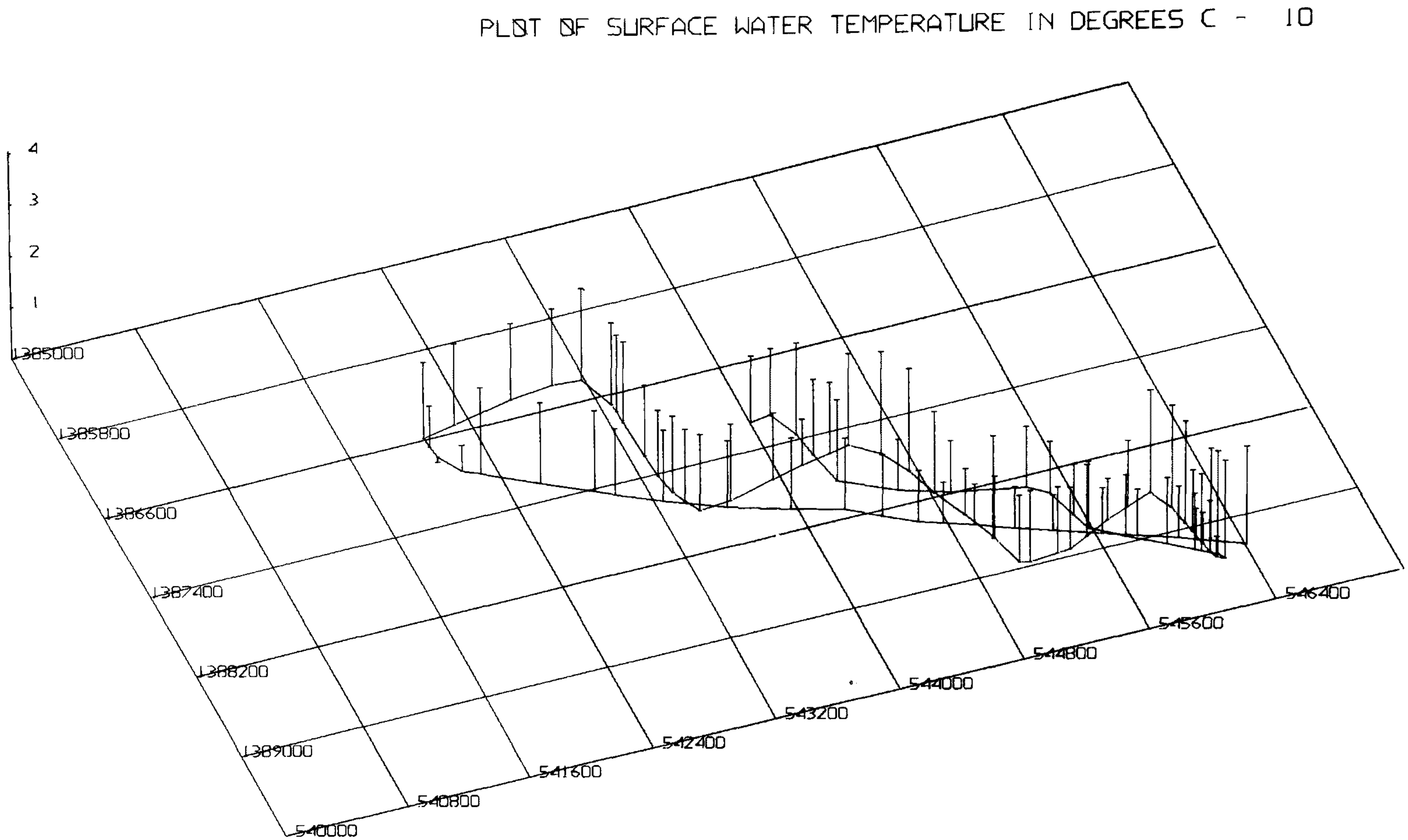


Figure 65. Surface water temperatures on August 7, 1969, run 1.

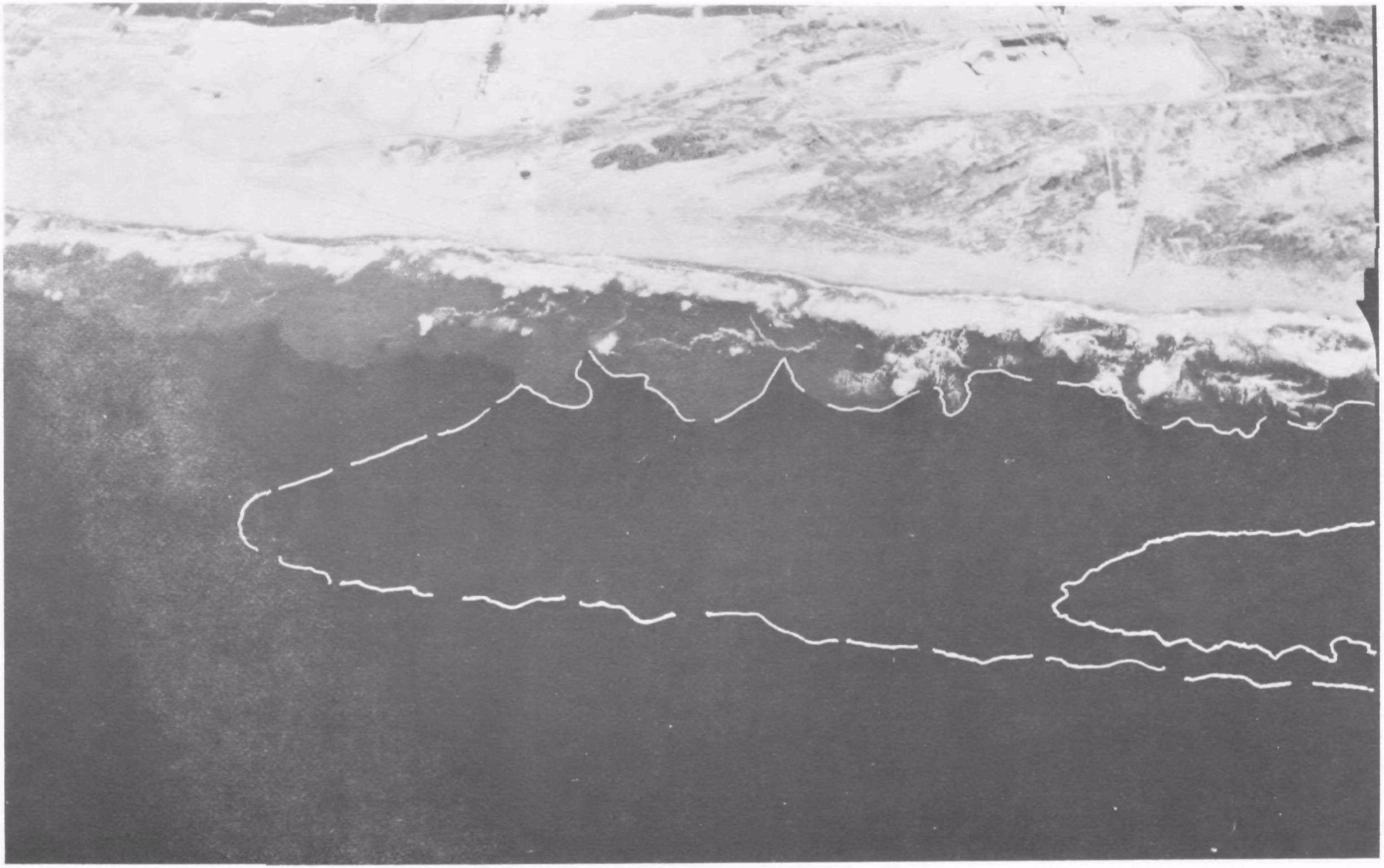


Figure 66. Aerial view of the plume on August 6, 1969.

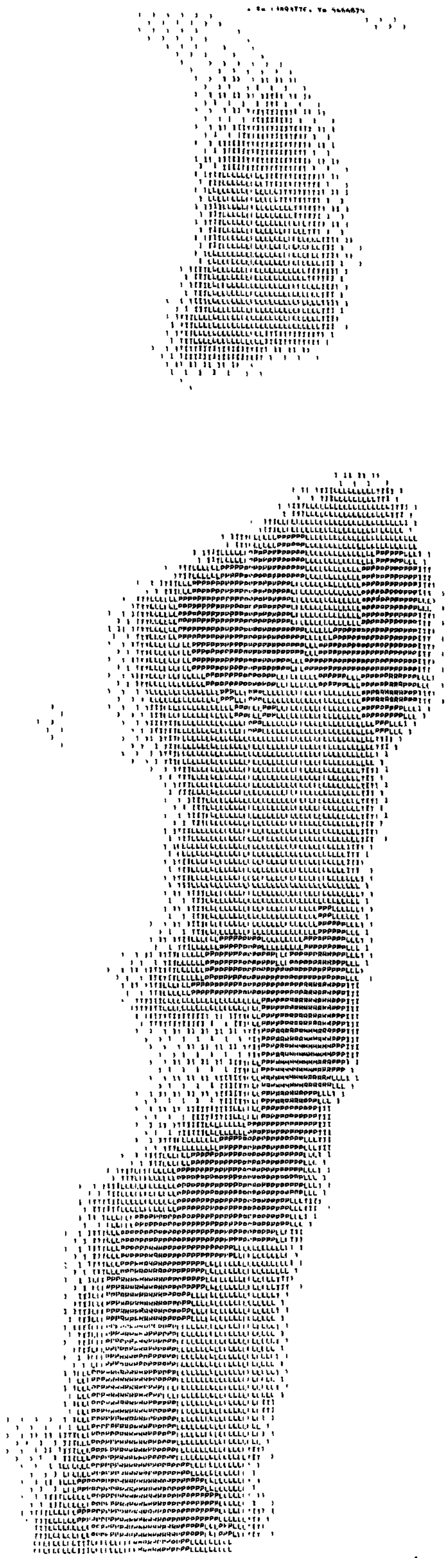


Figure 67. Symbolic plot of waste concentrations August 6, flight 1.

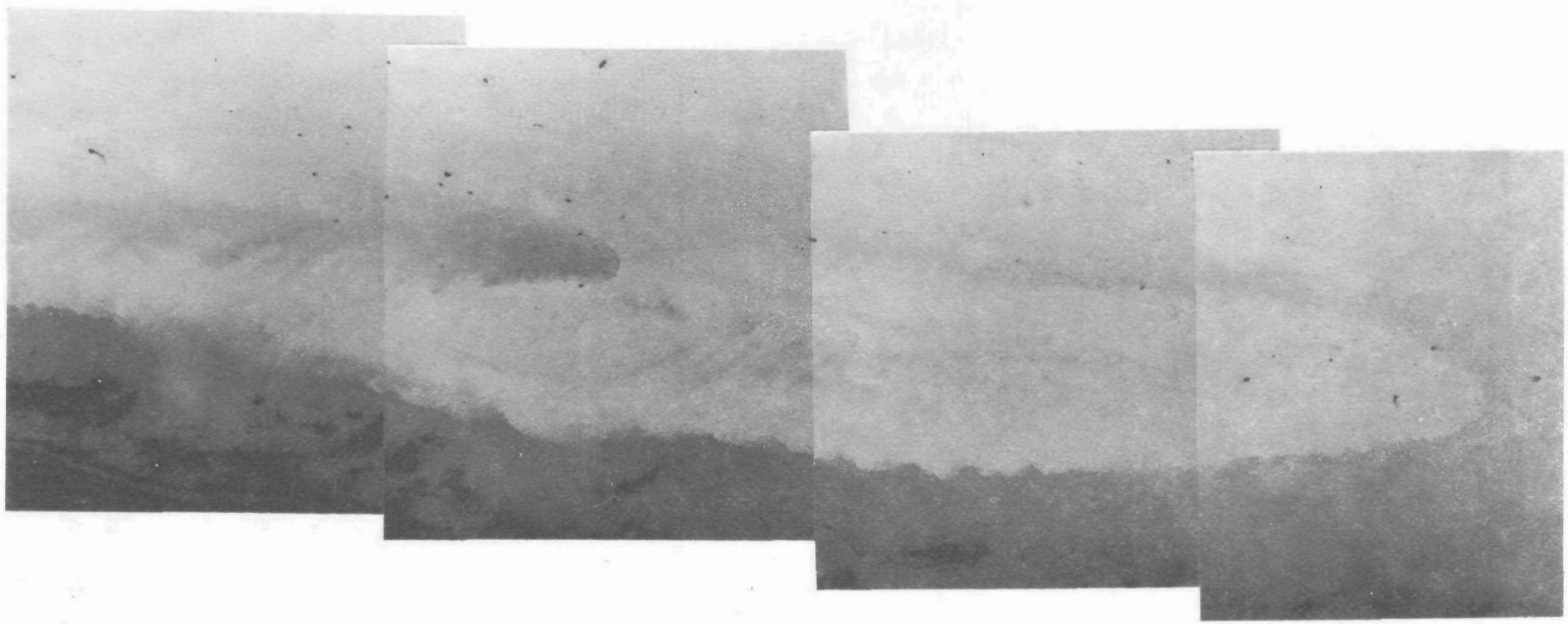


Figure 68. Mosaic of the plume on August 7, 1969.

SECTION VIII

SUMMARY

During the period of August 1968 through September 1969 field work was conducted on thirteen days at Newport, four days at Gardiner, and two days at Samoa. A summary of the sampling is shown in Table 11.

Observations were conducted at Gardiner on July 15-16, 1969 and August 19-20, 1969. As the sea and weather conditions were similar on consecutive sampling days, the results represent essentially only two independent observations. In the first sampling period, the waste moved away from the beach while during the second sampling period the plume extended into the surf zone. It is believed that there is a greater tendency for the waste field to extend into the surf at Gardiner than at Newport, because of its shorter and shallower outfall and greater flow rates, however, it is not known what percent of the time this occurs. Maximum concentration measured over the outfall was 23 ml/L or 2.3%.

Observations were conducted at Samoa on August 6-7, 1969 when the wind was from the northwest. A large plume extended south along the surf zone. Maximum concentration measured over the outfall was 18 ml/L.

Surface water temperature measurements were made at the three outfall locations. Since the warm effluent from the diffuser ports mixes with the cold subsurface water, the resulting mixture at the surface was generally colder than the surrounding sea water. Because of natural temperature variations in the sea water, temperature is not a sensitive tracer for tracking the waste field.

It can be seen from the table that during relatively calm periods the plume at Newport was submerged. On September 10, 11, and the morning of the 12, 1968, the plume formed below the sea surface. On the afternoon of the 12th the wind increased to 20 mph, white caps formed and the plume came to the surface. On June 30 and July 1, 1969, the plume was also submerged. Hourly wind records at the south jetty show that on June 30th, the wind was five mph in the morning, increased to about ten mph at noon, and remained at this level throughout the night. A surface plume may have formed during the night but during the day of July 1st the wind was 4-5 mph and the plume was submerged. On July 7, 1969, the hourly wind pattern was similar to that of July 8, 1969, except on the second day the wind was about three mph higher. On July 7th a surface plume could be seen only for a short distance from the outfall, while on the 8th the plume was on the surface.

The weather was calm on August 12, 1969, with a wind of 3-5 mph. Wind records show that the 11th was also calm yet a large surface waste field was observed on the 12th. The effluent discharge rate was nearly

Table 11. Sampling summary.

Date	Location	Tide[a] Range Ft.	Wave Height Ft.	Wind Dir.	Wind Velocity mph	Effluent Flow Rate gpm	PLUME Area[b] Acres	PLUME Length Ft.	PLUME Max. Concen. ml/L	PLUME Current Vel. ft/sec	PLUME Dif. Coef.[c] ft^2/sec	Remarks
8- 8-68	Newport	10.2	4	NE	10-20	5,550	100	4600	15	0.26	----	
8-14-68	Newport	6.0	4-6	SW	5-10	7,600	---	3400	21	--	----	No photography
8-16-68	Newport	6.3	6-8	SW	10-15	7,550	142	7000	23	0.42	2.0	
8-21-68	Newport	8.1	8-10	SW	0-5	7,400	---	7500	20	--	----	
9-10-68	Newport	6.8	1-2	--	0	7,450	0	--	--	0.0	----	Plume submerged
9-11-68	Newport	6.8	1-2	E	0-5	8,950	0	--	--	--	----	Plume submerged
9-12-68	Newport[e]	6.5	1-2	E	0-5	6,750	0	--	--	0.0	----	Plume submerged
9-12-68	Newport[f]	6.5	4-6	NW	15-20	6,750	---	3000	10	--	----	d
6-30-69	Newport	11.5	1-2	N	5-10	8,100	0	--	--	--	----	Plume submerged
7- 1-69	Newport	11.3	2-4	NW	4-5	8,100	0	--	--	0.06	----	Plume submerged
7- 7-69	Newport	6.4	4-6	N	5-12	9,000	5	--	--	0.4	----	Plume submerged
7- 8-69	Newport	7.7	4-6	N	6-15	9,000	93	5500	10	0.5	14.0	
7-15-69	Gardiner	8.0	4	NW	10-18	10,300	---	--	--	--	----	Equipment trouble
7-16-69	Gardiner	7.8	2-3	NW	10-18	10,000	103	4000	23	0.26	----	
8- 6-69	Samoa	5.5	3-4	NW	5-10	18,600	155	8000	18	0.45	2.1	
8- 7-69	Samoa	5.8	3-4	NW	5-10	16,500	---	8000	18	0.50	----	
8-12-69	Newport	8.4	2-3	W	3-5	8,300	127	4000	10	0.1	----	
8-19-69	Gardiner	6.1	4-5	W	0-5	10,100	123	2500	22	0.1	----	
8-20-69	Gardiner	6.5	4-5	W	0-5	7,500	87	2400	22	0.13	----	
9- 8-69	Newport	7.2	4	SW	5	8,400	39	2000	10	0.2	----	

a Maximum difference between adjacent high and low tides during the day.

b Area within the plume with concentrations greater than 2 ml/L.

c Steady state diffusion coefficient.

d Vertical photography not processed because of sunlight reflection.

e a.m.

f p.m.

the same on this day as it was on the days when the plume was submerged under nearly similar conditions. Possibly the offshore thermocline was deep and the dense subsurface water was not available to form density stratification in the outfall area.

Observations were made at Newport when the river flow was low. During the winter and spring when the wind is predominately from the southwest and the fresh water flow from the Yaquina River is high, there may be an increased tendency for density stratification to form over the outfall. There is also indication that the tidal range affects the density stratification and area of the surface plume, but sufficient observations for verification are not available.[1]

Subsurface plumes are believed less likely to occur at Gardiner and Samoa since they are located on the open coast. Newport outfall has the offshore reef which would tend to reduce the turbulence and mixing below the level of the reef.

The most foam was observed on September 10, 1968 and August 12, 1969. Both days were calm with a submerged plume on September 10 and a surface plume on August 12. On September 11, 1968, July 7 and July 8, 1969, and September 8, 1969, foam was observed. Except for July 8th, when the sea surface was choppy, these days were relatively calm. The foaming tendency may also be caused by a change in the composition of the waste. The primary source of foam did not appear to be caused by wind turbulence in the waste field, but rather the foam appeared to be mainly generated in the boil over the outfall.

When the current velocity is low in the receiving water, the initial width of the plume is greater than the width of the diffuser section of the outfall. On August 16, 1968 and July 8, 1969 at Newport and August 6 and 7, 1969 at Samoa, the current velocity was greater than 0.4 ft/sec and the initial plume width was about the same as the diffuser section of the outfall. On August 8, 1968 at Newport and July 16, 1969 at Gardiner, the current velocity was 0.26 ft/sec and the initial width of the plume was wider than the diffuser section with a ridge of high waste concentration near the outer edge of the plume. At current velocities less than about 0.2 ft/sec surface spreading caused by the hydraulic head from the effluent discharge appeared to be primarily responsible for the width of the plume. Diffusion coefficients are listed in Table 11 for only three days, since the model used in the diffusion computations and explained in Appendix E, would only be applicable to these situations.

The tide influences the flow patterns in the receiving water. The high flood and ebb currents at the river mouth tend to draw water from the adjacent ocean. Since the outfalls observed in this study were located several miles north of a river mouth, the effect of the tide was reduced and the wind generally provided the major driving force for water movement.

[1] Personal communication with Mr. P. O'Hara of the Georgia Pacific Corp. Toledo, Oregon.

The area of the waste field listed in Table 11 is the area where the concentrations were computed from the aerial photography as being greater than 2 ml/L or 0.2% waste. Normally from the photography, the plume can be distinguished from the open sea at concentrations greater than 0.4 ml/L. However, surface foam on July 8, August 12, and September 9 caused interference with the aerial photography. In the processing of the data, voltage ranges on the photo densitometer output were set and concentrations were not determined for points where the densitometer voltage was outside this range. Values for these points were obtained by interpolating from adjacent points. The infrared band was the most sensitive for this purpose. The area covered by the densitometer aperture could contain a small amount of surface foam and the value would not be rejected. Some scatter can be seen along the right side of the plumes shown on the symbolic plots in Figure 24 where there was a foam streak as can be seen from the photos of the plume in Figures 21 and 22. A summary of the aerial photography is listed in appendix F.

SECTION IX

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SECTION X

REFERENCES

1. Alderdine, D.F. and J.R. Brett. 1957. Some effects of kraft mill effluent on young pacific salmon. *Journal of the Fisheries Research Board of Canada.* 14:783-795.

2. Allen Hancock Foundation. 1964. An investigation on the fate of organic and inorganic wastes discharged into the marine environment and their effects on biological productivity. Los Angeles, University of Southern California. 118 p. (*California State Water Quality Control Board Publication 29.*)

3. Baumgartner, D.J., W.P. James, and G.L. O'Neal. 1969. A study of two ocean outfalls. *National Council for Air and Stream Improvement Technical Bulletin No. 231.* p 27-53.

4. Brooks, Norman H. 1960. Diffusion of sewage effluent in an ocean current. *Proceedings of the First International Conference on Waste Disposal in Marine Environment*, London, Pergamon Press. p. 246-267.

5. Burgess, F.J. and W.P. James. 1969. Airphoto analysis of ocean outfall dispersion. *Federal Water Pollution Control Administration Progress Report on Research Grant WP 01383.* April. 100 p.

6. Courtright, R.C. and C.E. Bond. 1969. Potential toxicity of kraft mill effluent after oceanic discharge. *The Progressive Fish-Culturist*, October, p. 207-212.

7. Howard, R.E. and C.C. Walden. 1965. Pollution and toxicity characteristics of kraft pulp mill effluents. *TAPPI.* 48:136-141.

8. Masch, F.D. 1961. Mixing and dispersive action of wind waves. Berkeley, University of California, *IER Technical Report 138-6.*

9. O'Neal, G.L. 1966. The degradation of kraft pulping waste in estuarine waters. Doctoral dissertation. Corvallis, Oregon State University. 125 numb. leaves.

10. Parrish, L.P. 1966. The predicted influence of kraft mill effluent on the distribution of some sport fishes in Yaquina Bay, Oregon. M.S. Thesis, Corvallis, Oregon State University. 99 numb. leaves.

11. Rawn, A.M., F.R. Boweman, and N.H. Brooks. 1960. Diffusers for disposal of sewage in sea water. *Journal of Sanitary Engineering Division*, American Society of Civil Engineers. 86 (2): 65-105.

12. Sprague, J.B. and D.W. McLeese. 1968. Different toxic mechanisms in kraft pulp mill effluent for two aquatic animals. *Water Research*, London, Pergamon Press. 2:761-765.

13. Stanford, R. 1969. *Lockwood's directory of the paper and allied trades*. New York, Lockwood Publishing Company, Inc. 1700 p.

14. Washington State Department of Fisheries. 1960. Toxic effects of organic and inorganic pollutants on young salmon and trout. *Research Bulletin No. 5*. 264 p.

15. Wiegal, R.L. 1964. *Oceanographical Engineering*. London, Prentice Hall International. 432 p.

SECTION XI

PUBLICATIONS

1. Burgess, F.J. and W.P. James. 1970. Monitoring and evaluation of pulp mill ocean outfalls by aerial photogrammetry. The article is to be released in the September issue of *Pulp and Paper*.

2. Courtright, R.C. and C.E. Bond. 1969. Potential toxicity of kraft mill effluent after oceanic discharge. *The Progressive Fish-Culturist*, October. p. 207-212.

3. Hansen, S.P. and F.J. Burgess, 1968. Carbon treatment of kraft mill condensate waste. *TAPPI*, 51: 241-246.

4. James, W.P. and F.J. Burgess. 1969. The use of photogrammetry in predicting outfall diffusion. *National Council for Air and Stream Improvement Technical Bulletin No. 231*. p. 2-26.

5. James, W.P. and F.J. Burgess. 1970. Pulp mill outfall analysis by remote sensing techniques. *Seventh Water and Air Conference Proceedings of TAPPI*, Minneapolis. p. 131-150.

SECTION XII

APPENDICES

APPENDIX A

SHORE CONTROL

Control surveys were conducted at Newport, Oregon, Gardiner, Oregon and Samoa, California. These surveys provided control for both the aerial photograph and the boat sampling. Figure A-1 shows the location of the beach traverse at Newport. The traverse extended between two coast and geodetic survey stations, Life on the south and Yaquina Head Lighthouse on the north. Angles along the seven-mile traverse were measured with a Wild T-3 theodolite while the distances were measured with the telurometer. The unadjusted state plane coordinates are listed in Table A-1. A closure of 1:21,000 shows the excellent quality of the survey work.

Table A-1. Beach survey at Newport, Oregon.

Station	Grid Distance Feet	Grid Azimuth From North ° ' "	Oregon North Zone State Plane Coordinates X	Y
LIFE C&GS			(1,071,316.29)	(356,348.11)
	49.99	7 02 57		
ECC 1 a			1,071,322.42	356,397.72
	10,344.61	357 46 58		
JET a			1,070,922.19	366,734.59
	7,510.12	15 39 39		
FALL a			1,072,949.50	373,965.91
	3,246.27	11 40 05		
JOE a			1,073,606.03	377,145.10
	4,253.66	16 36 02		
DOC a			1,074,821.29	381,221.47
	9,249.07	325 31 07		
ECC 2 a			1,069,585.04	388,845.57
	89.86	321 35 29		
CAP			1,069,529.21	388,915.88
YAQUINA HEAD LIGHTHOUSE C&GS			(1,069,529.52)	(388,914.28)

Closure 1:21,000

a - stations marked with 3/4-inch by 30 inch steel rods.

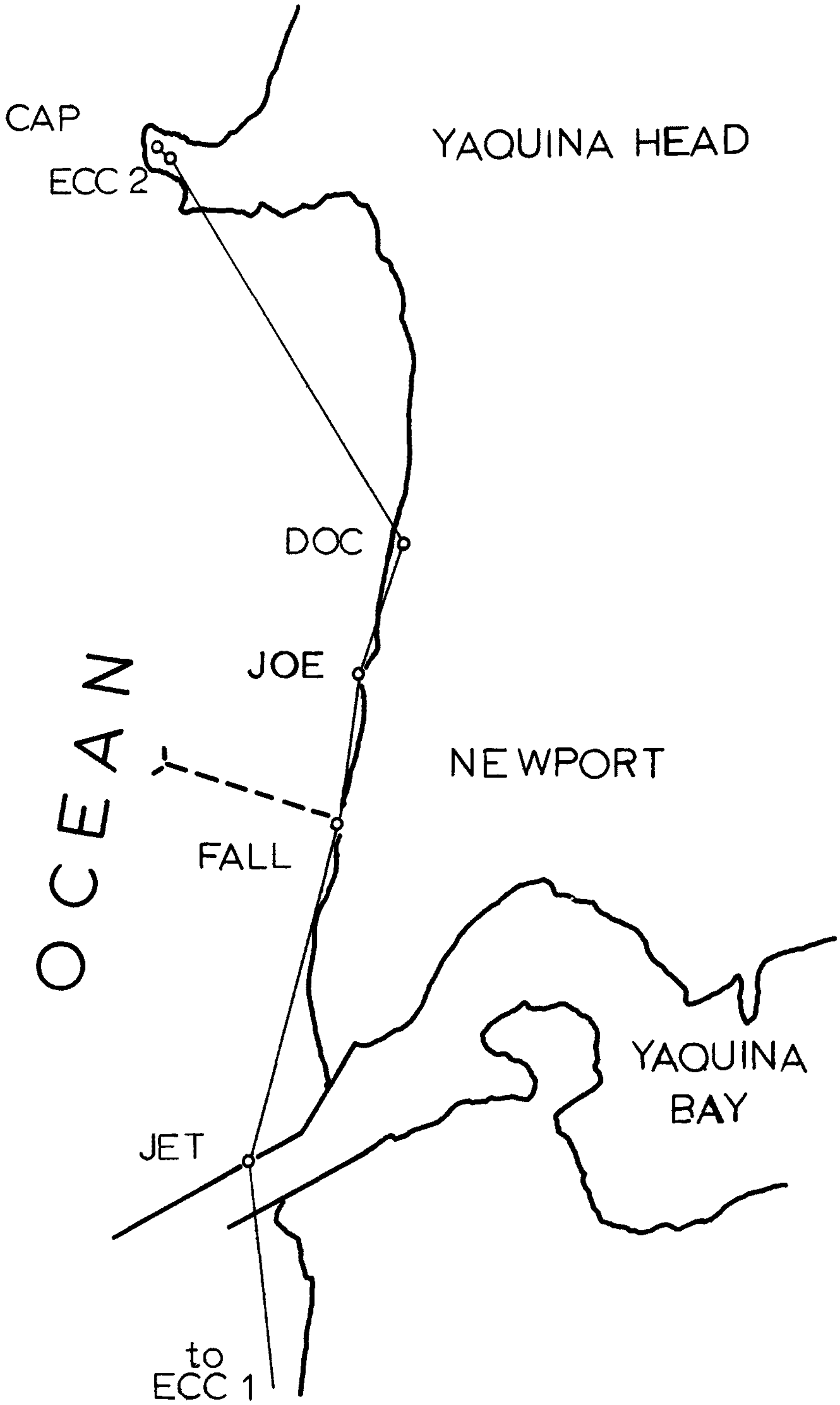


Figure A-1. Beach survey at Newport, Oregon.

The established stations were marked with cloth for photo identification. A typical shore control station while boat sampling was in progress is shown in Figure A-2. The tripod signal in the foreground was used to sight the station from the boat. For some of the preliminary survey work at Newport, the boats position was determined by three-point sextant fixes from the vessel. However, because of difficulty in training the crew, this method of boat positioning was replaced by shore triangulation.

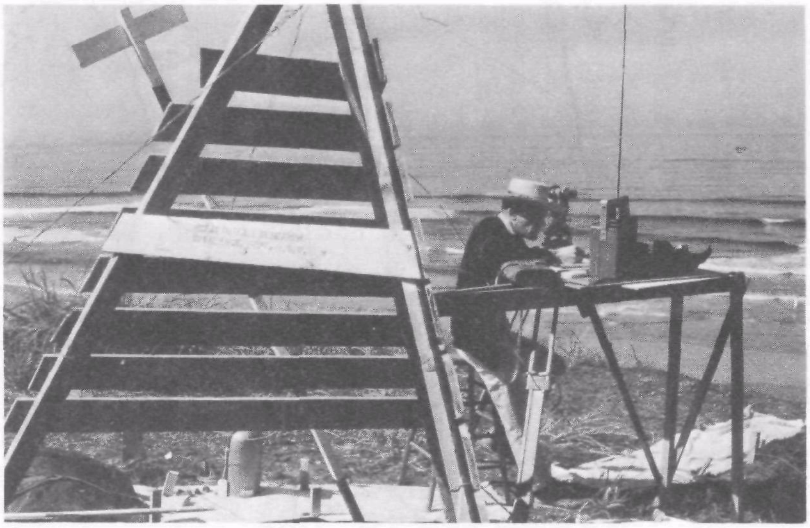


Figure A-2. Shore station.

The survey near Gardiner was conducted between two Oregon State Highway stations. The location of this survey is shown in Figure A-3. Coast and geodetic survey stations are in the vicinity of the outfall but since this is a sand dune area the station markers were not found. Results of the survey are tabulated in Table A-2.

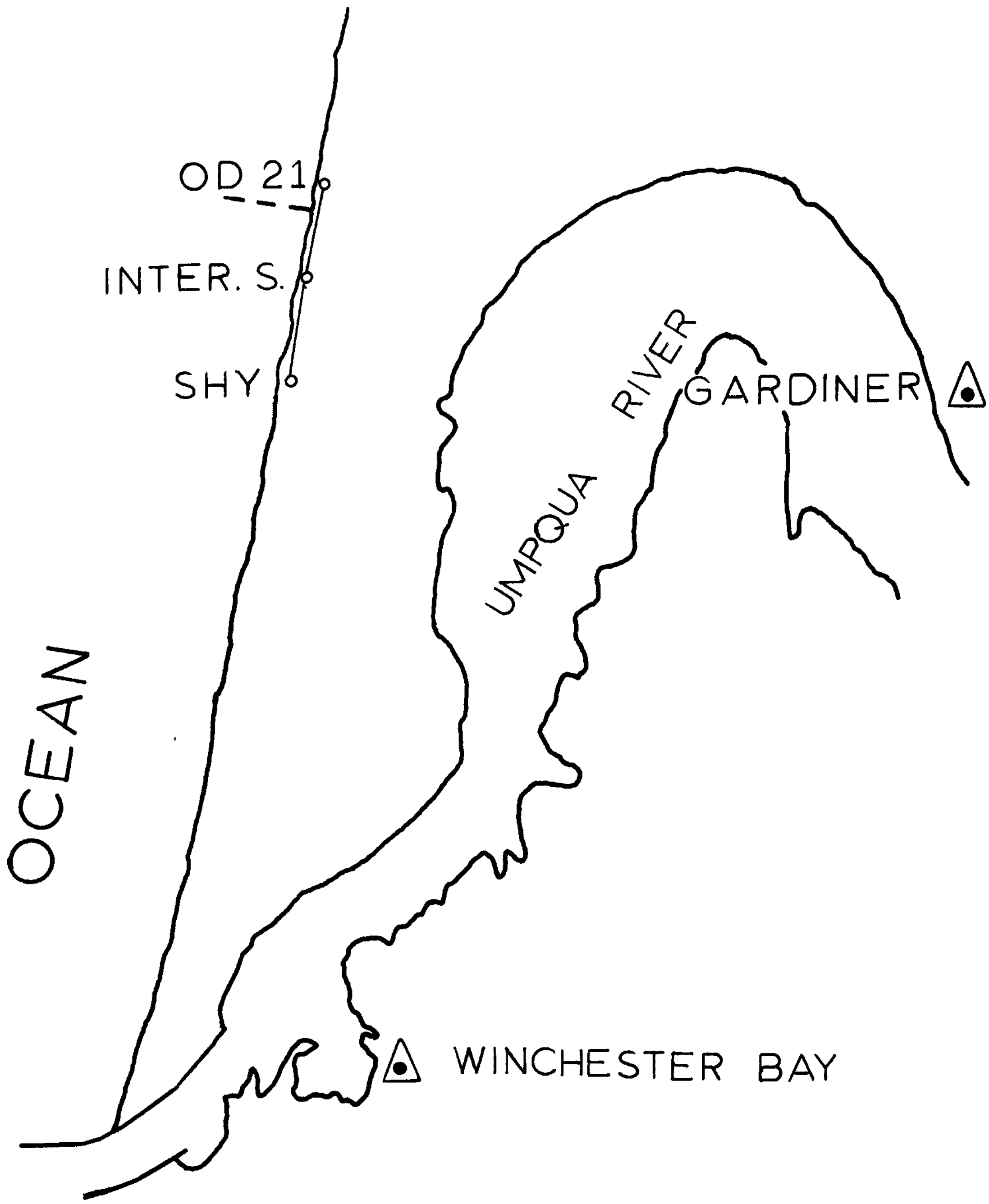


Figure A-3. Beach survey at Gardiner, Oregon.

Table A-2. Beach survey at Gardiner, Oregon.

Station	Grid Distance Feet	Grid Azimuth From North °	'	"	Oregon South Zone State Plane Coordinates X	Y
LAW						
		14	51	47		
SHY					(1,026,670.82)	(774,841.37)
OSH	3,054.62	13	23	10		
INTER.S. a					1,027,378.00	777,813.00
	2,835.73	13	39	11		
O.D. 21					1,028,047.35	780,568.60
O.D. 21 OSH					(1,028,047.06)	(780,568.31)

Closure 1:14,000

a - station marked with 1/2-inch by 60 inch steel rod.

The survey conducted at Samoa between two coast and geodetic survey stations is shown in Figure A-4. Station SAMOA 2 was reported destroyed previously but was found covered with three feet of sand. The traverse extended 2.1 miles between SAMOA 2 on the north and JOHN RM1 on the south. Station JOHN apparently has been destroyed but its reference mark no. 1 was recovered in good condition. Distances along the traverse were measured with the geodimeter. The closure for the survey listed in Table A-3 is better than that required for first order work.

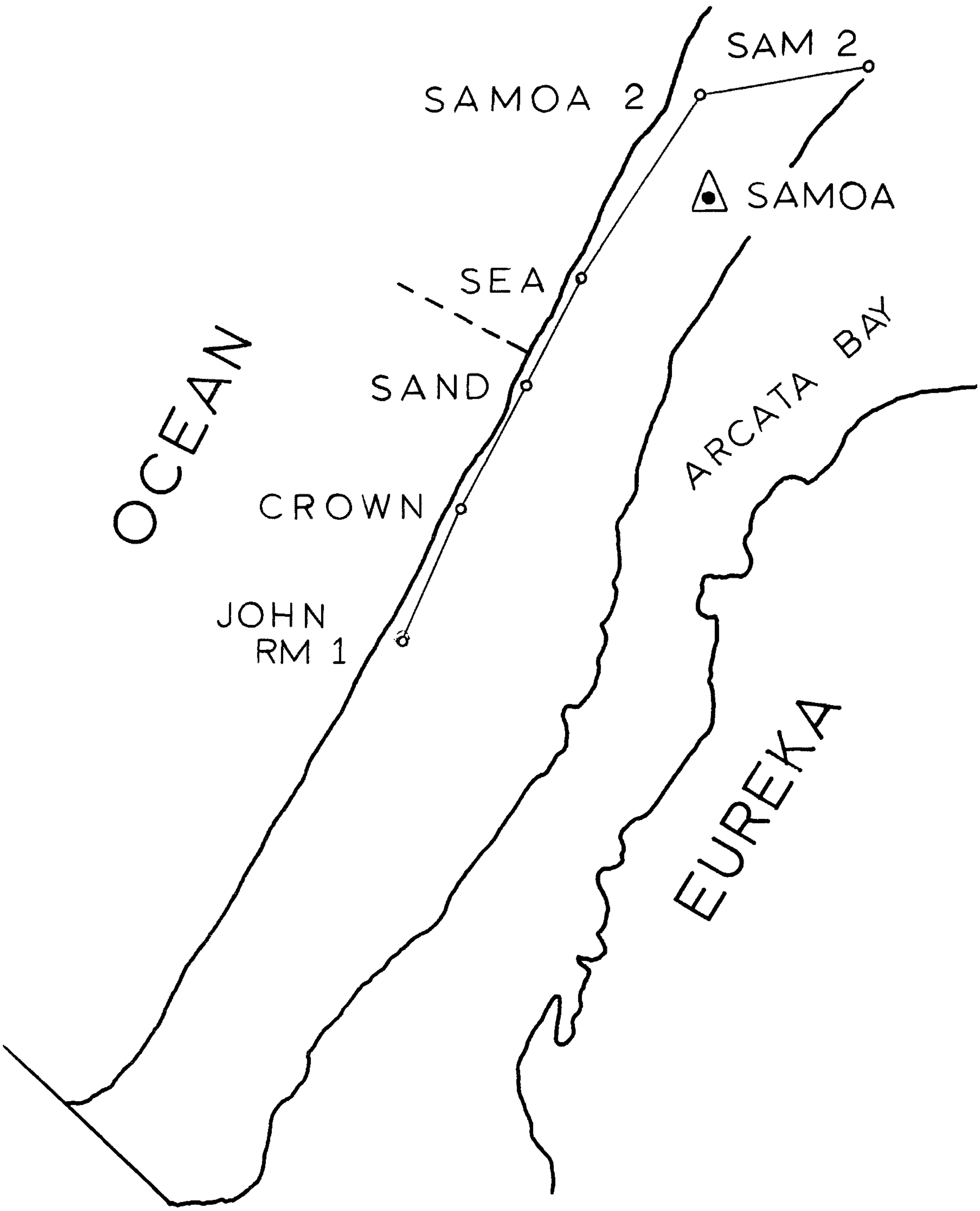


Figure A-4. Beach survey at Samoa, California.

Table A-3. Beach survey at Samoa, California.

Station	Grid Distance Feet	Grid Azimuth From North	California Zone 1 State Plane Coordinates X	Y
		° ' "		
SAM 2 C&GS				
		282 42 40		
SAMOA 2			(550, 067. 76)	(1, 395, 048. 96)
C&GS	4, 308. 80	216 31 47		
SEA a			546, 605. 43	1, 392, 484. 19
	2, 396. 39	208 48 30		
SAND a			544, 505. 63	1, 391, 329. 42
	2, 804. 25	209 53 39		
CROWN a			542, 074. 49	1, 389, 931. 78
	3, 141. 99	201 08 23		
JOHN RM1			539, 143. 94	1, 388, 798. 64
JOHN RM1 C&GS			(539, 144. 13)	(1, 388, 798. 43)

Closure 1:44, 000

a - stations marked with 3/4-inch steel pipe 60 inches long.

APPENDIX B

FLUOROMETER SAMPLING PROBE

During the 1968 field season tracer concentrations were measured in the waste field using two continuous flow fluorometers as shown in Figure B-1. In take ports for the instruments were along the leading edge of the five-foot keel of a six-foot long towed vessel. The vessel was constructed of fiber-glassed floatation foam and was towed eight feet off the beam of the survey boat. By a valve arrangement aboard the survey launch, the sampling depth for one fluorometer could be selected at either one-half foot or one foot below the water surface and the sampling depth for the other fluorometer was either at two feet or five feet below the surface. The fluorometer readings were continuously recorded by chart recorders. Generally the sampling depths were at one foot and five feet. A comparison of concentrations at these two sampling depths did not show any appreciable difference and indicated that the sampling device was inadequate to reach the lower limits of the waste plume.

A ten-foot sampling probe was constructed for the 1969 field season. This probe is shown mounted aboard the Humbolt State College research vessel Sea Gull in Figure B-2. The probe is attached on the starboard rail and the end of the probe is setting on the aft deck in a travelling position. The probe was designed to hang vertically at five knots. As it has a mechanical feed-back steering device, it is stable at higher speeds and through normal maneuvers. Drawings of the probe are shown in Figure B-3 through B-7.

Figure B-1. Fluorometers aboard the Paiute at Newport, Oregon.

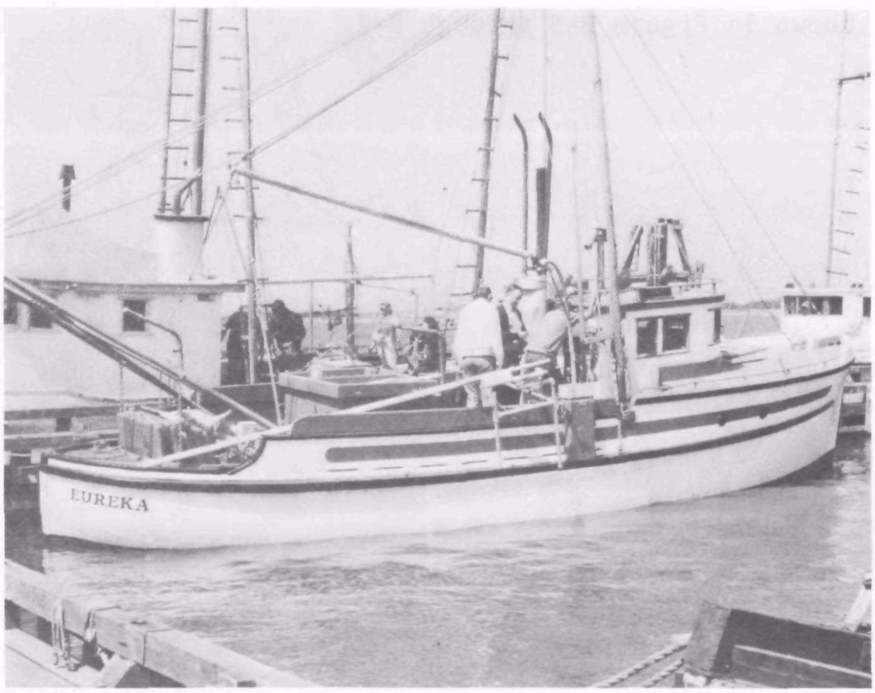


Figure B-2. Side view of the probe at Eureka, California.

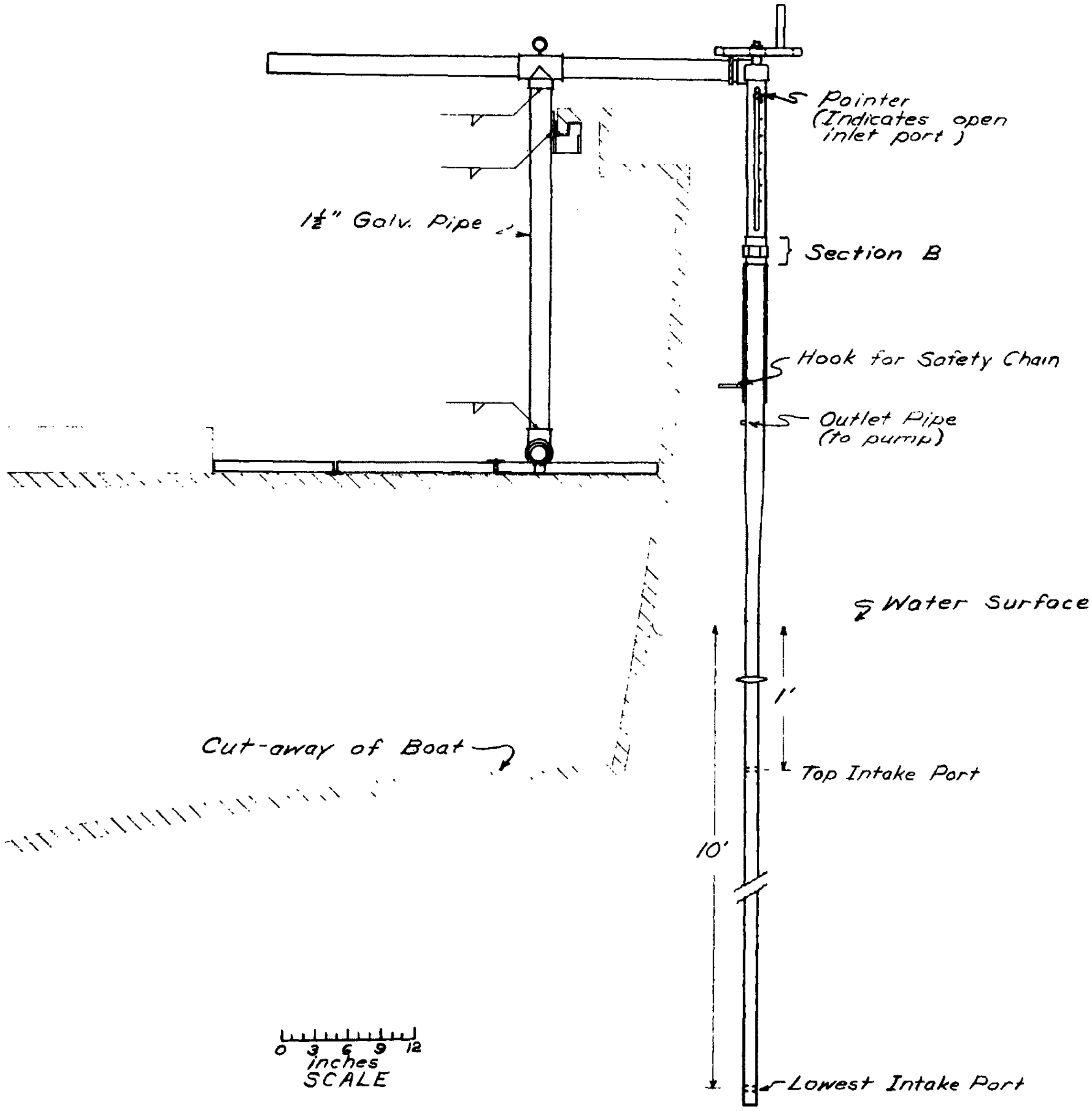


Figure B-3. Rear view of probe mounted on boat.

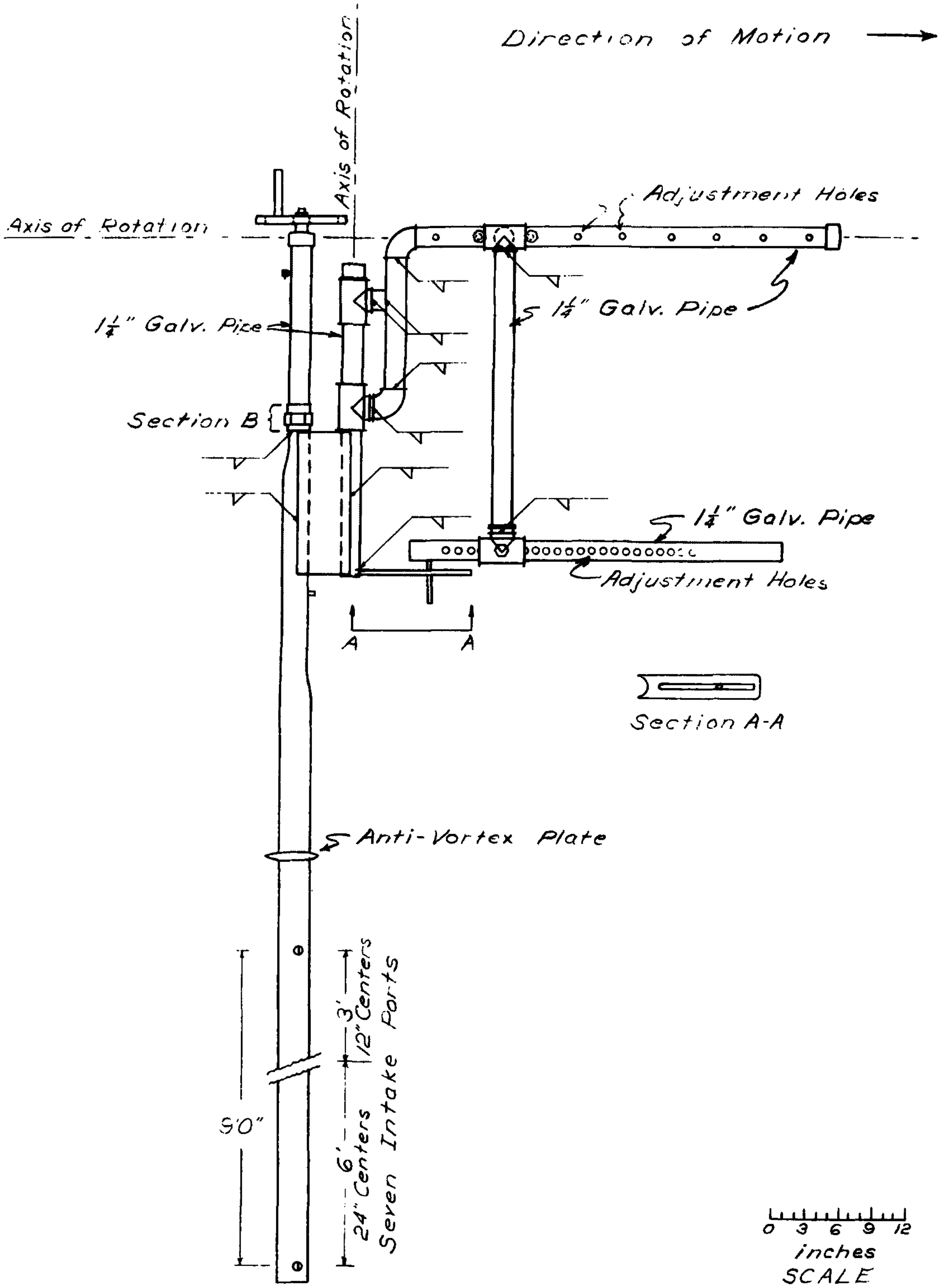
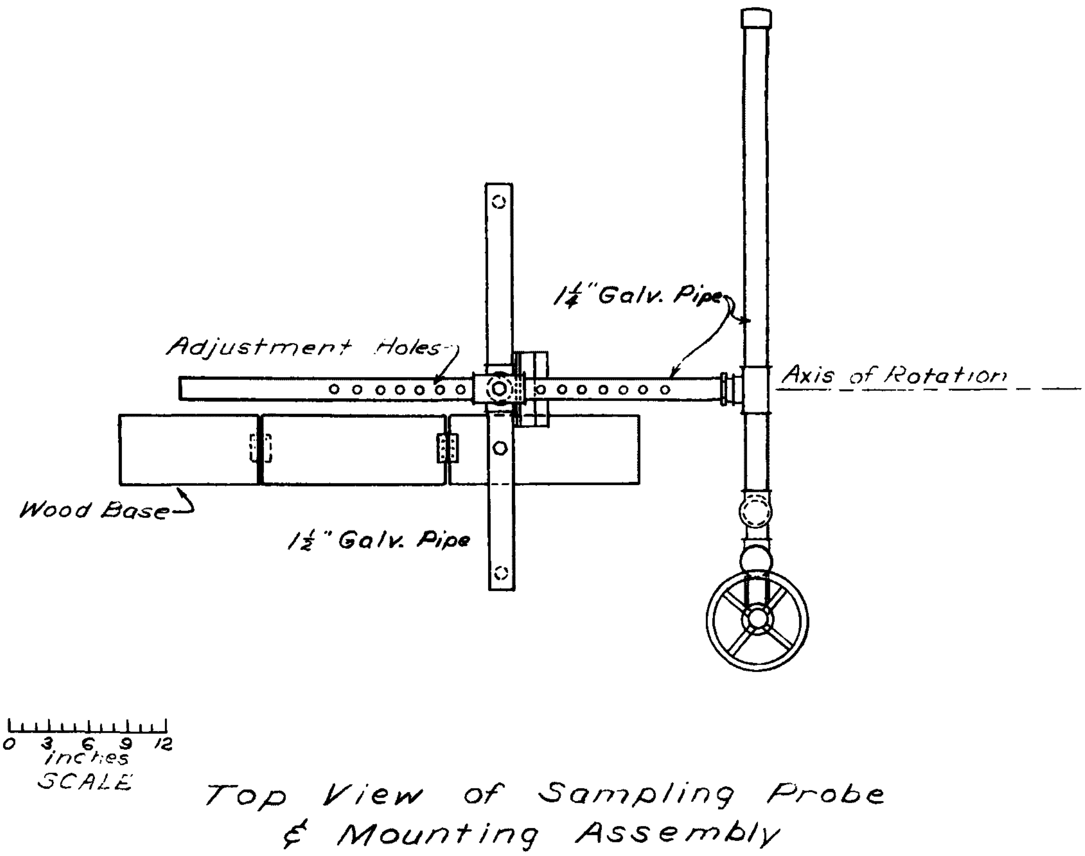


Figure B-4. Side view of probe.



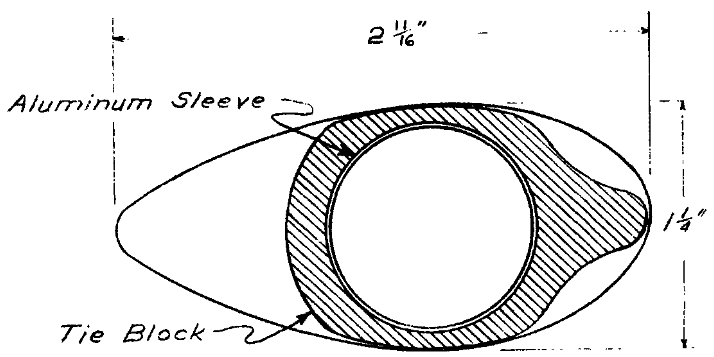


Figure B-5. Top and bottom view of probe.

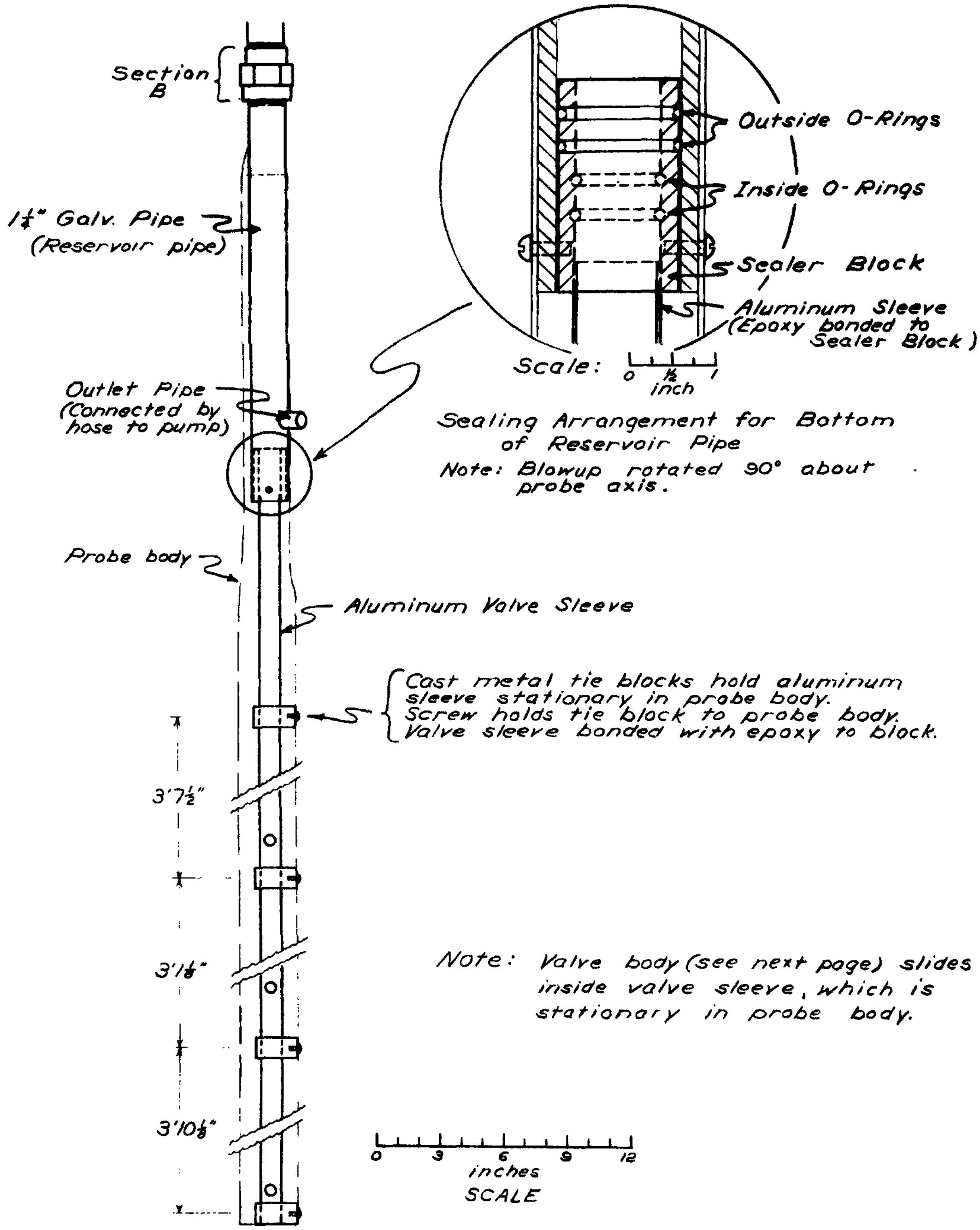


Figure B-6. Probe body details.

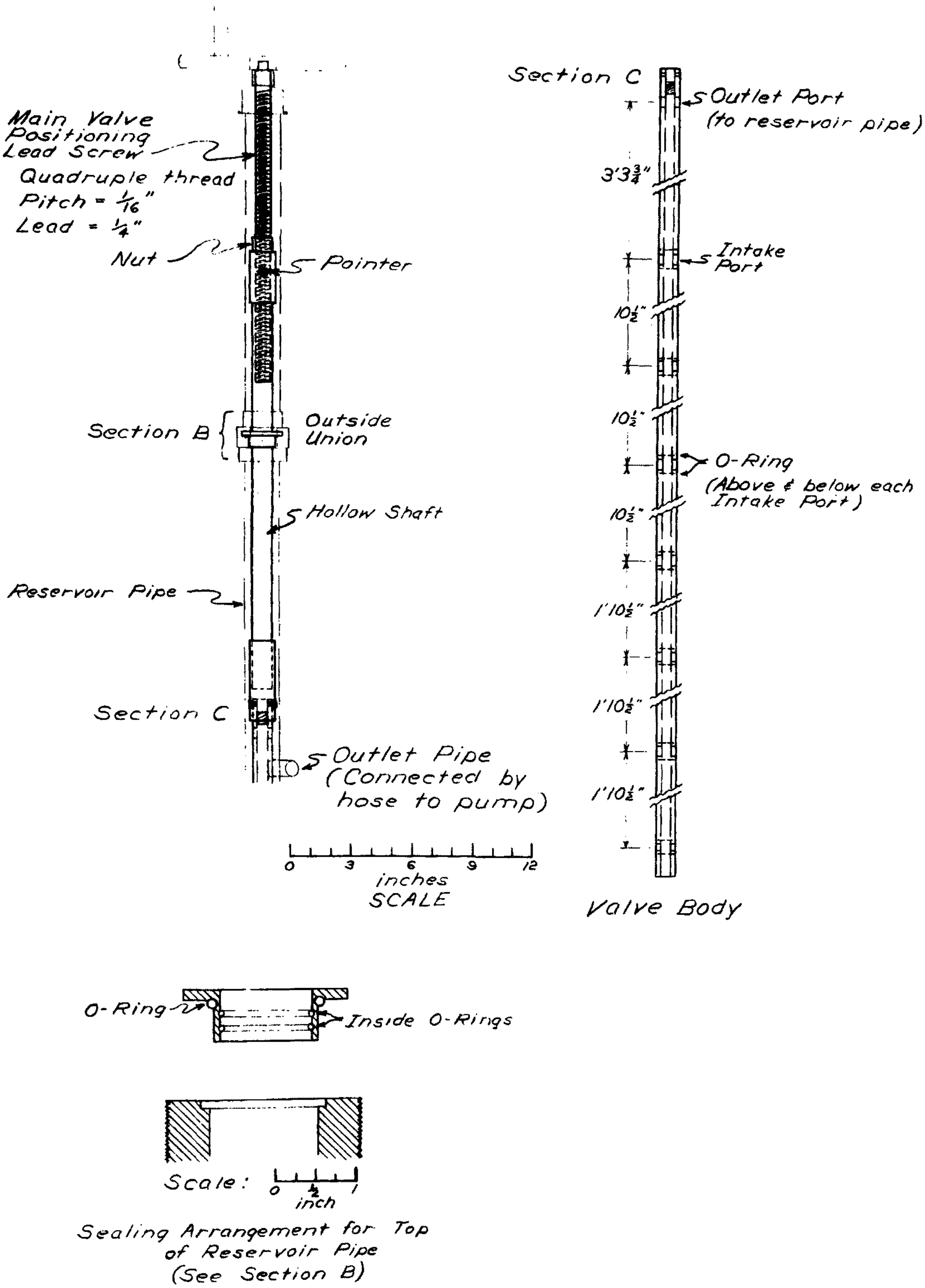


Figure B-7. Valve body.

APPENDIX C

REDUCTION OF BOAT SAMPLING DATA

Included in this appendix is the program listing of the computer program used to reduce the temperature and fluorometer data from the boat survey along with the instructions necessary for digitizing the strip chart records. The program was written for the CDC 3300 system in fortran IV language.

Input data for the program is either from a logical unit number (LUN) or from the teletype keyboard. The input statements include standard READ statement, FFIN(NO), TTYIN (4H X =). The free form input (FFIN) will accept data in any format from columns 1 through 72 as long as the words are separated by at least one space. The number in parentheses with the call command is the input LUN number. The teletype free form input command (TTYIN) allows the user to enter data from the teletype. The parameter in the TTYIN function is hollerith constant containing four characters. When the fortran statement is executed, the hollerith message is printed on the users teletype. Only a single variable can be entered each time the function is executed.

The main program called Boatdata (lines 1-82 of the listing) calls subroutines Readcord, Bcontrol and Concen. Subroutine Readcord (lines 83-196) converts the digitized strip chart data on LUN 1 to chart readings and writes the readings on LUN 2 according to the format listed on line 188. Subroutine Bcontrol (lines 188-313) reads from LUN 3 the angle and distance from the boat's mast to the sample intake ports (lines 203-204) coordinates of the shore station (lines 206-209), and the shore angles to the boat, buoys, or initial angles according to the code listed on lines 224-225. The subroutine writes the coordinates of the sample probe on LUN 4 along with the fix number and other positions (fixed sampling station, buoys, floats) on LUN 20.

Before the main program calls subroutine Concen, it reads from the teletype values of the effluent flow rate, dye injection ratio, time delay for sample to reach the instrument and data code as shown on lines 43-50. Subroutine Concen (lines 314-359) calls subroutine Fluoro if a fluorometer record is being processed, reads the chart readings from LUN 2 and computes either waste concentration in milliliters per liter, dye concentration in parts per billion or the water temperature depending on the value of the branching code as explained on line 47 of the main program. Output from the subroutine is written on LUN 6 according to the format list on line 351.

Subroutine Fluoro reads the fluorometer standardization data as explained by the comments in lines 371-381 of the listing and calls subroutine Leastfit which determines the least square estimate for the parameters in the model.

$$Y = B_0 + B_1 X + B_2 X^2 + e \tag{1}$$

or in matrix notation

$$\underline{Y} = X \underline{B} \tag{2}$$

where Y is the dye concentration in PPB, X is the scale reading and the B's are the coefficients. Solution to equation 2 is

$$\underline{B} = (X'X)^{-1} \underline{Y} \tag{3}$$

Subroutine Leastfit (lines 400-442) computes the X'X matrix, calls Matinv (lines 443-510) which computes $(X'X)^{-1}$ and then computes the B vector as shown in equation 3. Once the values of the parameters are estimated in equation 1, the concentrations can be computed in line 345 of subroutine Concen.

The main program then reads the fix numbers and concentrations or temperature from LUN 6, determines the coordinates of the sampling point from the data on LUN 4 and writes the coordinates and concentration or temperature on LUN 8 (lines 55-80).

Considerable savings in time resulted from digitizing the strip chart records with the coordinatograph rather than by hand scaling and coding. The following procedure was used to reduce the fluorometer and surface water temperature chart records to digital data.

The Rustrak strip chart was taped to the Kelsh plotter table with the longitudinal axis of the chart being approximately straight and approximately parallel to the X-axis. The X coordinate increasing with time and the Y coordinate increasing with the chart reading. The X and Y coordinates were measured with the Autotrol coordinatograph and punched on computer cards. First, the chart's longitudinal and transverse scales were digitized for calibration of the curve readings, next, the coordinates of the trace were recorded.

Each card contained constant data and three sets of event numbers, X,Y, & Z coordinates. The constant data in the first five columns was as follows:

Column 1	Month (one digit)
Columns 2 & 3	Day (two digits)
Column 4	Run number (either 1 or 2)
Column 5	Codes 1-4 Fluorometer
	5-8 Temperature

CODE

1 or 5	The X and Y coordinates are measured on the chart's zero reading at each consecutive fix (marked or unmarked). The event number is equal to the fix number. This information is used to interpolate the fix number and the zero scale when computing the readings.
2 or 6	The X and Y coordinates are measured at the chart's 0, 10, 20, 30, ..., 100 for the first fix number. The event number times ten is equal to the scale reading for the fluorometer trace and the event number times a half for the temperature trace as full scale is five degrees.
4 or 8	X and Y coordinates were measured along the trace at intervals as required to define the curve but not greater than one inch. For the fluorometer record, the first two digits of the Z coordinate represent the scale (1, 3, 10, or 30) while the last two digits of the Z coordinate represent the sampling depth. When reducing the temperature record, the first two digits of the Z represent the zero scale temperature (0,5, 10, 15, or 20°C). As the temperature probe was always one foot below the water surface, the depth was not indicated on the Z coordinate.

The event number is significant only when tracing about the chart for calibration (when the code in column five is one, two, or three for a fluorometer trace or five, six or seven for the temperature trace). The scale and sample depth need to be listed only when tracing the curve (code is either four or eight). Each card includes the constant data, event numbers, X & Y coordinates, scale and depth for up to three points according to the format listed on line 102 of the program listing.

```
      PROGRAM BOATDATA
C     THIS PROGRAM PROCESSES BOAT DATA.  INPUT IS THE
C     STRIP CHART RECORD FROM THE DIGITIZER ON LUN 1 AND THE
C     SHORE ANGLES ON LUN 3.  IF THE STRIP CHART HAS NOT BEEN
C     DIGITIZED, HAVE THE CHART READINGS ON LUN 2. THE FOLLOWING
C     LUNS ARE USED IN THE PROGRAM9
C     1      INPUT DIGITIZER STRIP CHART RECORD.  LUN MUST BE
C            EQUIPPED BEFORE RUNNING IF USING DIGITIZED CHART
C     2      OUTPUT CHART READINGS. IF CHART READINGS ARE
C            TO BE COMPUTED THE LUN IS EQUIPPED IN SUB READCORD
C     3      INPUT SHORE ANGLES.  LUN MUST BE EQUIPPED BEFORE
C            RUNNING IF BOAT COORD ARE TO BE COMPUTED
C     4      OUTPUT BOAT COORDINATES.  IF BOAT COORD ARE
C            COMPUTED THE LUN IS EQUIPPED IN SUB BCONTROL
C     5      INPUT OF FLUOROMETER STANDARDIZATION DATA. LUN
C            MUST BE EQUIPPED PRIOR TO RUNNING
C     6      OUTPUT WASTE CONCENTRATION ML/L,DYE CONCENTRATION
C            IN PPB,OR TEMPERATURE IN DEGREES C.
C            THE LUN IS EQUIPPED IN SUB CONCEN
C     8      OUTPUT IS X,Y STATE PLANE COORDINATES AND MATCHING
C            CONCENTRATION OR TEMP.  LUN EQUIPPED IN PROGRAM
C     20     COORDINATES OF BUOYS, FLOATS, OR SAMPLING STATIONS
C            LUN EQUIPPED IN SUB BCONTROL
C     22     FLUOROMETER CALIBRATION CURVES. LUN EQUIPPED IN
C            SUB FLUORO.
      DIMENSION XS(2,400)
      INTEGER HARDWARE
      IF (HARDWARE(1) .EQ. 1) 5,6
    5 CALL READCORD
    6 IF (HARDWARE(3) .EQ. 1) 7,8
    7 CALL BCONTROL
    8 DO 10 I=1,2
      DO 10 J=1,400
      XS(I,J)=0.0
   10 CONTINUE
      REWIND 4
   20 READ(4,1) IFIX,X,Y
    1 FORMAT(5X,I4,2F9.0)
      IF (EOD(4)) GO TO 50
      XS(1,IFIX)=X
      XS(2,IFIX)=Y
      GO TO 20
   50 WRITE(61,2)
    2 FORMAT(' TTYIN EFFLUENT FLOW RATE IN GPM'/,
     1 ' DYE INJECTION RATE IN ML PER MIN'/,
     2 ' TIME DELAY FOR SAMPLE TO REACH INSTRUMENT IN MIN'/,
     3 ' LUG 1 FOR CONTINUOUS, 2 FOR SLUG OR 3 FOR TEMP')
      FLOW=TTYIN(4HGPM=)
      DYE=TTYIN(4HDYE=)
      DELAY=TTYIN(4HMIN=)
      LUG=TTYIN(4HLUG=)
      CALL CONCEN(LUG,FLOW,DYE,DELAY)
      CALL EQUIP(8,5HFILE )
      REWIND 6
   60 READ(6,3) MO,IDATE,FIX,DEP,CON
    3 FORMAT(2I3,3F8.3)
      IF (EOD(6)) GO TO 500
```

Figure C-1. Program listing.

```
      KFIX=FIX
      IF (XS(1,KFIX)-1.) 100,100,110
  100 JFIX=KFIX-1
      IF (XS(1,JFIX)-1.) 60,60,120
  110 KL=KFIX
      GO TO 130
  120 KL=JFIX
  130 IF (XS(1,KFIX+1)-1.) 150,150,140
  140 KH=KFIX+1
      GO TO 170
  150 IF (XS(1,KFIX+2)-1.) 60,60,160
  160 KH=KFIX+2
  170 TOP=KL
      TOP=FIX-TOP
      BOT=KH-KL
      RAT=TOP/BOT
      DIFX=XS(1,KH)-XS(1,KL)
      DIFY=XS(2,KH)-XS(2,KL)
      X=XS(1,KL)+DIFX*RAT
      Y=XS(2,KL)+DIFY*RAT
      WRITE(8,4) FIX,X,Y,CON,MO,IDATE
    4 FORMAT(F7.1,2F14.0,F10.1,2I5)
      GO TO 60
  500 STOP
      END
      SUBROUTINE READCORD
C     THIS SUBROUTINE WILL READ THE CARDS FROM THE DIGITIZED
C     STRIP CHART ON LUN 1 ' WRITE THE CHART READINGS
C     ON LUN 2. USE A BLANK LINE TO STOP READING ON LUN 1.
      DIMENSION  X(2,300),IVEN(3),CX(3),CY(3),JS(3),JD(3),
     1Y(2,12)
      REWIND 1
      CALL EQUIP(2,5HFILE )
C     CLEAR ARRAY
      DO  100  I=1,2
      DO  100  J=1,300
      X(I,J)=0.0
  100 CONTINUE
      IFLUO=1
      IGO=1
      IDO=1
  105 READ (01,1) MO,IDA,IRUN,ICODE,IVEN(1),CX(1),CY(1),JS(1)
     1,JD(1),IVEN(2),CX(2),CY(2),JS(2),JD(2),IVEN(3),CX(3),
     1CY(3),JS(3),JD(3)
    1 FORMAT(I1,I2,2I1,3(I4,2F6.3,2I3,1X))
      IF (EOD(1)) GO TO 1000
      GO TO (108,110), IGO
  108 IST=IVEN(1)
      GO TO 113
  110 IF (IDA-LIDA) 1000, 112, 1000
  112 IF (IRUN-LIRUN) 1000,113,1000
  113 LIRUN=IRUN
      IGO=2
      LIDA=IDA
C     DETERMINE NUMBER OF POINTS ON CARD
      ITEST=1
      DO 116  I=2,3
      IF (IVEN(I)) 1000,118,115
```

Figure C-1. Program listing (continued)

```
  115 ITEST=I
  116 CONTINUE
  118 GO TO (120,150,200,250,500), ICODE
C     STORE COORDINATES OF ZERO SCALE READINGS AND FIX NUMBERS
  120 DO 130 I=1, ITEST
      J=IVEN(I)
      IND=J
      X(1,J)=CX(I)
      X(2,J)=CY(I)
  130 CONTINUE
      GO TO 105
C     DETERMINE THE Y SCALE
  150 DO 160 I=1,ITEST
      J=IVEN(I)+1
      Y(1,J)=CY(I)
  160 CONTINUE
      GO TO 105
  200 DO 210 I=1,ITEST
      J=IVEN(I)+1
      Y(2,J)=CY(I)
  210 CONTINUE
      GO TO 105
  250 GO TO (252,260), IDO
C     AVERAGE THE Y SCALE AT EACH END OF THE RECORD
  252 DIF=Y(1,1)+Y(2,1)
      DO 254 J=1,11
      Y(1,J)=(Y(1,J)+Y(2,J)-DIF)/2
  254 CONTINUE
      IDO=2
  260 DO 280 I=1,ITEST
C     DETERMINE FIX NUMBER
      IF (CX(I) .LT. X(1,IST) .OR. CX(I) .GT. X(1,IND)) 280,262
  262 DO 265 J=IST,IND
      IF(CX(I)-X(1,J)) 266,263,264
  264 IFIX=J
  265 CONTINUE
      J=IND
      FIX=IND
      GO TO 267
  263 IFIX=J
      FIX=J
      FRA=0.0
      GO TO 267
  266 IF (J-IST) 367,367,368
  367 IFIX=IST
      FIX=IST
      FRA=0.0
      GO TO 267
  368 FRA=(CX(I)-X(1,IFIX))/(X(1,J)-X(1,IFIX))
      FIX=IFIX
      FIX=FIX+FRA
C     DETERMINE CHART READING
  267 DIF=X(2,J)-X(2,IFIX)
      YLOW=X(2,IFIX)+DIF*FRA
      YDIF=CY(I)-YLOW
      IREAD=1
      DO 270 J=1,11
      IF(YDIF-Y(1,J)) 272,272,268
```

Figure C-1. Program listing (continued)

```
  268 IREAD=J
  270 CONTINUE
      READ=99.99
      GO TO 273
  272 DIFT=YDIF-Y(1,IREAD)
      J=IREAD+1
      DIFB=Y(1,J)-Y(1,IREAD)
      FRA=DIFT/DIFB
      READ=IREAD
      READ=(READ-1.0+FRA)*10.
  273 IF (IRUN-3) 274,278,278
C     IRUN IS ZERO FOR FLUOROMETER RECORD
  274 IRUN=0
  278 WRITE (02,2) MO,IDA,FIX,IFLUO,JD(I),JS(I),READ,IRUN
    2 FORMAT (I3,I3,F6.2,3I5,F7.2,I3)
  280 CONTINUE
      GO TO 105
C     ICODE GREATER THAN 4 INDICATES TEMP RECORD
  500 ICODE=ICODE-4
      IRUN=IRUN+2
      GO TO 118
 1000 RETURN
      END
      SUBROUTINE BCONTROL
      REWIND 3
      CALL EQUIP(4,5HFILE )
      CALL EQUIP(20,5HFILE )
C     READ DIRECTION AND DISTANCE FROM BOAT MAST TO SAMPLER
C     PORTS
      AZSA=FFIN(3)/180.*3.1416
      DISS=FFIN(3)
C     READ COORDINATES OF SHORE STATIONS NORTHERN STATION FIRST
      XA=FFIN(3)
      YA=FFIN(3)
      XB=FFIN(3)
      YB=FFIN(3)
C     DETERMINE AZIMUTH AND DISTANCE BETWEEN SHORE STATIONS
      BY=(XA-XB)/(YA-YB)
      BY=ATAN(BY)
      AZA=BY+3.1416
      IF (BY) 20,30,30
   20 BY=6.2832+BY
   30 AZB=BY
      DAB=SQRT((XB-XA)**2+(YA-YB)**2)
      I=1
   10 READ(3,1)MO,DAY,FIX,A1,A2,A3,B1,B2,B3,ICODE
    1 FORMAT(I1,F2.0,2F3.0,2F2.0,F3.0,2F2.0,I1)
      IF (EOD(3)) GO TO 1000
      A1=(A1+A2/60.+A3/3600.)*3.1416/180.
      B1=(B1+B2/60.+B3/3600.)*3.1416/180.
C     ICODE 0 FLUOROMETER SAMPLING, 1 BUOY LOCATION, 2 CURRENT
C     FLOAT, 3 BOAT SAMPLE LOCATION, AND 4 INITIAL ANGLES.
      IF (ICODE-4) 100,50,10
   50 AIZ=A1
      BIZ=B1
      I=1
      GO TO 10
C    TEST IF ANGLES ARE ZERO
```

Figure C-1. Program listing (continued)

```
  100 A=A1-AIZ
      B=B1-BIZ
      IF (ABS(A)-0.02) 10,10,110
  110 IF (ABS(B)-0.02) 10,10,120
C     DETERMINE AZIMUTH TO OBJECT
  120 AZAC=A+AZA
      AZBC=B+AZB
      IF (AZAC) 130,140,140
  130 AZAC=6.2832+AZAC
  140 IF (AZAC-6.2832) 160,160,150
  150 AZAC=AZAC-6.2832
  160 IF(AZBC) 170,180,180
  170 AZBC=6.2832+AZBC
  180 IF (AZBC-6.2832) 200,200,190
  190 AZBC=AZBC-6.2832
C     DETERMINE THE INTERSECTION ANGLE
  200 A=ABS(AZAC-AZA)
      B=ABS(AZBC-AZB)
      IF (B-3.1416) 220,220,210
  210 B=6.2832-B
  220 C=3.1416-A-B
C     DETERMINE THE DISTANCE TO THE OBJECT
      DAC=DAB*SIN(B)/SIN(C)
      DBC=DAB*SIN(A)/SIN(C)
C     DETERMINE COORDINATES OF OBJECT
      XCA=XA+DAC*SIN(AZAC)
      YCA=YA+DAC*COS(AZAC)
      XCB=XB+DBC*SIN(AZBC)
      YCB=YB+DBC*COS(AZBC)
      IF (ABS(XCA-XCB)-5.) 240,240,230
  230 WRITE (61,2) FIX
    2 FORMAT('ERROR IN FIX',F5.1)
      GO TO 250
  240 IF (ABS(YCB-YCA)-5.) 250,250,230
  250 XC=(XCB+XCA)/2.0
      YC=(YCB+YCA)/2.0
      ICODE=ICODE+1
      GO TO (600,300,400,500),ICODE
  300 WRITE (20,3) MO,DAY,FIX,XC,YC
    3 FORMAT(I2,'/',F3.0,'    FIX',F4.0,'   BUOY   POSITION',
     12F9.0,'   CONTROL')
      I=1
      GO TO 10
  400 WRITE (20,4) MO,DAY,FIX,XC,YC
    4 FORMAT(I2,'/',F3.0,'    FIX',F4.0,'   FLOAT POSITION',
     12F9.0,'  CURRENT')
      I=1
      GO TO 10
  500 WRITE (20,5) MO,DAY,FIX,XC,YC
    5 FORMAT(I2,'/',F3.0,'    FIX',F4.0,'   BOAT   POSITION',
     12F9.0,'    SAMPLE')
      I=1
      GO TO 10
  600 IF (I-1) 1000,610,620
  610 XS=XC
      YS=YC
      GO TO 900
C     COMPUTE THE POSITION OF THE SAMPLER INTAKE PORTS
```

Figure C-1. Program listing (continued)

```
  620 DFIX=FIX-AFIX
      IF (DFIX-2.0) 625,610,610
  625 DY=YC-YL
      DX=XC-XL
      RAZ=ATAN(DX/DY)
      IF(DY) 660,630,630
  630 IF (DX) 640,700,700
  640 RAZ=6.2832+RAZ
      GO TO 700
  660 RAZ=RAZ+3.1416
  700 SAZ=RAZ+AZSA
      IF (SAZ-6.2832) 720,720,710
  710 SAZ=SAZ-6.2832
  720 XS=XC+DISS*SIN(SAZ)
      YS=YC+DISS*COS(SAZ)
  900 XL=XC
      YL=YC
      WRITE(04,6) MO,DAY,FIX,XS,YS
    6 FORMAT(I2,F3.0,F4.0,2F9.0)
      I=I+1
      AFIX=FIX
      GO TO 10
 1000 RETURN
      END
      SUBROUTINE CONCEN(LUG,FLOW,DYE,DELAY)
C     THIS SUBROTTINE DETERMINES THE WASTE CONCENTRATION IF
C     LUG=1 FOR CONTINUOUS DYE INJECTION IN ML/L, THE DYE
C     CONCENTRATION IN PPB FOR DYE PLUGS IF LUG = 2, OR THE
C     TEMPERATURE IN DEGREES C IF LUG=3.
      DIMENSION B(3,4,4)
      REWIND 2
      CALL EQUIP(6,5HFILE )
C     FLOW IS THE EFFLUENT FLOW RATE IN GPM, DYE IS THE 20= DYE
C     INJECTION RATE IN ML/MIN, DELAY IS THE TIME DELAY IN MIN.
C     FOR THE SAMPLE TO REACH THE INSTRUMENT PLUS CHART MARKING
C     SHIFT
      GO TO (12,10,100),LUG
   10 DILP=1.0
      GO TO 14
   12 DYE=DYE/(5.0*3785.)
      DILP=DYE/FLOW*10.**6
   14 CALL FLUORO(B)
  100 READ(02,1) MO,IDATE,FIX,IFLUO,DEP,ISCA,RED,ITEST
    1 FORMAT(I3,I3,F6.2,I5,F5.0,I5,F7.2,I3)
      IF (EOD(2)) GO TO 1000
      IF (ITEST) 100,200,500
  200 IF (ISCA-3) 210,220,230
  210 I=1
      GO TO 300
  220 I=2
      GO TO 300
  230 IF (ISCA-10) 220,240,250
  240 I=3
      GO TO 300
  250 I=4
  300 CON=B(IFLUO,I,1)+B(IFLUO,I,2)*RED+B(IFLUO,I,3)*RED*RED
      IF (CON) 310,320,320
  310 CON=0.0
```

Figure C-1. Program listing (continued)

```
  320 CON=CON/DILP
      FIX=FIX-DELAY
  330 WRITE(6,2) MO,IDATE,FIX,DEP,CON
    2 FORMAT(2I3,3F8.3)
      GO TO 100
C     TEMPERATURE FULL SCALE READING IS 5 DEGREES CENT.
  500 SCA=ISCA
      CON=SCA+RED/20.
      FIX=FIX-DELAY
      GO TO 330
 1000 RETURN
      END
      SUBROUTINE FLUORO(B)
      DIMENSION X(5,20),B(3,4,4),C(4)
C     LEAST SQUARE ESTIMATE OF FLUOROMETER STANDARDIZATION
C     CURVES.  READ INPUT ON LUN 5 AND WRITE ON LUN 22
      CALL EQUIP(22,5HFILE )
      REWIND 5
      DO 10 I=1,3
      DO 10 J=1,4
      DO 10 K=1,4
      B(I,J,K)=0.0
   10 CONTINUE
C     READ  NO. OF FLUOROMETERS TO STANDARDIZE
      IFLNO=FFIN(5)
      DO 500 I=1,IFLNO
C     READ NO. OF CURVES TO BE DETERMINED FOR THIS FLUOROMETER
      KCUR=FFIN(5)
      DO 400 J=1,KCUR
C     READ SCALE 1=1X,2=3X,3=10X,4=30X
      ISCAL=FFIN(5)
C     READ NO. OF POINTS ON THIS CURVE
      NO=FFIN(5)
C     READ POINTS ON CURVE.  SCALE READING AND CONCEN IN PPB
      DO 100 K=1,NO
      X(1,K)=1.0
      X(2,K)=FFIN(5)
      X(3,K)=X(2,K)*X(2,K)
      X(4,K)=FFIN(5)
  100 CONTINUE
      N=4
      CALL LEASTFIT(X,N,NO,C)
      DO 200 L=1,3
      B(I,ISCAL,L)=C(L)
  200 CONTINUE
      WRITE(61,5) I,ISCAL,(B(I,ISCAL,L),L=1,3)
    5 FORMAT(' FLUOR NO.',I2,' SCALE',I3,/
     1'COEFFICIENTS',/3E12.4)
  400 CONTINUE
  500 CONTINUE
      RETURN
      END
      SUBROUTINE LEASTFIT(X,N,NO,B)
      DIMENSION X(5,20),XX(4,4),XY(4),B(4),ZITX(4,1)
C     N=NO OF VARIABLES,NO=NO. OF DATA,B=COFF
      KK=N-1
      DO 15 J=1,KK
      XY(J)=0.
```

Figure C-1. Program listing (continued)

```
      DO 10 I=1,NO,1
      XY(J)=XY(J)+X(J,I)*X(N,I)
   10 CONTINUE
   15 CONTINUE
      DO 20 K=1,KK
      DO 20 J=1,KK
      XX(J,K)=0.
      DO 20 I=1,NO
      XX(J,K)=XX(J,K)+X(J,I)*X(K,I)
   20 CONTINUE
      CALL MATINV (XX,KK,ZITX,0,DETERM)
      DO 30 J=1,KK
      B(J)=0.
      DO 30 I=1,KK
      B(J)=B(J)+XX(J,I)*XY(I)
   30 CONTINUE
      WRITE(22,1)
      WRITE(22,5) (B(J),J=1,KK)
      YY=0.
      DO 40 J=1,NO
      YY=YY+X(N,J)*X(N,J)
   40 CONTINUE
      BXX=0.
      DO 50 J=1,KK
      BXX=BXX+B(J)*XY(J)
   50 CONTINUE
      IDF=NO-KK
      RES=(YY-BXX)/IDF
      WRITE(22,3) RES,IDF
    1 FORMAT (32H LEAST SQ ESTIMATE OF PARAMETERS )
    3 FORMAT (23H MEAN SQ OF RESIDUALS= ,E16.7,5X,4HDF= ,I3)
    4 FORMAT (28H VARIANCE-COVARIANCE MATRIX )
    5 FORMAT (/4E15.5)
      WRITE(22,4)
      WRITE(22,5) ((XX(I,J),I=1,KK),J=1,KK)
      RETURN
      END
      SUBROUTINE MATINV(A,N,B,M,DETERM)
C     MATRIX INVERSION WITH ACCOMPANYING SOLUTION OF LINEAR EQ
      DIMENSION IPIVOT(4), A(4,4), B(4,1), INDEX(4,2), PIVOT(4)
      DETERM=1.0
      DO 20 J=1,N
   20 IPIVOT(J)=0
      DO 550 I=1,N
C     SEARCH FOR PIVOT ELEMENT
      AMAX=0.0
      DO 105 J=1,N
      IF (IPIVOT(J)-1) 60, 105, 60
   60 DO 100 K=1,N
      IF (IPIVOT(K)-1) 80, 100, 740
   80 IF (ABSF(AMAX)-ABSF(A(J,K))) 85, 100, 100
   85 IROW=J
      ICOLUM=K
      AMAX=A(J,K)
  100 CONTINUE
  105 CONTINUE
      IPIVOT(ICOLUM)=IPIVOT(ICOLUM)+1
C     INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
```

Figure C-1. Program listing (continued)

```
      IF (IROW-ICOLUM) 140, 260, 140
  140 DETERM=-DETERM
      DO 200 L=1,N
      SWAP=A(IROW,L)
      A(IROW,L)=A(ICOLUM,L)
  200 A(ICOLUM,L)=SWAP
      IF(M) 260, 260, 210
  210 DO 250 L=1, M
      SWAP=B(IROW,L)
      B(IROW,L)=B(ICOLUM,L)
  250 B(ICOLUM,L)=SWAP
  260 INDEX(I,1)=IROW
      INDEX(I,2)=ICOLUM
      PIVOT(I)=A(ICOLUM,ICOLUM)
      DETERM=DETERM*PIVOT(I)
C     DIVIDE PIVOT ROW BY PIVOT ELEMENT
      A(ICOLUM,ICOLUM)=1.0
      DO 350 L=1,N
  350 A(ICOLUM,L)=A(ICOLUM,L)/PIVOT(I)
      IF(M) 380, 380, 360
  360 DO 370 L=1,M
  370 B(ICOLUM,L)=B(ICOLUM,L)/PIVOT(I)
C     REDUCE NON-PIVOT ROWS
  380 DO 550 L1=1,N
      IF(L1-ICOLUM) 400, 550, 400
  400 T=A(L1,ICOLUM)
      A(L1,ICOLUM)=0.0
      DO 450 L=1,N
  450 A(L1,L)=A(L1,L)-A(ICOLUM,L)*T
      IF(M) 550, 550, 460
  460 DO 500 L=1,M
  500 B(L1,L)=B(L1,L)-B(ICOLUM,L)*T
  550 CONTINUE
C     INTERCHANGE COLUMNS
      DO 710 I=1,N
      L=N+1-I
      IF (INDEX(L,1)-INDEX(L,2)) 630, 710, 630
  630 JROW=INDEX(L,1)
      JCOLUM=INDEX(L,2)
      DO 705 K=1,N
      SWAP=A(K,JROW)
      A(K,JROW)=A(K,JCOLUM)
      A(K,JCOLUM)=SWAP
  705 CONTINUE
  710 CONTINUE
  740 RETURN
      END
```

Figure C-1. Program listing (continued)

APPENDIX D

PHOTOGRAPHIC EQUIPMENT

Included in this report are photographic data taken during the 1968 and 1969 field season. Aerial photography was taken the first year by a commerical aerial photography firm using a precise mapping camera mounted vertically. As the firm was located approximately 100 miles from the study area scheduling the photography was difficult. Several times clouds moved over the work area during the time it took the aircraft to reach the outfall site. In addition sunlight reflection from the water surface created serious problems with the processing of the vertical photography even though it was taken when the sun altitude was between 30 and 35 degrees.

During the 1969 field season the photography was taken with two 70 mm Hasselblads and a K-17 mapping camera. These cameras are shown in Figure D-1 and were mounted obliquely to avoid the sunlight reflection from the water surface. The cameras were mounted in the baggage compartment of a rented aircraft and pictures were taken through the baggage compartment opening. The door of the compartment was removed while the cameras were mounted.

The camera shutters were synchronized with the timing delay device shown in Figure D-2. The cameras were lined up end to end without their magazines. The variable resistor shown in Figure D-2 was adjusted until a light could be seen through the cameras when the shutters were actuated at 1/100 of a second.

The aerial photography is digitized in the photogrammetry laboratory. The equipment used in this setup of the processing is shown in Figure D-3. The densitometer is located on the Kelsh plotter table. Output from the densitometer is punched on computer cards. The operator is able to accomplish three steps of the processing at one time. While the densitometer is digitizing one photo, the operator is visually scanning the line printer listing of a previous photograph searching for illegal characters caused by double punches. At the same time he can operate the teletype which preliminarily processes the data from another photograph on the computer. This program reduces the voltage output from the densitometer to film densities, rejects extreme values of densities, interpolates photo coordinates and displays the difference in film densities between adjacant bands on the line printer. Output from this program is stored on magnetic tape waiting final processing as explained by Burgess and James (1969).

The densitometer and scanning table is shown in Figure D-4 processing a 70 mm picture. Voltage output from the densitometer goes to the digital voltmeter shown directly behind the densitometer. The BCD digital voltmeter logic (-24V = 0, - 1V = 1) is converted to the Autotrol digital recorder logic (-15V = 0, 0V = 1) by the circuit shown in Figure D-5.

The limits on the photograph are marked with black tape. When the densitometer senses the tape (voltage output greater than 750 volts), the recording of data is stopped, the direction of scan is reversed, the film is advanced one scan and the recording of data started again. The circuitry required for this operation is shown in Figures D-6 through D-9. Figure 3 referred to in Figures D-6, and D-7 is Figure D-8 of the report.

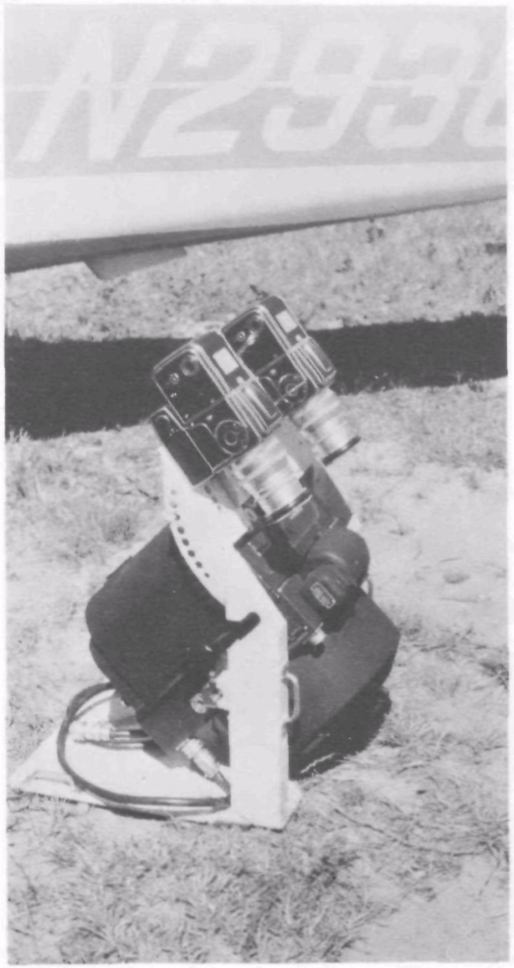


Figure D-1. Aerial camera.

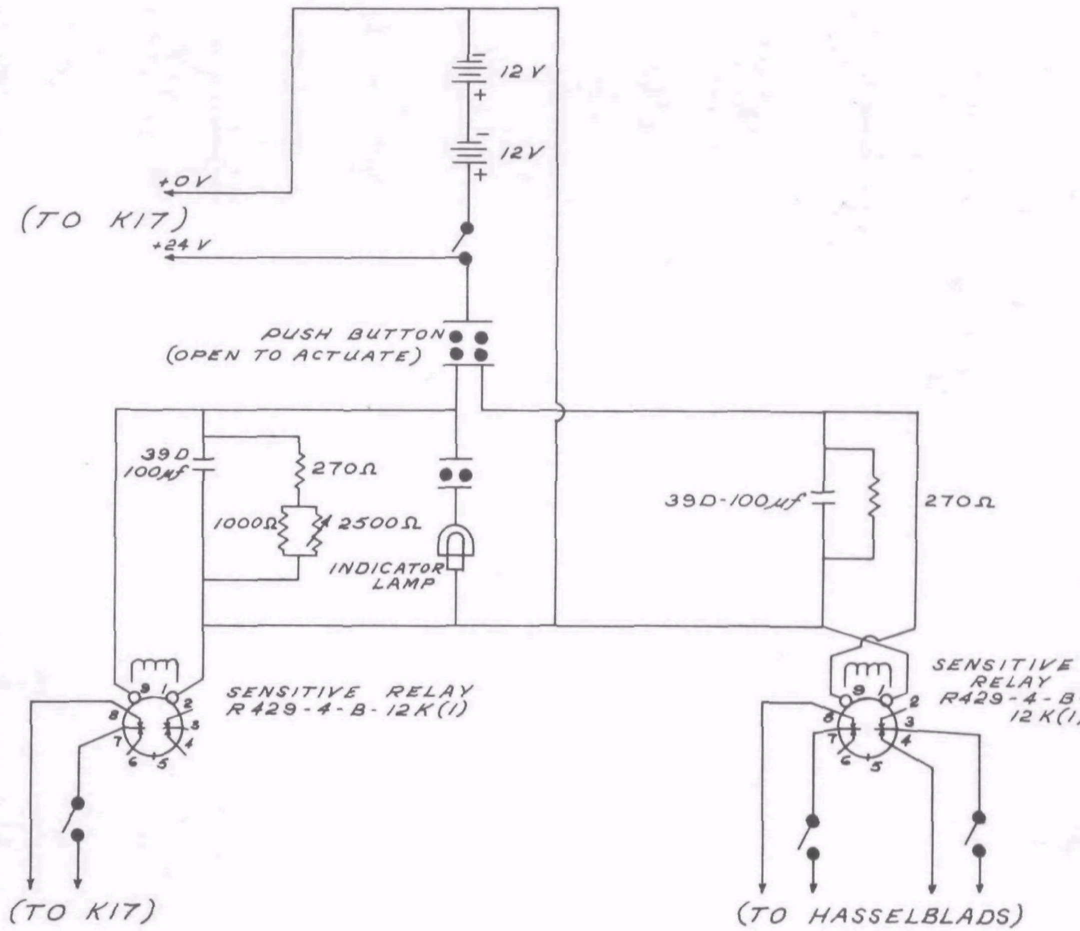


Figure D-2. Shutter timing diagram.

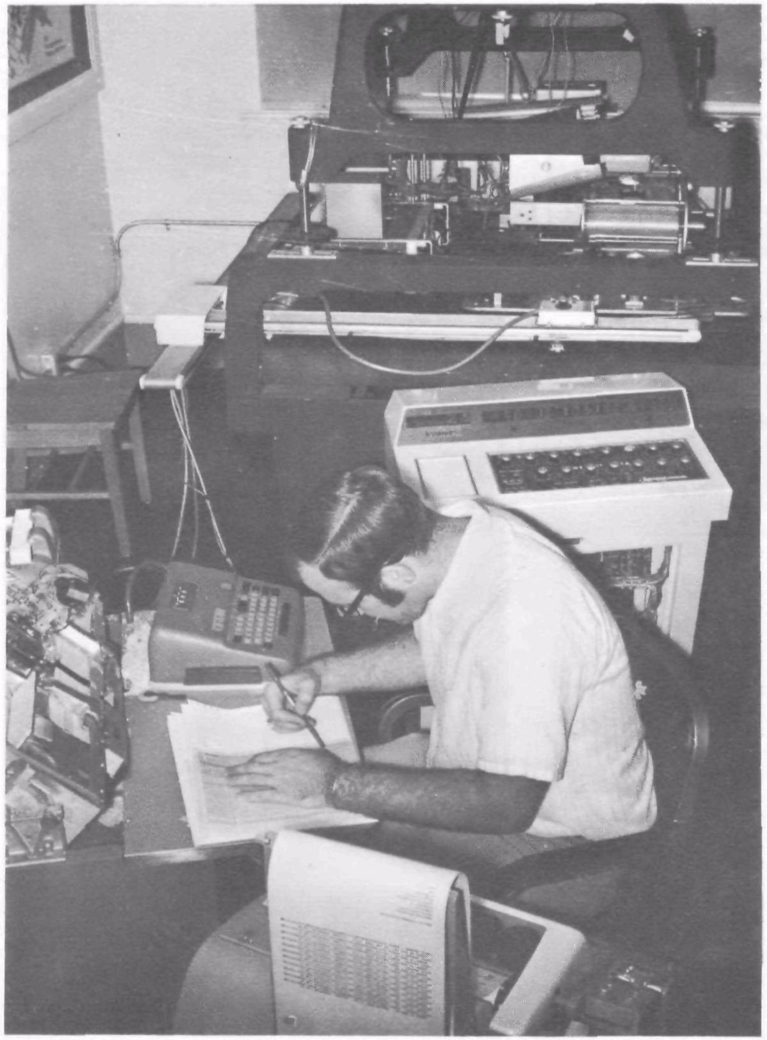


Figure D-3. Digitizing aerial film.

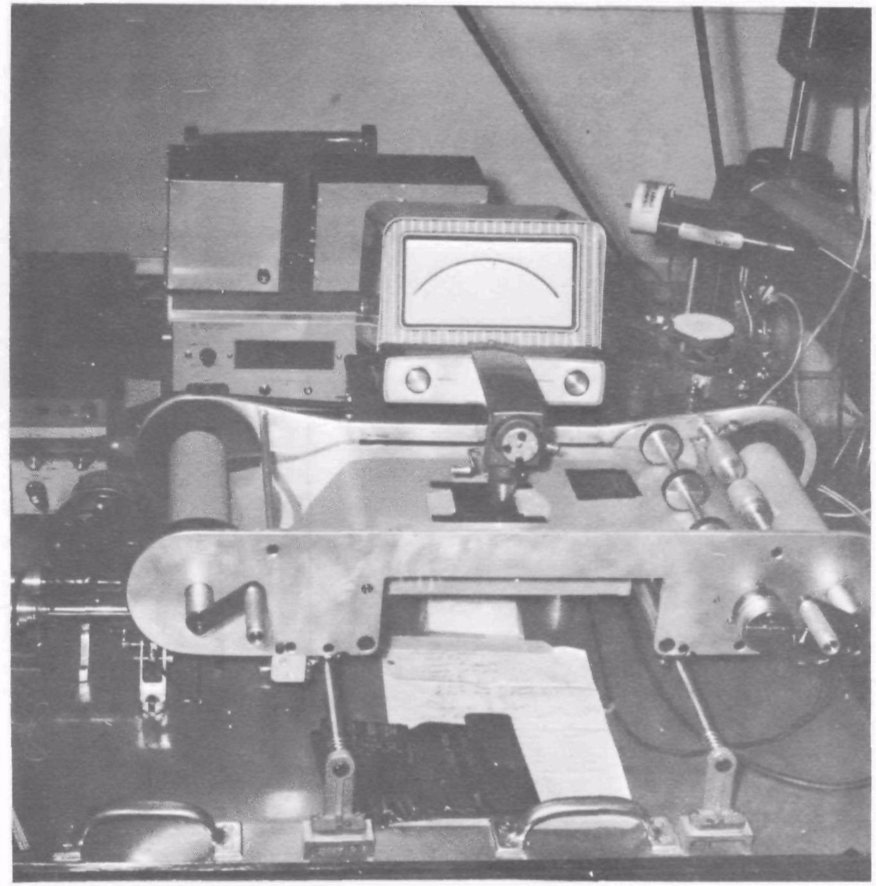


Figure D-4. Scanning densitometer.

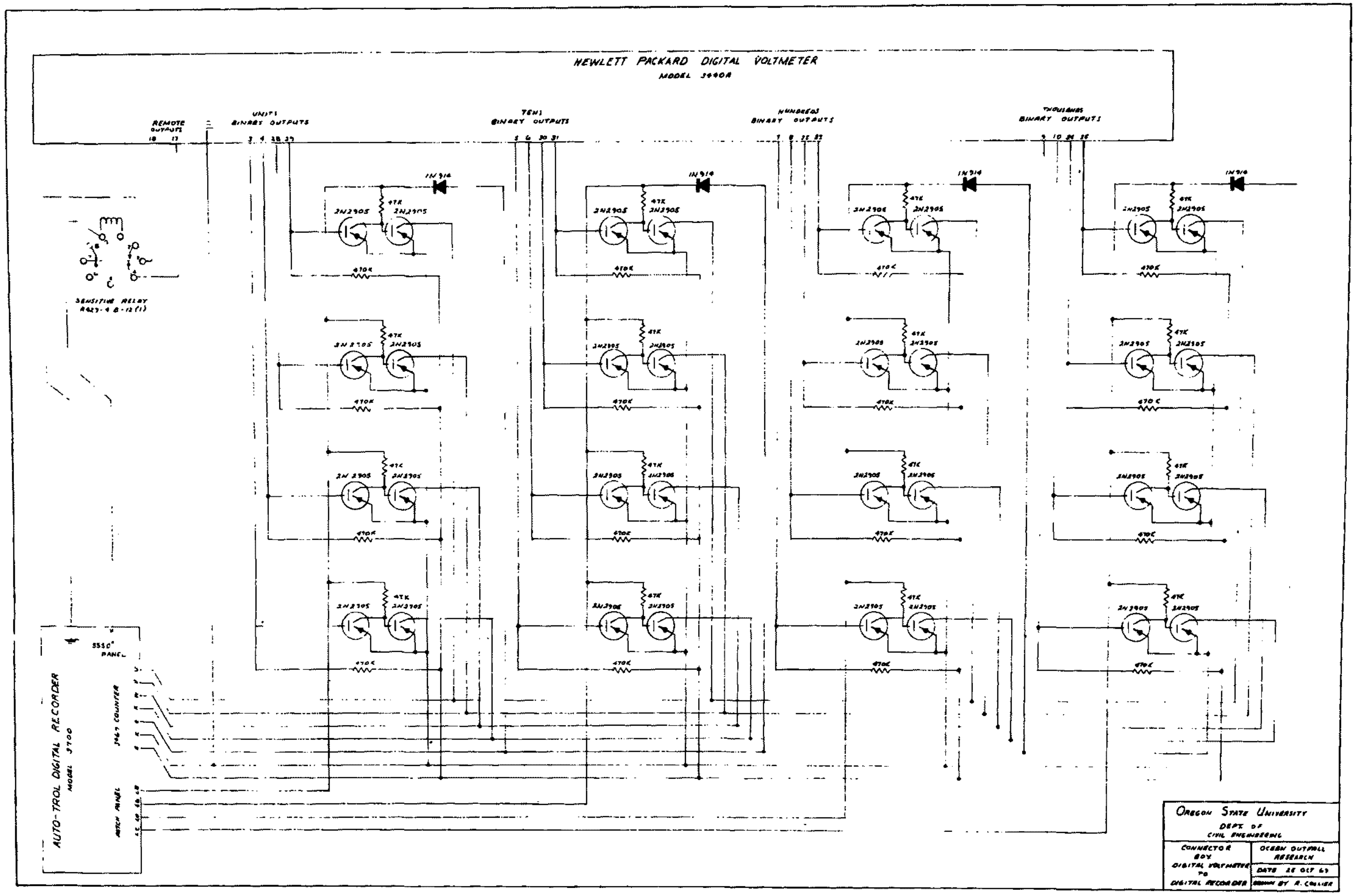


Figure D-5. Voltmeter to digitizer logic converter diagram.

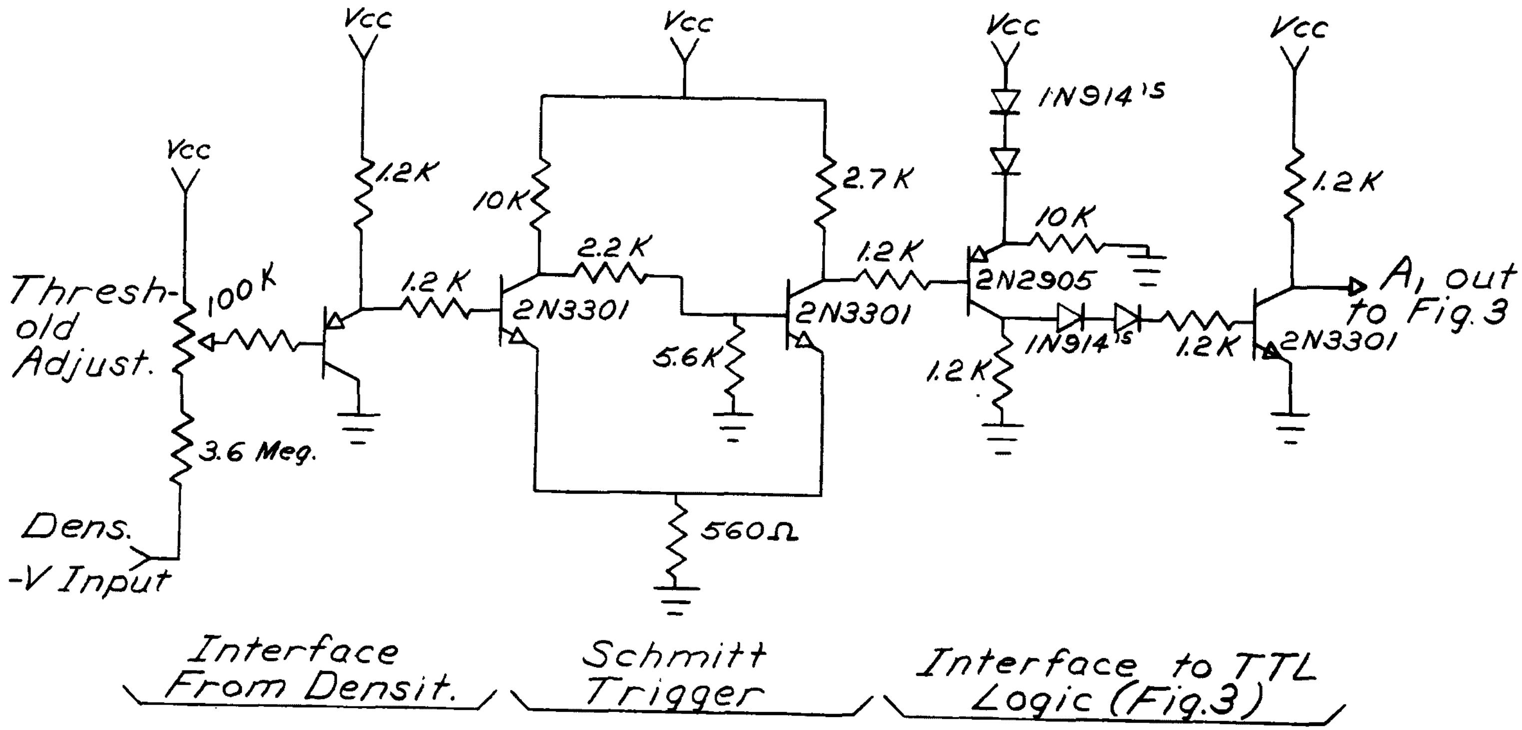


Figure D-6. Densitometer to logic circuit.

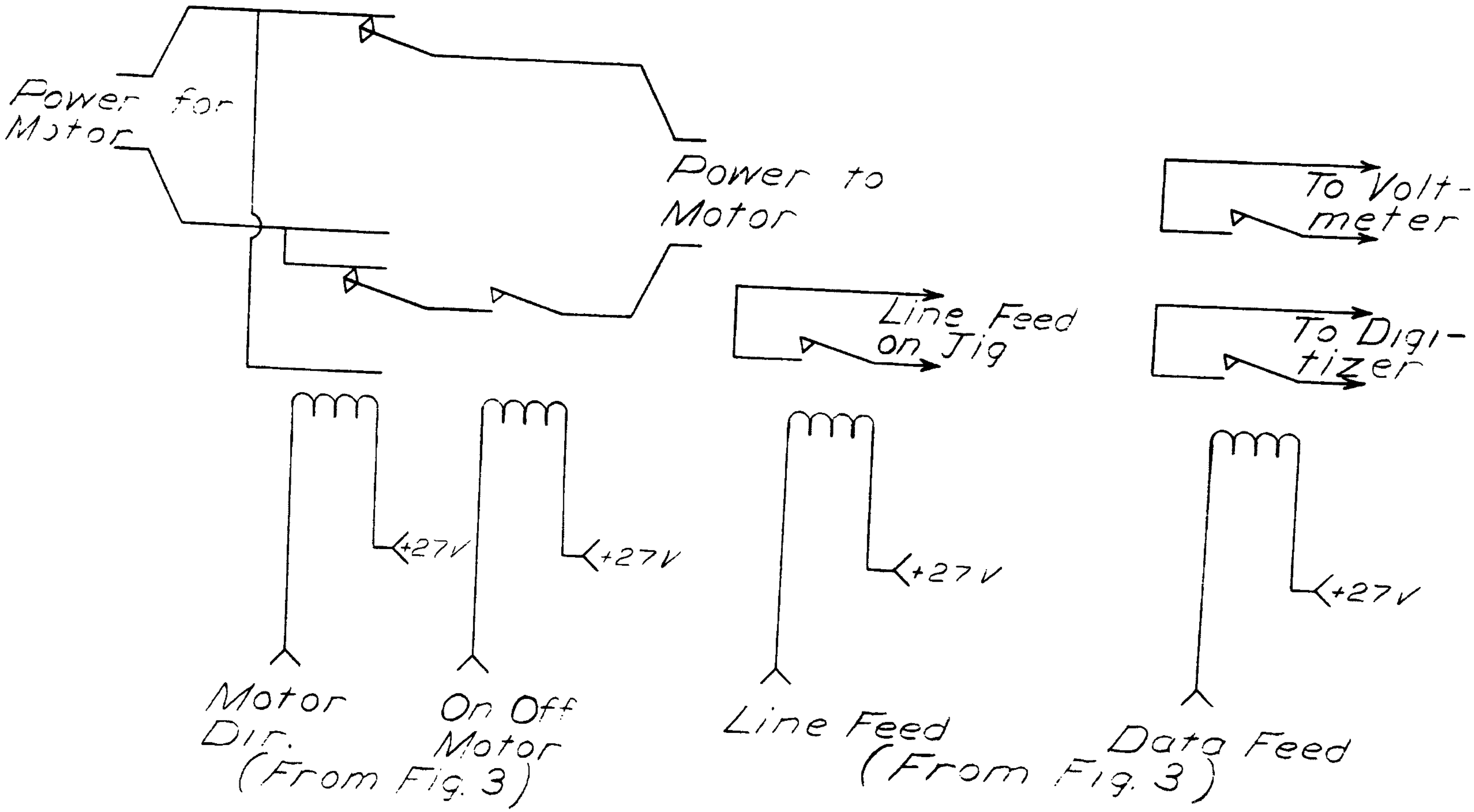


Figure D-7. Relay circuits.

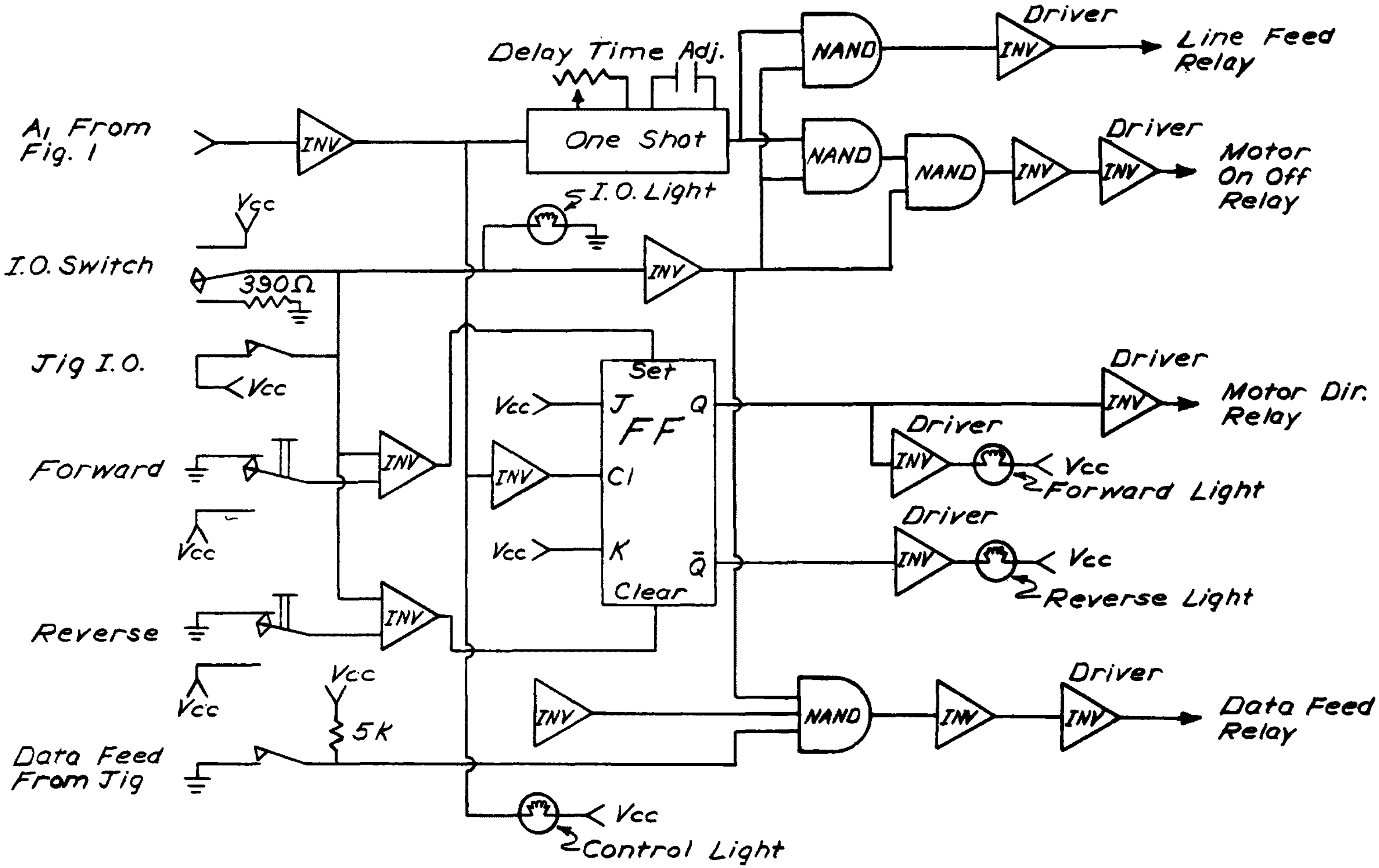


Figure D-8. Logic circuit.

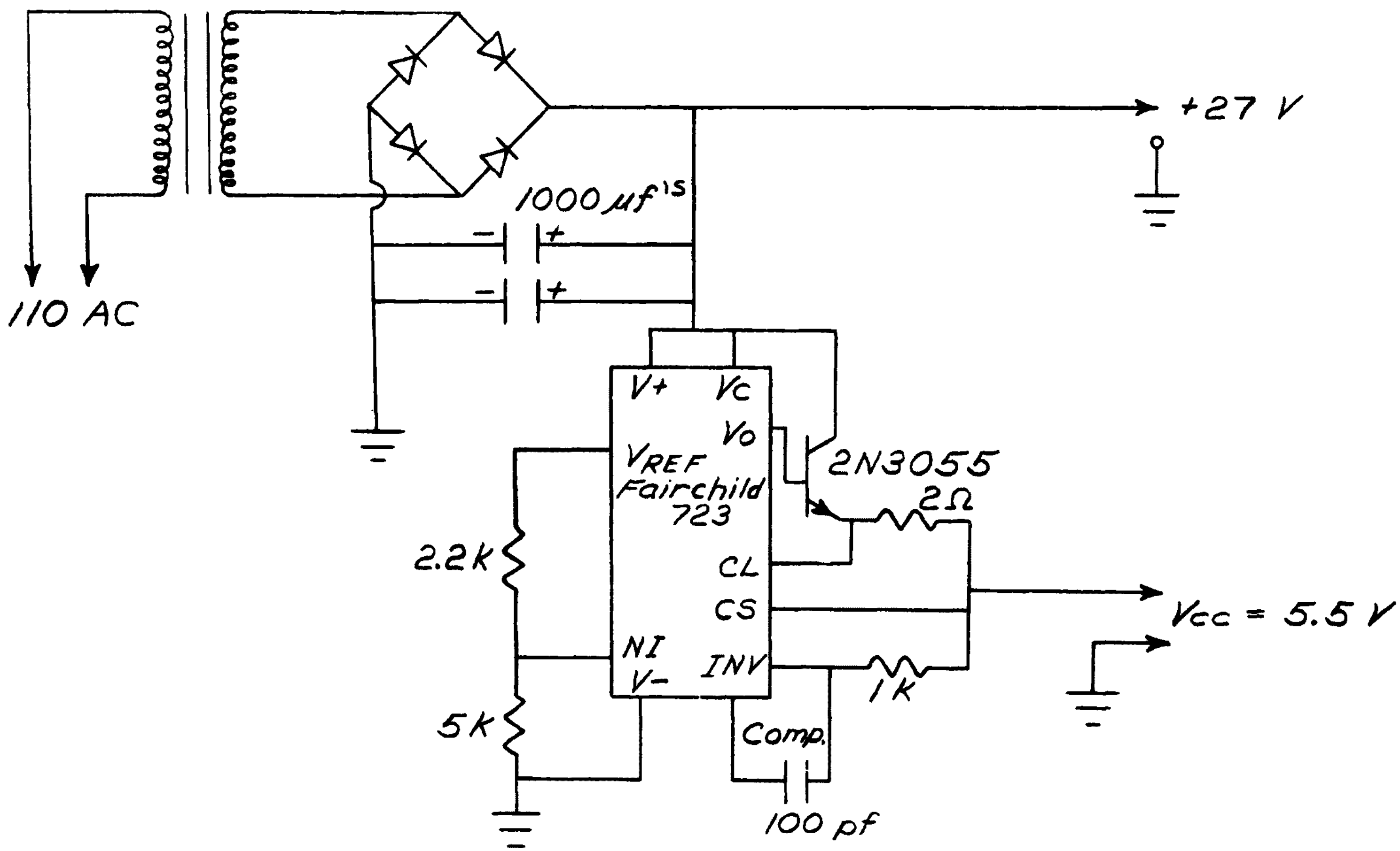


Figure D-9. Power supply circuit.

APPENDIX E

DIFFUSION COMPUTATIONS

Numerous investigators have employed solutions to the diffusion equations for the estimation of waste concentrations in the waste plume that occurs at an outfall location. If the scale of the current eddies is much smaller than the dimensions of the waste field, then the Fickian form of diffusion equation can be applied. The basic equation is:

$$\frac{\partial W}{\partial T} = \frac{\partial}{\partial Y}\left(D_y \frac{\partial W}{\partial Y}\right) + \frac{\partial}{\partial X}\left(D_x \frac{\partial W}{\partial X}\right) + \frac{\partial}{\partial Z}\left(D_z \frac{\partial W}{\partial Z}\right) - \left[\frac{\partial}{\partial Y}(V_y W) + \frac{\partial}{\partial X}(V_x W) + \frac{\partial}{\partial Z}(V_z W)\right] + S \qquad \text{(E-1)}$$

where V is velocity, W is waste concentration, D is eddy diffusivity. The first three terms on the right are the diffusion terms, the next three are convection terms and S represents the sources and sinks.

Solutions to the equations have required various assumptions such as steady state condition, no vertical or longitudinal mixing and unidirectional transport velocity in the X direction. With these assumptions, the equations becomes:

$$V_x \frac{\partial W}{\partial X} = \frac{\partial}{\partial Y}\left(D_y \frac{\partial W}{\partial Y}\right) + aW \qquad \text{(E-2)}$$

where "a" is a first order decay constant and "aW" represents a sink or loss in the system.

Early solutions to this equation assumed D_y constant; however, investigators have found it to range from 3×10^2 to 4×10^8 cm^2/sec. Brooks (1960) has reported a solution to the diffusion equation with a variable coefficient of diffusivity. The coefficient was assumed to vary with the four thirds power of the scale.

In a study of diffusion of wastes for a near shore area by the Allen Hancock Foundation (1964), it was found that "4/3 law" relating the lateral coefficient of eddy diffusion as a function of average eddy scale did not hold for the particular oceanic areas studied in their experiments. Mathematical models used in their experiments were statistical models based on the Gaussian distribution. Another important conclusion reached in this study was that vertical diffusion can contribute significantly to the overall diffusion process when wind speeds exceed approximately eight knots and/or when column stability is low.

The stability of the waste field established at the outfall site is dependent on the initial mixing from the diffusers. The initial dilutio for a properly designed outfall should be sufficient so that the density stratification induced by the waste field may be destroyed by vertical turbulent diffusion. The depth of the established field at the outfall is also a function of the initial dilution. The ratio of waste field depth to the length of the jet path from the point of release to the water surfac has been found by Rawn, Boweman and Brooks (1960) to vary from 1/12 to 1/6.

Vertical mixing does occur in the waste field as well as horizontal mixing. As indicated by Wiegel (1964), vertical mixing is difficult to study in the laboratory because of limitations of tank size. In these studies the wind drags the surface water to the down wind end of the tank producing a hydraulic head which causes a flow in the opposite direction.

Laboratory studies have indicated that wind drag on the water surface produces very little mixing. However, when wind generated waves appear, extremely rapid mixing occurs as wind waves are rotational in the generating area. On the other hand, there is some indication that swell is not important to the mixing process as it is apparently nearly irrotational (Wiegel, 1964).

Masch (1961) conducted a wave study in a wave tank and developed the following relationship for the coefficient of eddy diffusivity:

$$D_y = 0.0038\ (Vs + Qw)^{3.2} \qquad \text{(E-3)}$$

where Vs is the surface current and Qw is the water particle orbit speed ($Qw = H/T$, H = significant wave height and T = average wave period)

Steady state diffusion coefficients were determined for a steady state model with unidirectional transport velocity in the X direction. By neglecting the loss to the lower layers and assuming the diffusion in the Y direction was not a function of Y, the basic diffusion equation becomes

$$V_x \frac{\partial W}{\partial X} = D_y \frac{\partial^2 W}{\partial Y^2} \qquad \text{(E-4)}$$

where X is the distance along the center line of the plume, Y is the distance right or left of the plume center line, V_x is velocity along the plume center line, W is the waste concentration, and the D_y is the diffusion coefficient. A solution to equation E-4 is

$$W = \frac{K}{2(\pi D_y t)^{1/2}} \exp [-Y^2/4tD_y] \quad \text{(E-5)}$$

For computational purposes this equation can be reduced to

$$W = W_0 \exp [-Y^2/2\sigma_y^2] \quad \text{(E-6)}$$

where W_0 is the concentration at the center line of the plume and σ_y^2 is variance of normal curve. The diffusion coefficient is equal to one half the change in variance divided by the time interval or

$$D_y = \frac{1}{2} \frac{\Delta\sigma^2}{\Delta t} \quad \text{(E-7)}$$

In the computer program, the variance was computed every 300 feet along the center line of the plume. The change in time for this steady state model was equal to the distance between sections in feet divided by the velocity in feet per second. The velocity was determined photogrammetrically from the current floats.

The variance (σ^2) can be estimated for a normal distribution from the sample variance (S^2_y). The concentration (W) is equivalent to the frequency of occurrence in the computations. The sample variance is

$$S^2_y = \frac{\Sigma\, W(Y-\bar{Y})^2}{N} \quad \text{(E-8)}$$

where $\bar{Y}$ is the mean distance from the origin and

$$N = \sum_{i=1}^{n} W_i \quad \text{(E-9)}$$

In computational form equation E-8 is

$$S_y^2 = \frac{1}{N} \left[\sum_{i=1}^{n} W_i Y_i^2 - \frac{\left(\sum_{i=1}^{n} W_i Y_i \right)^2}{N} \right] \qquad \text{(E-10)}$$

From equation E-10 an estimate of the variance can be made for any section across the plume. Equation E-7 was used to determine the diffusion coefficient.

Nonsteady-state diffusion coefficients were determined from two flights over the area using equation E-7. In this equation for the nonsteady state

$$\Delta\sigma_i^2 = \sigma_{1,i}^2 - \sigma_{2,\, i+c}^2 \qquad \text{(E-11)}$$

where the subscripts 1 and 2 refer to the flight numbers, i refers to the section number across the plume in flight one and $i+c$ is the section number in flight two adjusted for the movement of the waste field between flights. In solving equation E-7 for the nonsteady-state case, Δt is the time difference between the flights.

Diffusion coefficients presented in this report were determined at existing outfall sites. At proposed outfall locations the currents and diffusion coefficients can be determined by photographing dye patches. By knowing the currents and diffusion coefficients in the area, the waste field can be simulated on the computer prior to construction and operation of the outfall.

Equation E-1 was reduced to

$$\frac{\partial W}{\partial T} = D_y \frac{\partial^2 W}{\partial Y^2} + D_x \frac{\partial^2 W}{\partial X^2} - \frac{\partial}{\partial Y}(V_y W) - \frac{\partial}{\partial X}(V_x W) + KW \qquad \text{(E-12)}$$

where K represents the decay coefficient. This equation was programmed to simulate the waste field from either a line source or point source and for either a continuous effluent discharge or a dye patch.

Figure E-1 is a symbolic print out of the waste field at times 0.5, 1.1, 1.9, and 3.0 hours from the start of effluent discharge. Symbols in the plots represent different concentrations but at this reduced scale only the difference in shading can be seen. While the program was written to handle a variable velocity as a function of X, Y and T, the example shown here is for a unidirectional velocity of 0.3 fps. In this example the grid size was $\Delta X = \Delta Y = 60$ ft, the diffusion coefficients were $D_y = D_x = 10$ ft sq per sec and the decay coefficient representing a loss to the lower layers was 0.1 per hour.

Figure E-2 shows the effect of the diffusion coefficients on the waste field. The symbolic plots were made 2.7 hours after the start of the effluent discharge for $D_y = D_x = 5$, 10, and 20 ft^2/second. Except for the diffusion coefficients, the other variables were the same as those in Figure E-1.

This finite difference model was used to reproduce the waste fields measured by aerial photography from the computed diffusion coefficients and current velocities. The model can be expanded to include variable diffusion coefficients and vertical mixing.

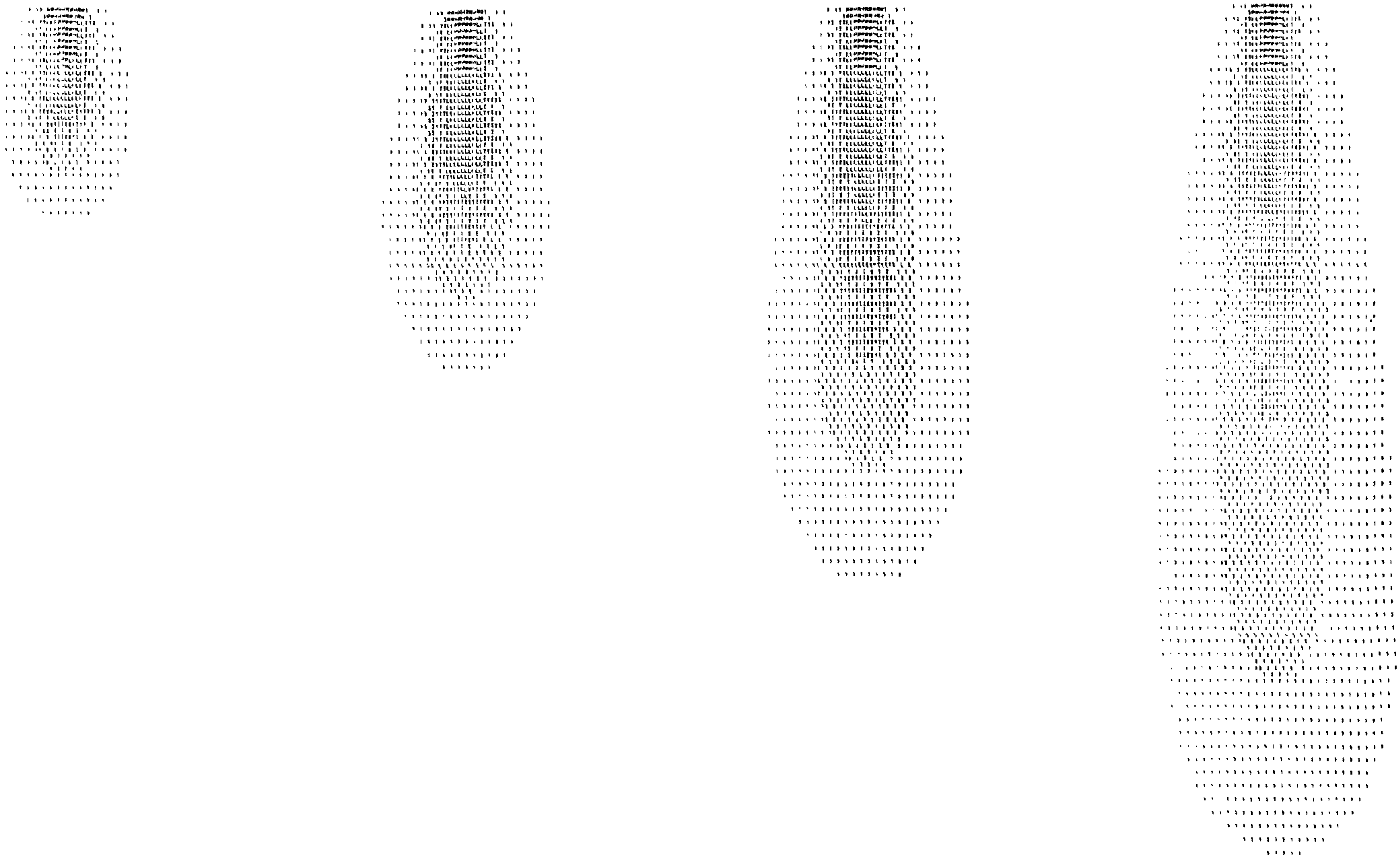


Figure E-1. Waste field by computer simulation at T= 0.5, 1.1, 1.9 and 3.0 hours with Dy = Dx = 10 ft^2/sec, Vx = 0.3 fps, $\Delta x = \Delta y$ = 60 ft and k = 0.1 per hr.

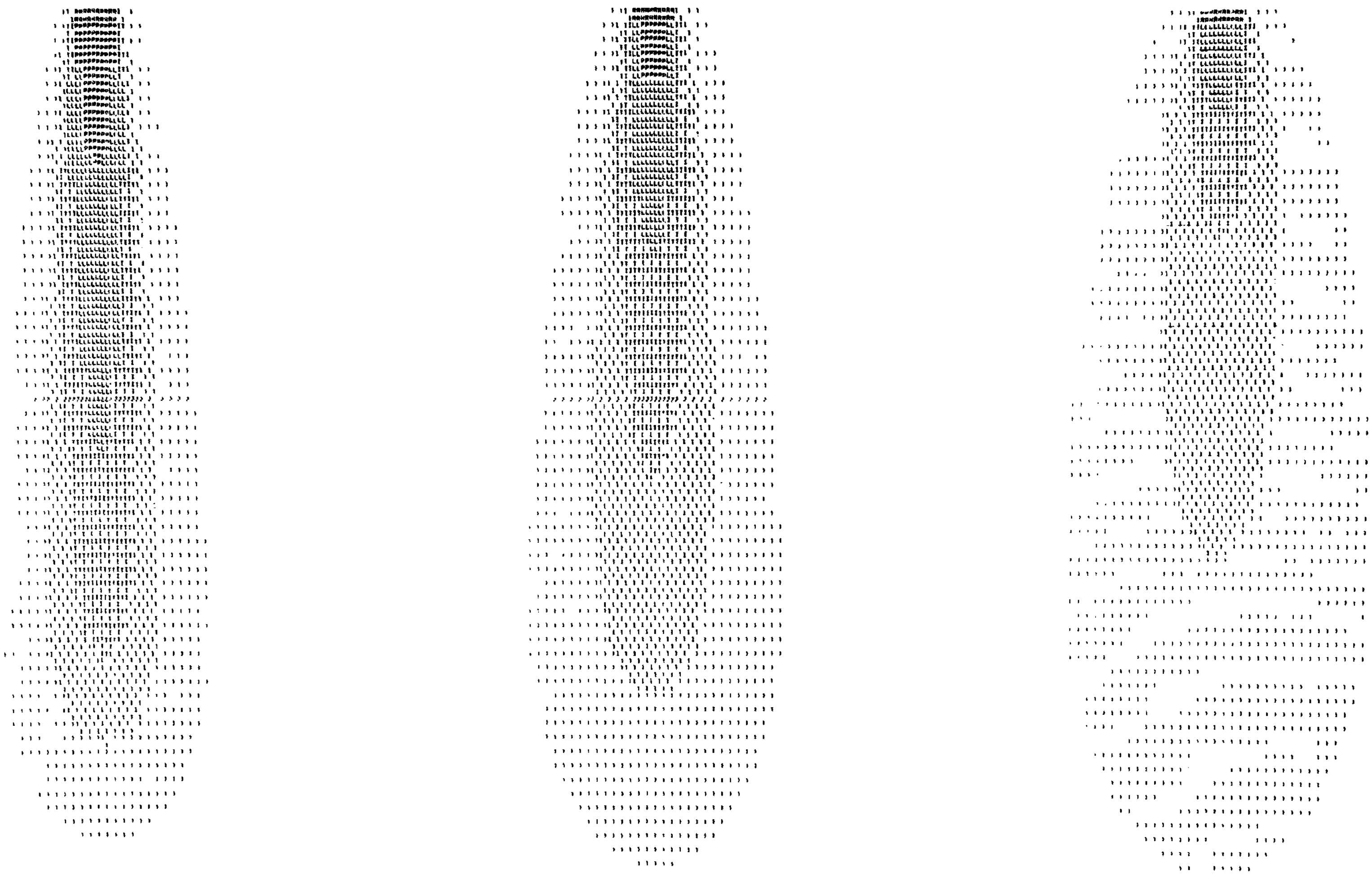


Figure E-2. Waste field by computer simulation Dy = Dx = 5, 10, and 20 ft^2/sec. at T=2.7 hrs. with Vx = 0.3 fps, Δx = Δy = 60 ft and k= 0.1 per hr.

APPENDIX F

SUMMARY OF AERIAL PHOTOGRAPHY

Interference caused by direct sunlight reflection on the water surface can be reduced or eliminated by oblique photography. Surface foam from the waste at times may prevent the computation of waste concentration in the waste field from the photography. However, the photography shows the area and extent of the foam which is valuable information in the study of ocean outfall waste disposal.

Since the computations require that the light from the open sea be measured, concentration determined from aerial photography are less reliable when the waste field extends into the surf zone and background light from the sea is not available from both sides of the plume. A uniformly cloudy sky increases the amount of surface light reflection in all the photographic bands. With oblique photography, most of this reflected light can be prevented from reaching the film with a polarizing filter. Photography containing areas of scattered shadows from partial cloudy skies is less adapted to automatic computerized processing. Generally when broken clouds are present, the photography can be taken when the outfall area is free of shadows.

Color film was used in the mapping camera during the 1968 season and on July 7 and 8, 1969. Color film is difficult to process with the rewind processor and uneven development occurs for 5 to 15 frames on each end of the roll. The prints in Figure 21 and 22 show the uneven development. While the effect of the film streaks can be reduced in the data processing, it was decided in the future to use only black and white film in the mapping camera.

Correlation coefficients between the photographic values and the concentrations determined from boat sampling varied from 0.85 to 0.95 with a standard error of about 25% of the maximum concentration measured over the outfall. This standard error is the same magnitude as the standard error determined from the boat sampling data at cross lines or points where the concentration is determined twice at one point. A summary of the aerial photography is listed in Tables F-1 and F-2.

Table F-1. Summary of aerial photography, 1968.

Date	Location	Flight	Time PDT	Altitude (ft.)	Photos per Flight	Boat - Photo [a] Std. Error	Boat - Photo [a] Deg. Free.	Within Boat [b] Std. Error	Within Boat [b] Deg. Free.	Camera	Film
8- 8-68	Newport	1	17:09	8250	1	---	---	3.46	3	8-1/4"	Ektachrome
		2	17:20	4125	2	2.3	172	---	---	Zeiss	8442
		3	17:30	4125	2	2.7	195	---	---	RMKA	
		4	17:41	4125	1	2.7	142	---	---		
		5	17:50	8250	1	---	---	---	---		
8-16-68	Newport	1	15:51	8250	2	6.2	178	9.59	4	8-1/4"	Ektachrome
		2	16:00	4125	3	5.6	156	---	---	Zeiss	8442
		3	16:13	4125	2	6.3	187	---	---	RMKA	
		4	16:21	8250	1	---	---	---	---		
8-21-68	Newport	1	10:13	3500	1	---	---	4.74	5	3-1/2"	Ansco
		2	10:21	1750	2	---	---	---	---	Wild	D200
		3	10:36	1750	2	---	---	---	---	RC-9	
		4	10:44	3500	1	---	---	---	---		
9-10-68	Newport	1	10:10	5625	1	---	---	---	---	11-1/4"	Ansco
		2	10:25	11250	1	---	---	---	---	K-17	D200
		3	10:35	5625	1	---	---	---	---		
9-10-68	Newport	1	15:56	5625	1	---	---	---	---	11-1/4"	Ansco
		2	16:11	11250	2	---	---	---	---	K-17	D200
		3	16:21	5625	1	---	---	---	---		
9-12-68	Newport	1	10:12	5625	1	---	---	---	---	11-1/4"	Ansco
		2	10:30	11250	1	---	---	---	---	K-17	D200
		3	10:43	5625	1	---	---	---	---		
9-12-68	Newport	1	16:31	3000	1	---	---	5.32	6	6"	Ektachrome
		2	16:46	6000	2	---	---	---	---	Zeiss	MS
		3	16:54	3000	1	---	---	---	---	RMKA	Aerographic

a Statistic from a comparison between boat data and photo results.

b Statistic from a comparison within boat data.

Table F-2. Summary of aerial photography, 1969.

Date	Location	Flight	Time PDT	Altitude (ft.)	Photos per Flight	Boat - Photo[c] Std Error	Boat - Photo[c] Deg. Free.	Within boat[d] Std Error	Within boat[d] Deg. Free.	FILM K-17[a]	FILM HB-1[b]	FILM HB-2[b]
7- 8-69	Newport	1	15:15	3000	1	2.0	147	3.33	5	8442	8401	5424
		2	15:21	4000	2	1.7	130	----	---	8442	8443	5424
		3	15:56	4000	3	1.5	148	----	---	8442	8443	5424
7-16-69	Gardiner	1	14:50	6000	1	6.0	134	3.92	7	5425	5424	8443
		2	15:03	5000	2	4.4	121	2.91	3	5425	5424	8443
		3	15:10	4000	2	5.8	99	----	---	5425	5424	8443
8- 6-69	Samoa	1	17:27	3000	5	4.6	183	4.84	5	2402	5424	8442
8- 7-69	Samoa	1	15:35	4000	4	---	---	7.83	4	2402	5425	8442
		2	16:20	6000	4	5.1	169	----	---	2402	8401	8443
8-12-69	Newport	1	12:52	4000	2	4.1	176	3.86	4	5425	5424	8442
		2	13:01	6000	1	4.1	195	----	---	5425	5424	8442
8-19-69	Gardiner	1	12:39	4000	3	5.6	91	2.59	2	2402	5424	8442
		2	13:53	6000	2	5.6	93	----	---	2402	5424	8442
		3	16:28	4000	2	4.0	39	----	---	2402	5424	8442
8-20-69	Gardiner	1	11:58	6000	1	4.8	12	4.40	4	2402	5424	8442
		2	15:14	6000	1	4.6	111	----	---	2402	5424	8442
		3	15:41	5000	3	4.8	110	5.36	4	2402	8401	8443
9- 8-69	Newport	1	11:21	3000	1	2.7	110	----	---	2402	5424	8443
		2	11:38	6000	1	2.2	181	----	---	2402	5424	8443
		3	14:44	8000	1	2.2	70	----	---	2402	5424	8443

a Mapping camera with 6-inch focal length lens.
b 70 mm Hasselblad camera with 150 mm focal length lens.
c Statistic from a comparison between boat data and photo results.
d Statistic from a comparison within boat data.

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

5 Organization

Oregon State University, Corvallis, Oregon 97331

6 Title

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10 Author(s)

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25 Identifiers (Starred First)

27 Abstract

Aerial photography taken of waste plumes from Kraft pulp mill ocean outfalls was shown to be an effective tool in the study of waste disposal sites. This technique is not limited by sea conditions and permits monitoring and evaluation of outfall sites throughout the year. Photography taken at one instant provides comprehensive information throughout the waste field. Manpower requirements and costs for this method are considerably less than for conventional boat sampling surveys.

Field studies were conducted on the waste plumes from Kraft pulp mill ocean outfalls at Newport and Gardiner, Oregon and Samoa, California. Waste concentrations were measured by conventional boat sampling techniques while aerial photography was taken of the outfall area from altitudes ranging from 3,000 to 11,000 ft. Computerized procedures were used to compute water currents, waste concentrations, toxicity zones and diffusion coefficients from the photography.

The highest concentration measured directly over the outfalls was 2.3 percent waste by volume and the maximum area of influence with concentrations greater than 0.2 percent waste was 155 acres. The maximum concentration determined over the outfall for each field study was generally less than that shown to have a detrimental effect on young salmon for a 14-day exposure.

Surface water current was found to be the dominant factor in the resulting plume pattern. During periods of low current velocities in the receiving water, the hydraulic head created by the effluent source was a significant factor in the resulting plume shape. The steady state form of the Fickian diffusion equation and unidirectional transport velocity was not applicable to the majority of the observations.

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