United States
Environmental Protection
Agency

Region 4
345 Courtland Street, NE
Atlanta, GA 30365

EPA 904/6-84 120
June 1984

EPA

A Dye Dispersion and Movement Study Off Northern Pinellas County, Florida

A Technical Report

Volume III

A DYE DISPERSION AND MOVEMENT STUDY

OFF NORTHERN PINELLAS COUNTY, FLORIDA

A TECHNICAL REPORT

By

W.H. Taft, B.E. Ross, E.D. Estevez,
G.W. Patton and K.S. Caraccia

Edited by S. Mahadevan

Submitted to:

Gannett Fleming Corddry
and Carpenter, Inc.
Post Office Box 1963
Harrisburg, Pennsylvania 17105

Submitted by:

Mote Marine Laboratory
1600 City Island Park
Sarasota, Florida 33577
(813) 388-4441

January 15, 1981

This report was totally funded by the Environmental Protection Agency. It has been reviewed for technical accuracy. However, any conclusive statements about the suitability of a wastewater outfall into the Gulf of Mexico are those of the contractor and not necessarily those of the Agency.

F. Theodore Bisterfeld
Project Officer
U.S. Environmental Protection Agency
Region IV
345 Courtland Street, N.E.
Atlanta, Georgia 30365

ABSTRACT

A study to evaluate the dispersion and movement of Rhodamine WT dye discharged four miles off the coast of Clearwater, Florida, was conducted between the period of May 27, 1980 and June 26, 1980. The study was conducted to simulate proposed wastewater discharges. The first dye-tracking occurred for six and one-half hours (May 27) and the second, thirty-nine and one-half hours (June 24-26). Analysis of the collected data indicates that the dominant movement of the dye was in the south and southwest directions.

Except for wind from the south, every other quadrant has been investigated to date, and we have concluded that wastewater, if released at Station 3F (the location of dye drop) should not adversely affect recreational beaches in the area. We have yet to determine the distribution of dye when strong winds come out of the south.

Although recreational beaches may not be affected, data exist to indicate potential movement of wastewater to the recreational reefs in the area.

Therefore, wastewater, if released at the proposed location, should not adversely affect recreational beaches in the area, but may adversely affect recreational reef fishing.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF AERIAL PHOTOGRAPHS

I. INTRODUCTION

Pinellas County, Florida is faced with a critical need to dispose of sewage effluent from the northern part of the county. Three alternatives have been proposed: 1) spray irrigation, 2) advanced waste treatment, and 3) an ocean outfall in the vicinity of Clearwater, Florida, five miles offshore. To evaluate the environmental effects of these three alternatives, an Environmental Impact Statement (EIS) is being prepared by Gannett Fleming Corddry and Carpenter, Incorporated, for the Environmental Protection Agency, Region 4. This study was conducted to provide support data for the EIS.

The primary objective of the dye study was to:

> Release a detectable dye (Rhodamine WT) at the location of the proposed wastewater outfall and to follow the dye for up to forty-eight (48) hours in order to determine its direction and time of travel as well as dilution characteristics. Of particular interest and concern are the beaches, reefs and fishing gounds that constitute a major economic resource to the Northern Pinellas community.

II. MATERIALS AND METHODS

A. Study Area

The study area is located west of Clearwater, Florida (latitude: 28°03'30"; longitude: 82°53'29"). Figure 1 shows the general location of the study area. Specifically, Station 3F was the location of the dye drop.

B. Study Systems

To conduct the study, the following were employed: 1) Rhodamine WT dye, 2) discharge sampling equipment, 3) monitoring equipment, 4) navigation equipment, 5) a transport vessel, 6) drogues, and 7) an airplane.

220 kg (100 lbs) and 55 kg (250 lbs) of Rhodamine WT dye were released at Station 3F during May 27 and June 24, respectively.

Discharge/sampling equipment consisted of a drum of liquid dye, a Jabsco pump operated off the ship's battery and a garden hose for discharging the dye. This equipment successfully delivered all the dye to a depth of 1 m (ca. 3 ft) below the sea surface in less than five minutes, thus simulating an instantaneous injection of sewage effluent. After being used to discharge the dye, this equipment was used for sampling and was placed on-line downstream of the fluorometer. Rubber-hoses were used for intake at depths of 1.5 m (5 ft) and 4.5 m (15 ft) to permit instantaneous switching and sampling from either depth.

A Turner Model 10-005 Fluorometer was used to monitor dye concentrations and output was recorded on a Linseis LS 24.70.80 two-channel flatbed recorder. Such a configuration permitted flow-through sampling while the ship was underway. The instrument was pre- and post-calibrated by Inter Sea Research. Data from the tracings were tabulated and used to construct the dye location and configuration.

Navigation equipment consisted of Loran C. Loran coordinates were recorded at the beginning and end of each traverse through the dye patch, as well as locations where dye concentrations varied significantly. In addition, time of significant events such as changes in boat heading were recorded, time, heading of boat and chart speed were used to replace missing information.

A thirty-three foot Egg Harbor craft was used as the transport vessel for this study. This boat can comfortabley accommodate four scientists and a boat operator.

It was suggested that drogues might be employed in an attempt to assist in following the dye during the night. One-gallon plastic milk containers were filled to 90-95 percent of capacity and released during the early evening of July 24, 1980.

An aircraft was used during daylight hours to assist in locating and photographing distribution of the dye. Through CB radio, the plane was in contact with the dye measurement vessel.

C. Dye Drops

The first dye drop, consisting of only 220 kg (100 lbs) of Rhodamine WT, was released at 1245 hours on May 27, 1980. The study was terminated at 1850 hours the same day, and the dye could not be located on the following morning. Based upon the experience from the May 27th dye drop, when the dye was visible for at least six hours, it was decided to make the June drop in darkness at low tide and follow the dye without taking initial measurements of concentration. As a result of releasing the dye in darkness, there are no comparable pictures of the dye during and after the drop as there are for the May drop. The second drop was made at 0327 hrs on June 24, 1980 at low tide.

After releasing the dye on June 24, no attempt was made to measure dispersion during darkness. The dye, even though released at a depth of one meter, rose to the surface, and because it was released so rapidly, initially maintained itself as a relatively small patch. A floating strobe light was released with the dye, but it disappeared to the northeast, apparently in response to a persistent wind from the southwest.

As many times as was practical, traverses through the dye patches were coordinated with fly-overs by an airplane equipped to photograph the dye and communicate with the dye-tracking vessel. The aircraft was useful in describing the shape of the patch so the tracking vessel could initiate traverses that would define the boundaries of the dye. In addition, on the morning of June 25th, the aircraft was particularly useful in locating a major concentration of dye.

D. Data Processing Methodology

During the 39.5 hours of the second dye drop, five periods of data were collected and labelled from I to V in chronological order. Each period varied in duration and number of transects through the dye based upon apparent complexity of the dye as observed from the vessel and the aircraft. Data was not collected at times other than those noted. Each transect (major heading) was numbered in chronological order and data were obtained between the origin and destination of the transect to map isopleths. To keep track of the data, Loran lines of position (LOP), heading and time were recorded directly on the chart paper for the origin and destination of each transect.

Sensitivity and voltage output from the fluorometer were plotted directly by the recorder. Three scales of sensitivity were used: x1, x3.16 and x10. To convert voltage to parts per billion (ppb), the baseline of ambient fluorescence was calculated for each sensitivity. All maxima, minima and averages between extremes as well as maximum slope were measured for each transect. After correction for baseline, voltages were read directly from the chart record for each chosen peak. Dye concentrations were computed by using the corrected voltages in the following formulas calibrated for each sensitivity scale (see example, page 6):

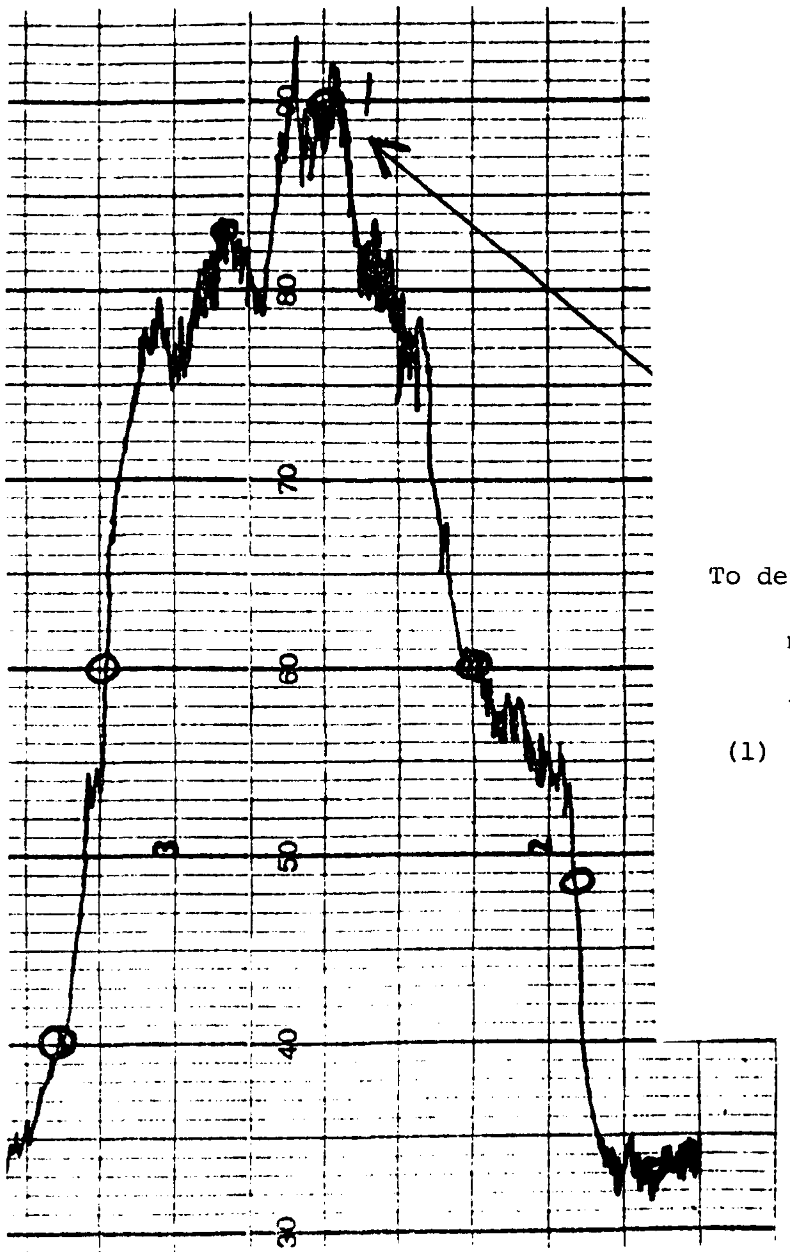
1. (x1) (measured voltage) (2.041) + 0.1429 = concentration (ppb)
2. (x3.16) (measured voltage) (0.6579) + 0.0397 = concentration (ppb)
3. (x10) (measured voltage) (0.2100) + 0.0126 = concentration (ppb)

Actual position of dye concentrations for transects were either located by Loran C coordinates or interpolated by using chart speed and time of transect run between known points.

E. Graphics

Time, location and dye concentrations were plotted on enlargements of the dye drop study area. In addition, plots were made of the center of the dye for each transect sequence so that the dye's path could be

For example:



To determine concentration at 1:

measured voltage = 2.85v

therefore,

(1) (2.85) (2.041) + 0.1429 = 5.95ppb

easily followed for the duration of the study. The dye's center was determined and tabulated by locating the intersection of lines connecting opposite and most distant sides of the dye.

F. Study Limitations

Specific limitations of the present study were:

(1) Weather was a constant problem. In the dye drop of June 24, 1980, dye was followed for approximately 39.5 hours before strong westerly winds forced project termination.

(2) Duration of the dye study was quite short relative to the length of time wastewater would flow into the area.

(3) Oceanographic relationships in the study area are quite complex. The relationships among shoreline configuration, nearshore currents, wind directions, tidal currents and dye movement are not clearly understood. All of these parameters have a direct bearing on the ultimate fate of wastewater released at the proposed outfall.

(4) Location of Loran C during darkness is questionable. For unknown reasons, fixes taken during the evening proved to be unreliable and were not used.

(5) Sampling at 5- and -15 feet. Although on paper it seemed practical to sample for dye at two depths, in the field it was deemed impractical. In order to make timed and fixed traverses so that accurate data can be plotted, one must be able to record data instantly while continuing along a fixed tract.

When an attempt was made to switch from -5 ft to -15 ft, the vessel had to be stopped because of the time necessary to purge the intake line from dye at -5 ft, thus terminating the -5 ft transect. When this difficulty was identified, it was decided to stay with -5 ft traverse and forsake simultaneous data at -15 ft.

III. RESULTS

A. Influence of Wind on Current Direction

Comparison of instantaneous current data from Chapter 5* for falling and rising tides for May 27-June 2 and June 23-25, 1980 is summarized below:

(1) Falling Tides May 27 - June 2.

Surface currents at all stations were affected by prevailing winds: north and northwest winds resulted in southeast currents (Transect 1, May 29 and June 2); northeast winds caused southwesterly currents (Transect 5, May 27); sustained easterly winds drove falling surface currents to the west (Transect 1, May 28), whereas evanescent land-breezes had little effect. Falling currents at depth were more conservative in response to wind but often exhibited higher speeds. The influence of sustained winds on mid-depth and bottom currents was seen at offshore stations (Transect 1, May 28).

(2) Rising Tides May 27 - June 2.

Currents at all stations were affected by prevailing winds differently than noted for falling tides. Intermittent east winds weakened and confused currents, whereas sustained east winds drew currents toward land. Rising currents at depth were stronger and affected by wind less than surface currents. Deep currents in the northwest quadrant of the project area were notably strong. The greatest vertical shear (175^{o}) observed during the study period was noted on a flood tide at Station 3G, at 1815 hrs on May 27 in 10.5 m (34.5 ft); surface currents were headed at 265^{o} and bottom currents were moving due east.

3. Falling Tides and Rising Tides June 23 - 25.

Tidal effects were more complex in the survey of June 23-25 than in the previous study due to westerly winds and the progression from mixed to semi-diurnal tides. Tides were earlier and amplitudes were greater at the north end of the NPCEA project area than the south.

Effects of westerly winds were seen in the easterly component of rising and falling tides. From the combined studies, data on currents now are available for winds from all but southerly quarters

*Chapter 5 - Marine Sampling and Measurement Program off Northern Pinellas County, Florida. A Technical Report. EPA 904/9-82-102. Region 4, 345 Courtlant Street, N.E., Atlanta, GA. pp 97-197.

(SE, S, SW) and for periods of no wind. While currents in calm weather could be inferred from available data, no basis exists for the assessment of current response to southerly winds. Studies should be conducted under prevailing southerlies to assess heading and speed of currents, mass-transport and tidal effects, since winds from the south are common (Defense Mapping Agency, 1975).

West winds may have accumulated a mass of water nearshore which affected or caused some of the trends observed in the combined studies. Notable differences in current direction and speed, the movement of drogues and dye and patterns of water chemistry were seen between the first study, when easterly winds prevailed, and the second. In particular, the rapid offshore movement of currents and dye under east winds was not paralleled by onshore drift under west winds of comparable duration and intensity.

Comparison of instantaneous current data for rising and falling tides for June 24 and June 25 suggest little variation at each station when surface, mid-water and bottom velocities are compared. On the rising tides (Figure 2: June 24, 0750-0915 and 1700-1813), five out of seven stations showed a strong easterly component of current movement. On falling tides, with a westerly or southwesterly wind (Figure 3: June 24, 1980, 1245-1635 and Figure 4: June 25, 1980, 1030-1450) currents tend to flow to the southeast or south at an angle approximately 90° to the direction of the wind.

Thus, the June drop, released at low tide, should have migrated eastward, ranging between east-northeast and east-southeast in response to the rising tide through 0940 and then turned and migrated in a direction ranging between south and southeast until 1700 hours.

B. Center of the Dye

Tabulated data of the dye's center (Table 1) was used to show its migration pattern (Figure 5). According to the data, the June dye drop moved southward, east-northeast, northeast, southwest, and then south.

Based upon the relationship between wind and current direction, it seems hard to believe the dye followed the path shown in Figure 5. Because of the now acknowledged problem with using Loran C at night, it seems more reasonable that the dye was not dropped at Station 3F (Loran coordinates were used to fix the location), but the station was not marked with a buoy.

After 39.5 hrs the dye continued to be visible, but with difficulty. An attempt was made to locate the dye on June 26, 1980 at 0830 hrs by returning to the location where the dye was last recorded the evening before and using the monitoring equipment from the location to the entrance of Clearwater Harbor. No dye was located by this effort.

Drogues proved to be worthless in following the dye. As fast as they were thrown overboard they disappeared to the east while the dye continued to move to the northeast the evening of June 24, 1980. Presumably, the rapid eastward movement of the drogues was a direct result of persistent westerly winds at the time.

C. Time - Distance Migration of the Dye

Aerial Photos 1-4, taken of the first dye drop on May 27, 1980, show the initial release and subsequent configurations of the dye. Twenty minutes after the dye was released (Aerial Photo 3) it had moved a significant distance to the south and away from the dye release vessel (at anchor). By this time it had developed its characteristic leading edge of concentrated dye and comet-like tail. After two hours and seven minutes (Aerial Photo 4), the dye continued its characteristic pattern, but by that time had swung toward the southwest. At 1850 hrs the dye tracking was discontinued. The leading edge at that time remained the most concentrated.

In an attempt to follow the dye and show its configuration and distribution during the June study, five isopleth maps (Figures 6-10) were constructed from the tabulated data (Tables 2-6).

Although no data was collected for the construction of isopleth maps on the morning of June 24, an aerial photograph (Aerial Photo 5) shows the dye to be a relatively small patch four hours and twenty-eight minutes after the dye drop. Because the patch was so small, we elected to follow rather than disturb it by making traverses through the body. Instead of developing the characteristic leading edge ball of concentrated dye and comet-like tail of the May drop, the June drop developed an elliptical shape oriented in a northeast-southwest direction (Figure 6) and migrated slowly as compared to the relatively rapid movement of the May drop.

Between 1415-1507 hrs (Figure 6) and 1830-2033 hrs (Figure 7) the dye orientation appears to have rotated to an east-west direction with three lobes extending toward the north. At 1610 hrs there remained a visibly sharp southern and very diffuse northern boundary (Aerial Photo 6). By 1956 hrs the sharp southern boundary had disappeared (Aerial Photo 7) and the dye was becoming more difficult to follow visually.

During the evening of June 24 and the early morning hours of June 25, the dye was tracked by using the fluorometer, but traverses were not made.

Figure 8 suggests there was not a great deal of difference between the dye's shape on the morning of June 25 as compared to the isopleth constructed between 1320-1503 hrs (Figure 9) the dye had migrated a significant distance to the southwest and became more elongate in a north-south direction and had become significantly dilute.

Between 1320-1503 hrs (Figure 9) and 1645-1900 hrs (Figure 10) the most concentrated portion continued to move to the southwest and the patch continued to become elongate to the north. Presumably, the northeast-southwest elongation was in response to predominant westerly winds and current flow to the south and southwest on falling tides and on incoming tides a northeast component.

IV. DISCUSSION

Predominant wind direction appears to influence, but not necessarily dominate direction of dye migration. During the May drop, predominant winds in the area were from the east and northeast, and the dye moved from Station 3F to the south and southwest--a direction consistent with wind affected dye migration and falling tide. However, in June, when winds were consistently from the west, overall movement of the dye was to the south. Thus, although an offshore wind may help to move dye away from the beach, an onshore wind of the velocities sampled will not necessarily move dye onto the beaches. It is possible that the water mass between 3F and the shoreline acts as a barrier and prevents eastward migration of the dye when the area is affected by a west wind.

There is an apparent discrepancy between the concentration of dye in Figure 7 and Figure 8. The last transects taken on the evening of June 24 show no concentration of dye in excess of 3.51 ppb, whereas the next morning, 0804-0953 hrs, concentration in excess of seven (7) ppb were recorded. This apparent discrepancy is a function of the operation of the fluorometer and dye distribution. Because the fluorometer, when it records increasing concentrations of dye automatically changes sensitivity through a cycle of increasing sensitivity to minimum sensitivity, when the dye is not spread out appreciably, the boat passes through the high concentration before a record is made. On the evening of June 24, according to the record from the recorder, the fluorometer passed through the various sensitivities associated with increasing concentration, but passed through the most concentrated dye before a record of the high concentration was complete.

V. SUMMARY AND CONCLUSIONS

1. A study was conducted to determine dye dispersion and movement characteristics at the location of a proposed offshore wastewater outfall.

2. Two dye drops and subsequent tracking were conducted. The first was conducted on May 27, 1980 and the second on June 24, 1980.

3. In both cases, dye did not approach the beach. Rather, net movement was to the southwest in May and south in June. May data is of questionable value because of the short duration of the dye-tracking endeavor.

4. Relative to other areas off the west coast of Florida, the study area appears rich in reefs inhabitated by numerous fish species.* Hence, an important recreational fishery appears to thrive in the area.

5. Because the dye approached the northern edge of one of the major reef areas, serious consideration should be given to the biological implications of placing a wastewater outfall in the study area.

---

*See Rept. No. EPA 904/9-82-102. Marine Sampling and Measurement Program off Northern Pinellas County. U.S.E.P.A., Region 4, Atlanta, GA.

APPENDIX

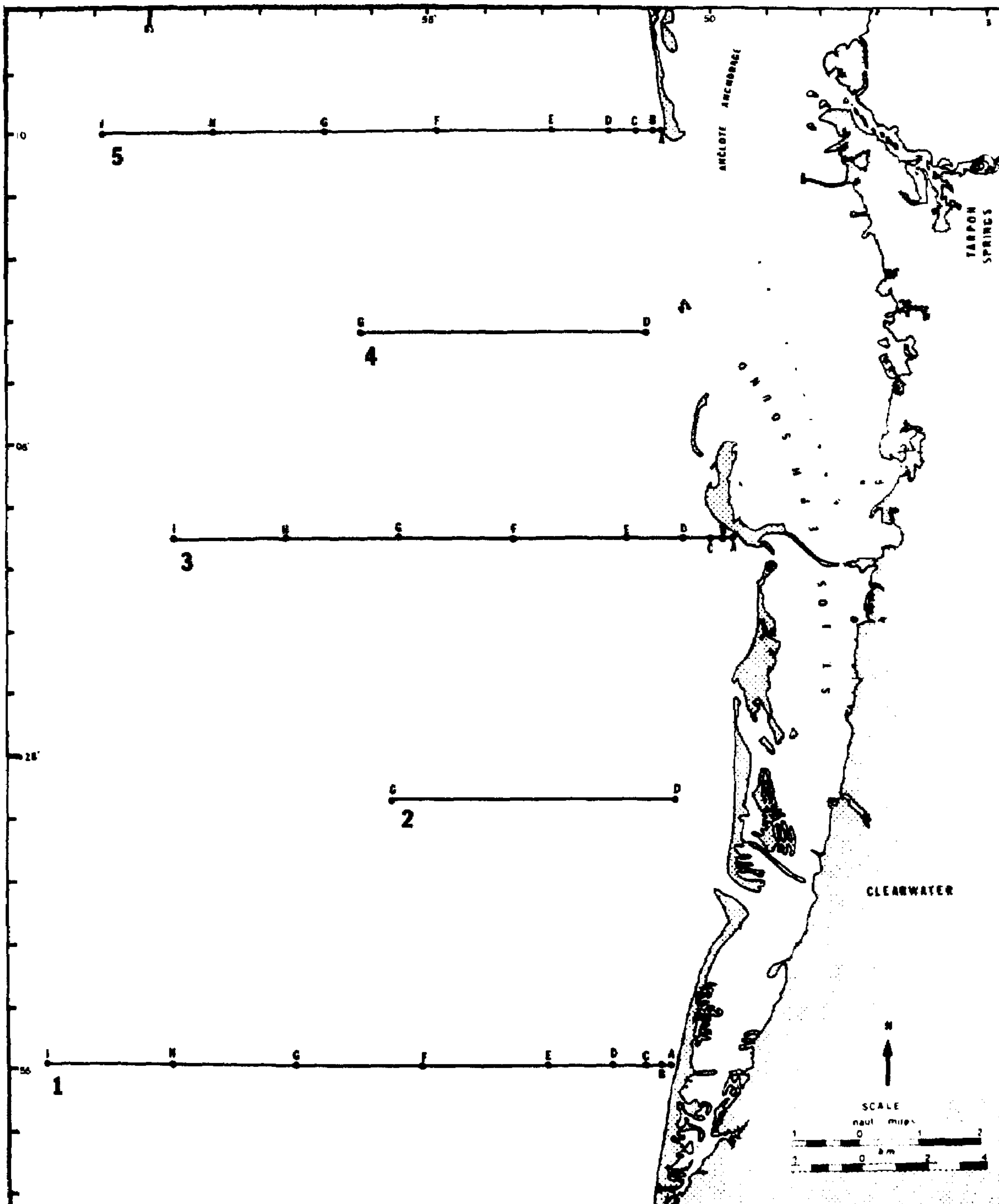


Figure 1. Location of dye drop off the coast of Clearwater, Florida. Station 3F is the location of dye drop.

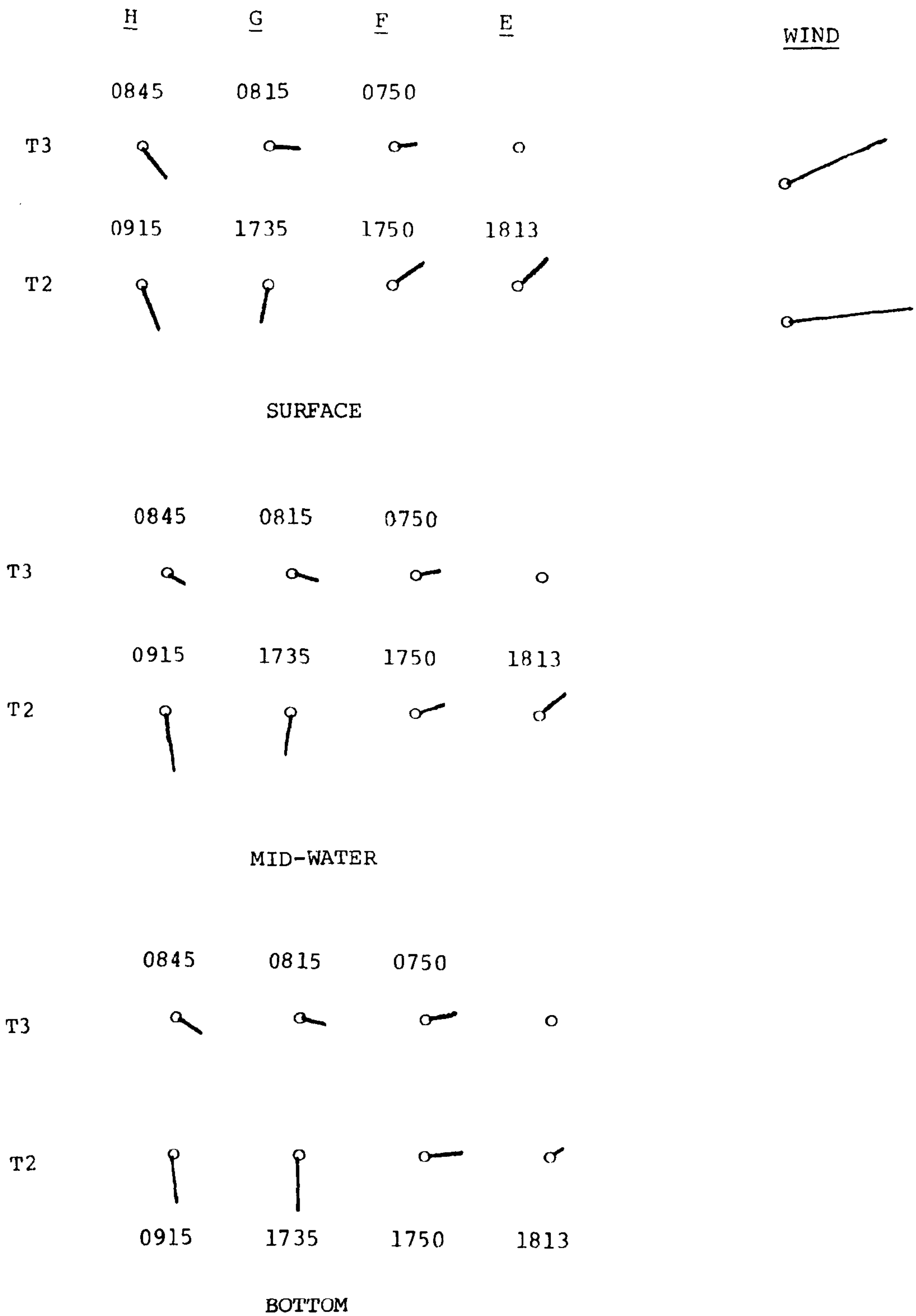


Figure 2. Summary of pertinent current directions at surface, mid-water and bottom. Rising tide between 0750 - 0915 and 1700 - 1813 on June 24, 1980.
Current scale: 1mm = 5cm/sec; Wind scale: 1mm = 1km/hr

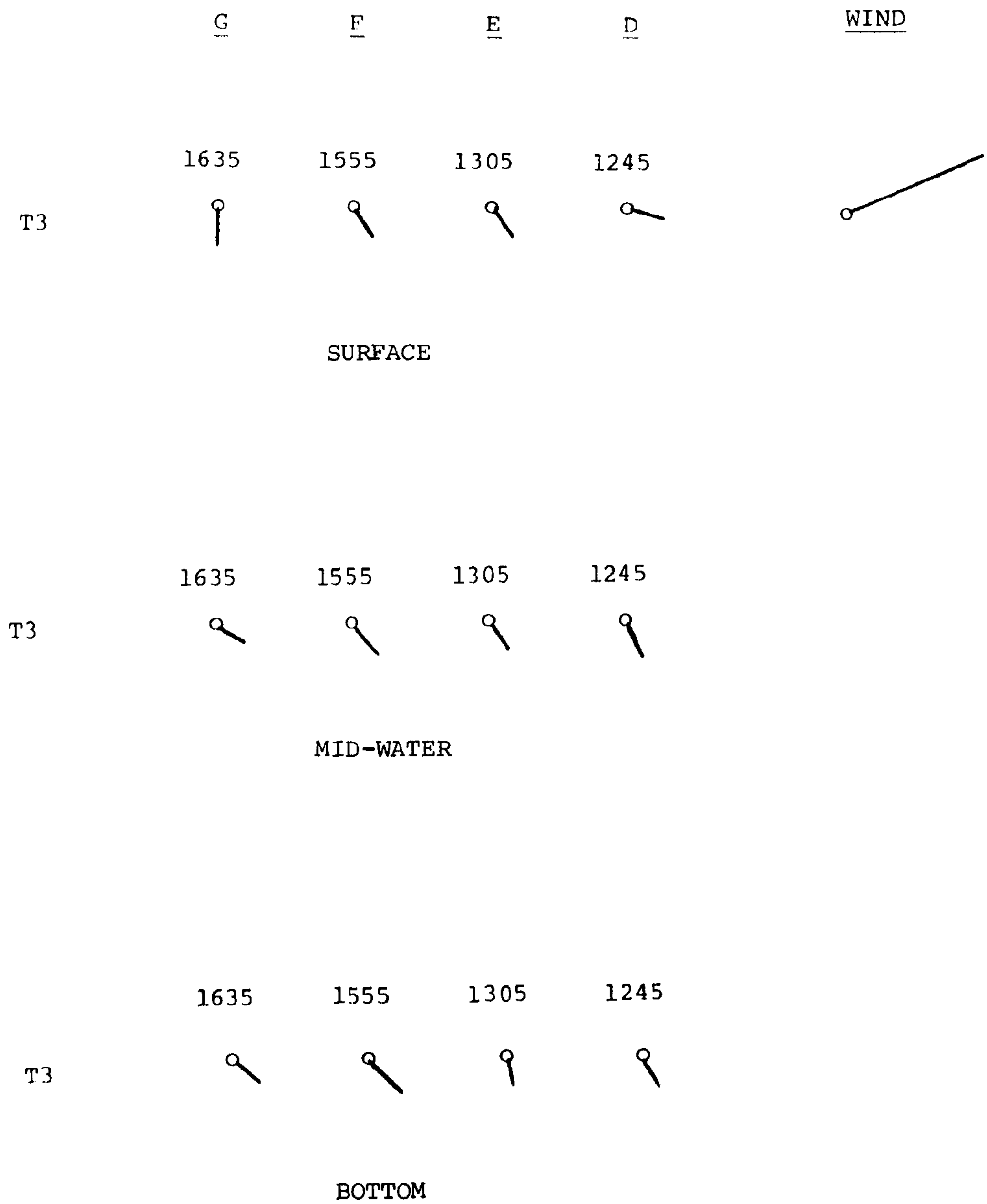


Figure 3. Summary of pertinent current directions at surface, mid-water and bottom. Falling tide between 1245 - 1635 on June 24, 1980.
Wind scale: 1mm = 1km/hr; Current scale: 1mm = 5cm/sec

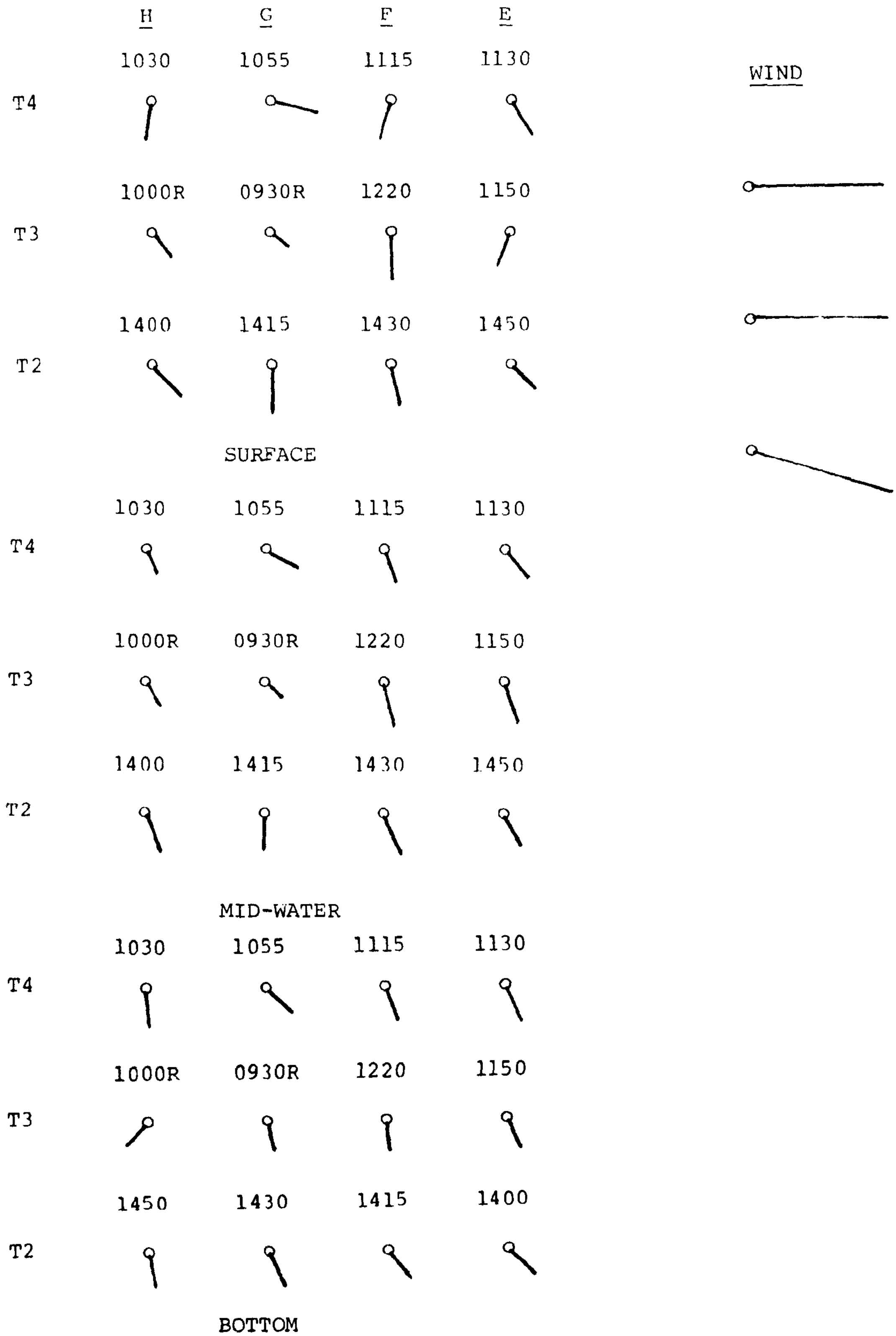


Figure 4. Summary of pertinent current directions at surface, mid-water and bottom. Falling tide between 1030 - 1450 hours on June 25, 1980.
Current scale: 1mm = 5cm/sec; Wind scale: 1mm = 1km/hr

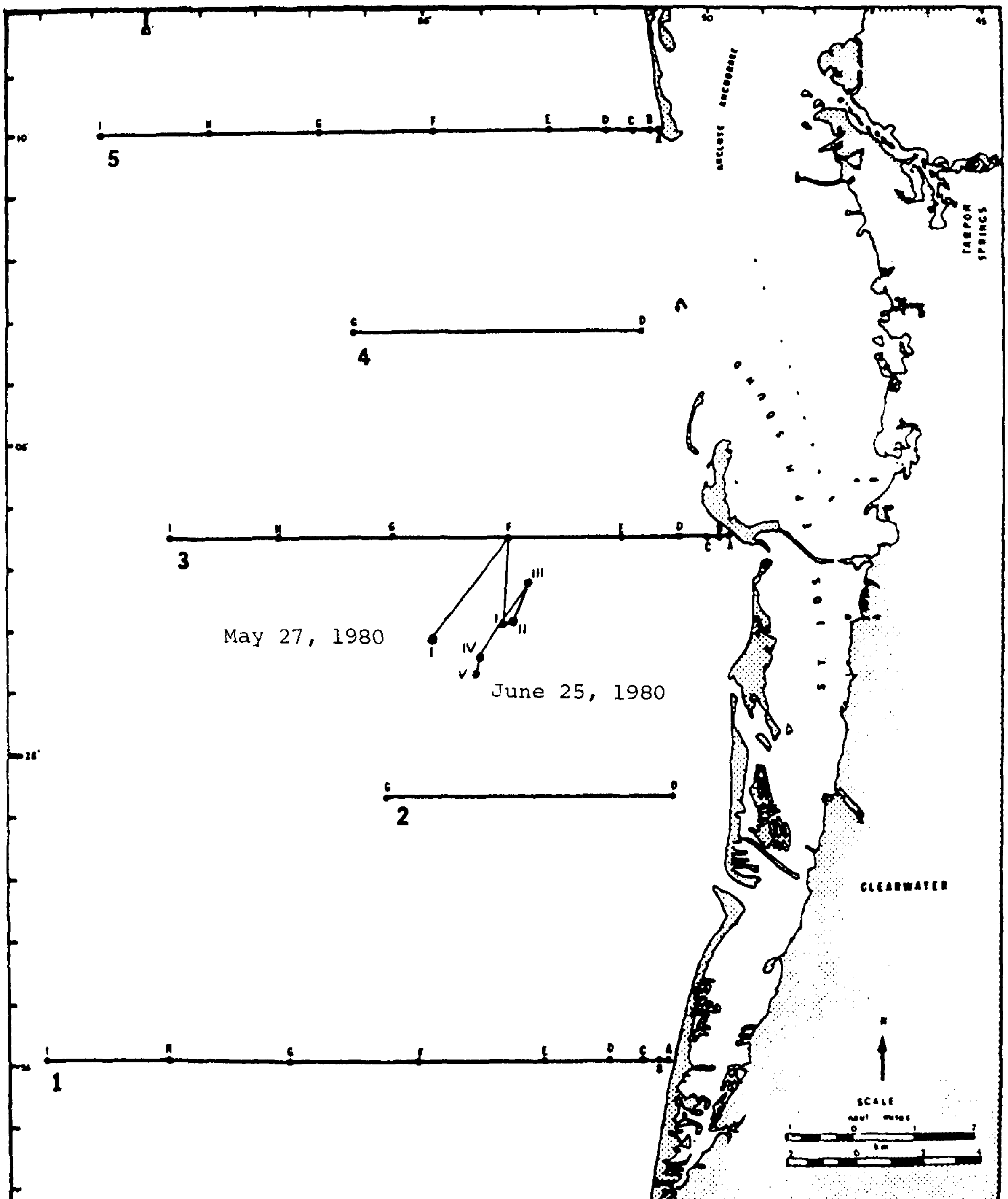


Figure 5. Migration of dye from 1245 to 1850 hours, May 27, 1980, and migration of the dye's center from 0327 hours, June 24, 1980 to 1900 hours, June 25, 1980. Station 3F is the location of dye drop.

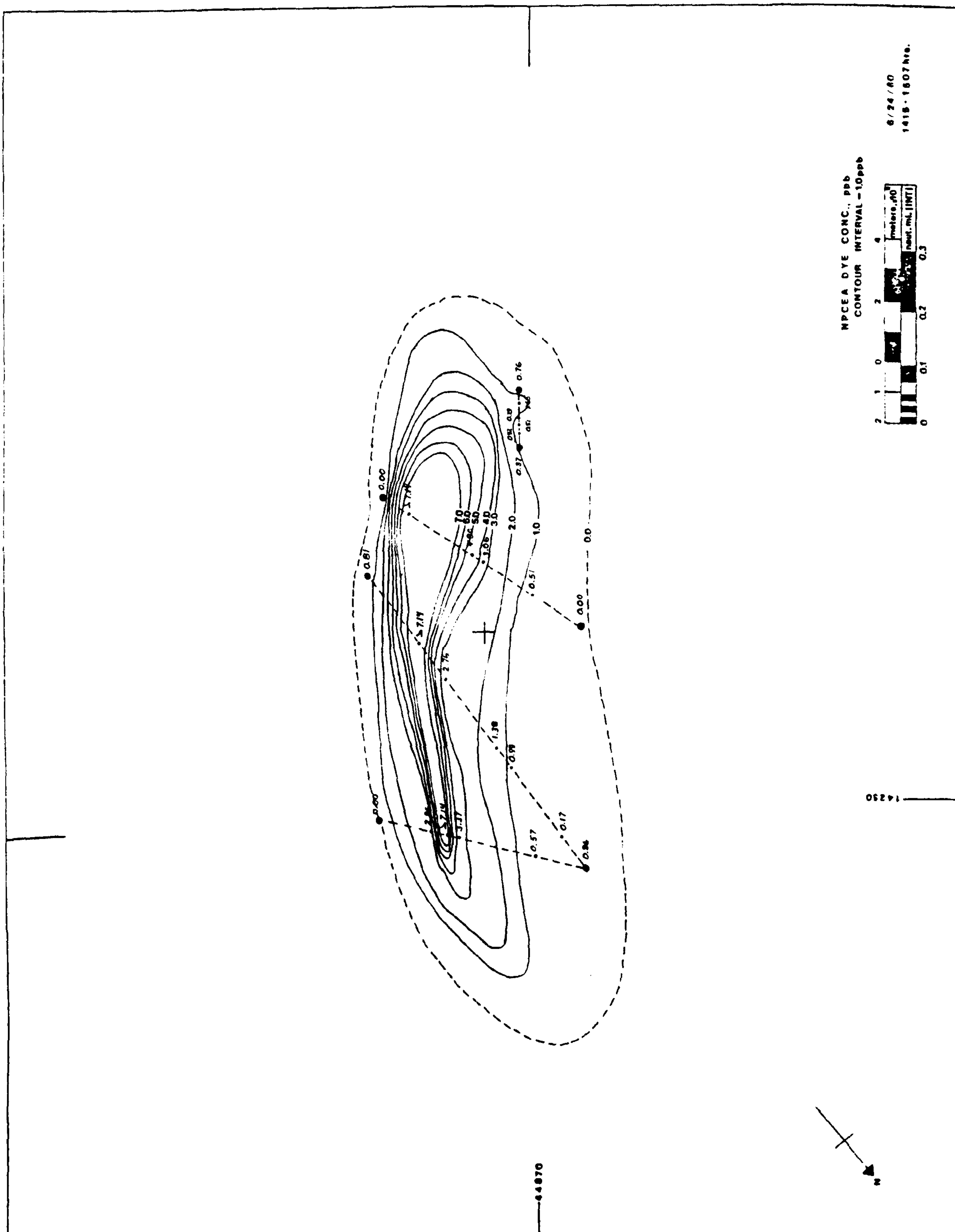


Figure 6. Isopleths showing configuration of dye between 1415 - 1507 hours, June 24, 1980.

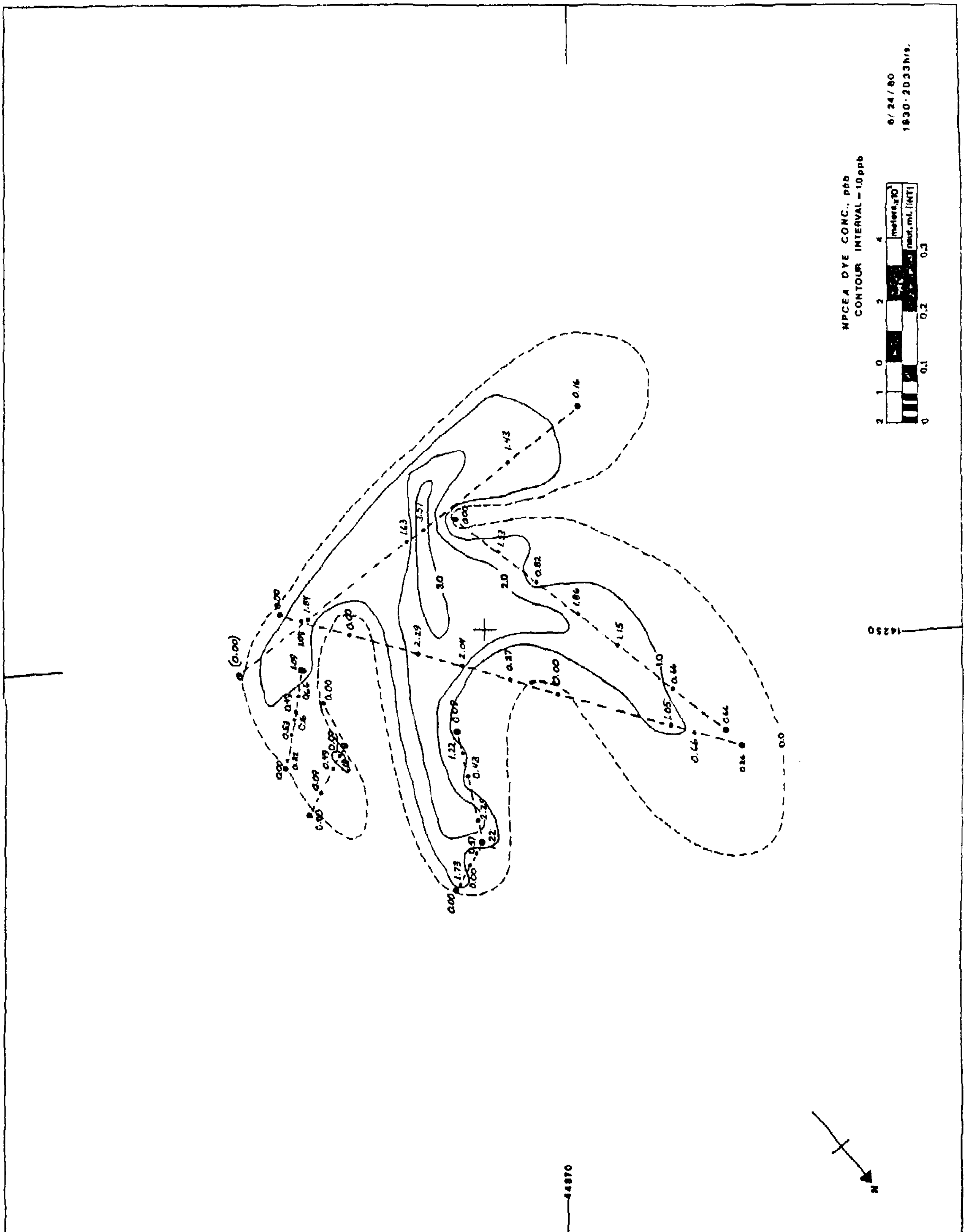


Figure 7. Isopleths showing configuration of dye between 1830 - 2033 hours, June 24, 1980.

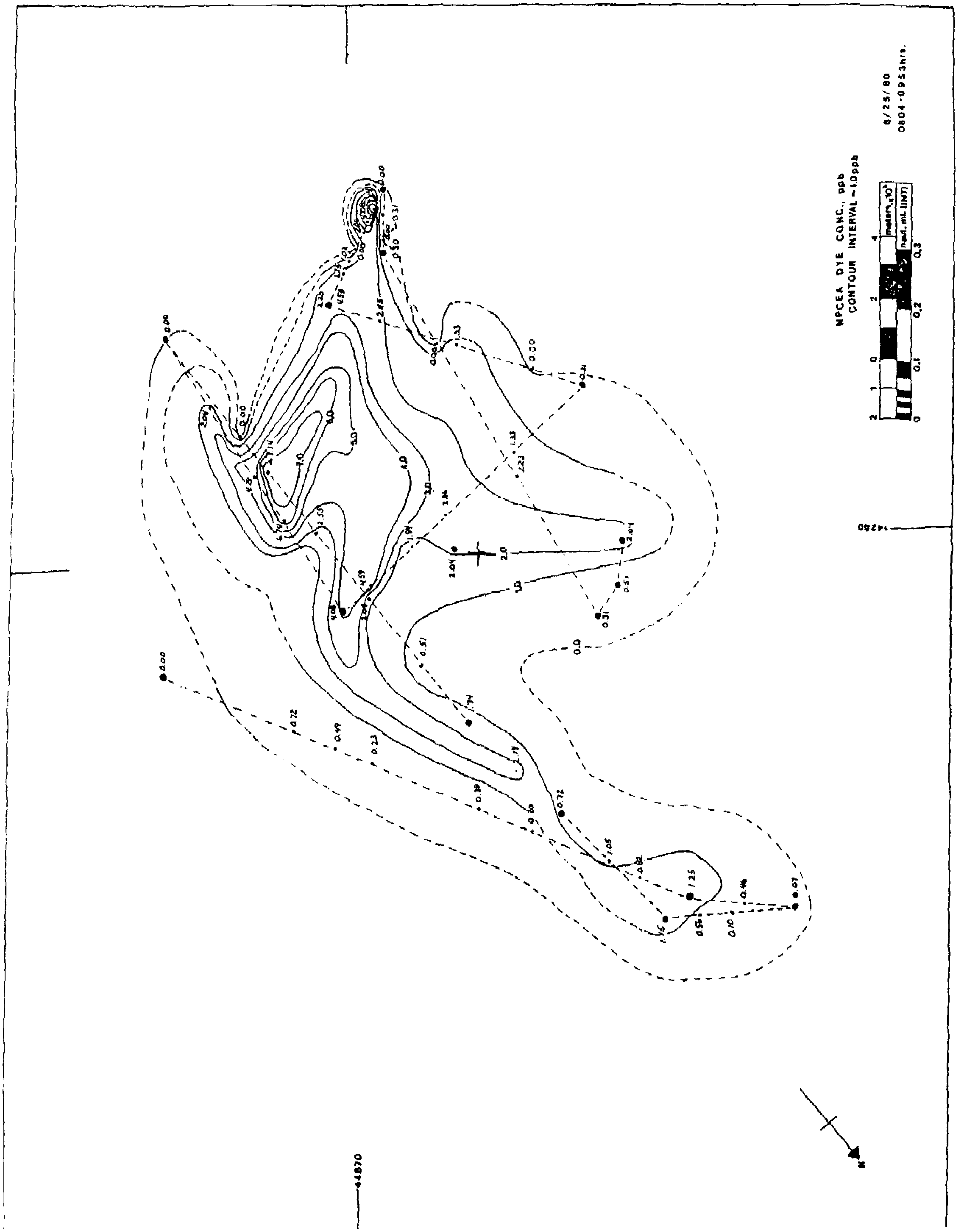


Figure 8. Isopleths showing configuration of dye between 0804 - 0953 hours, June 25, 1980.

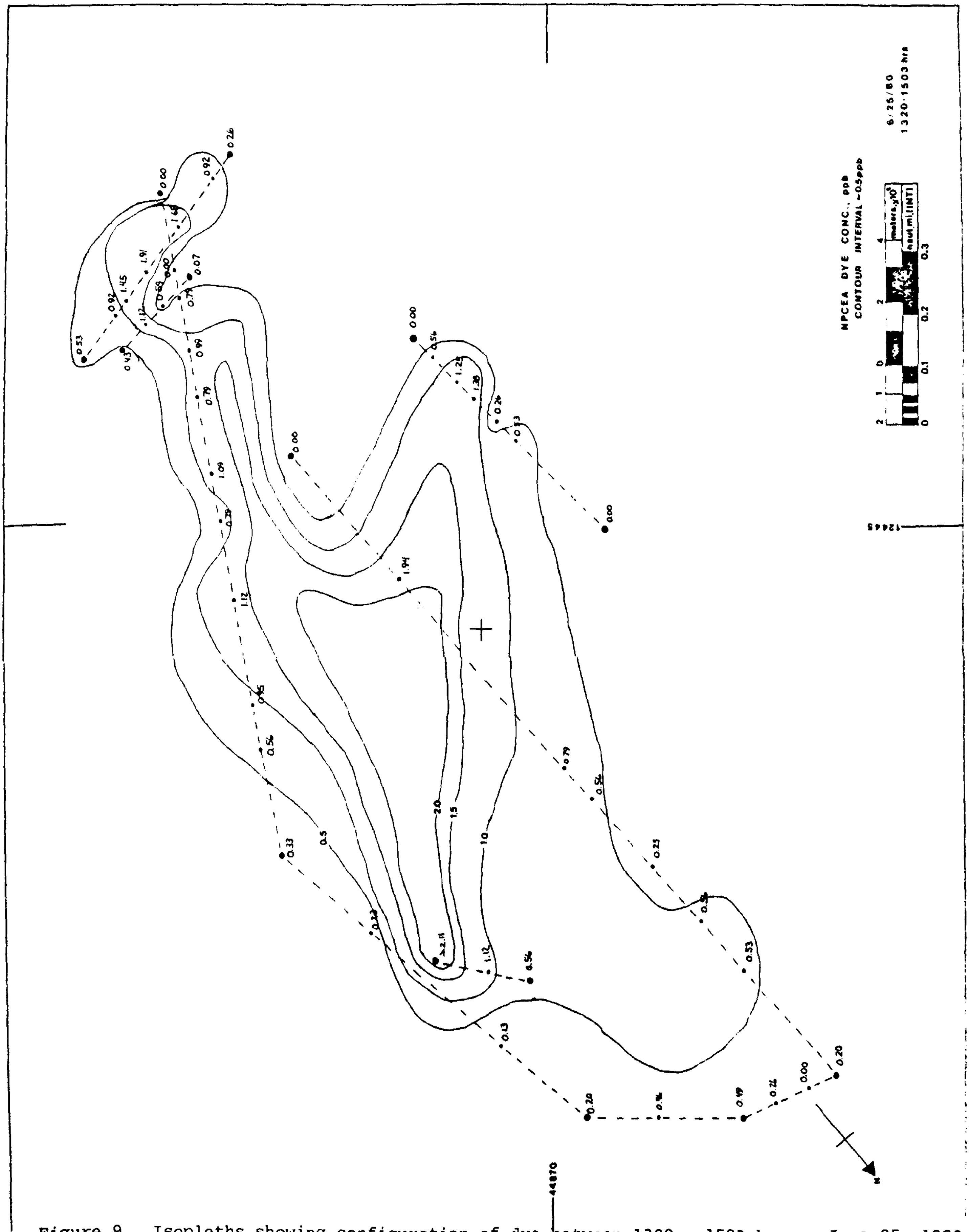


Figure 9. Isopleths showing configuration of dye between 1320 - 1503 hours, June 25, 1980.

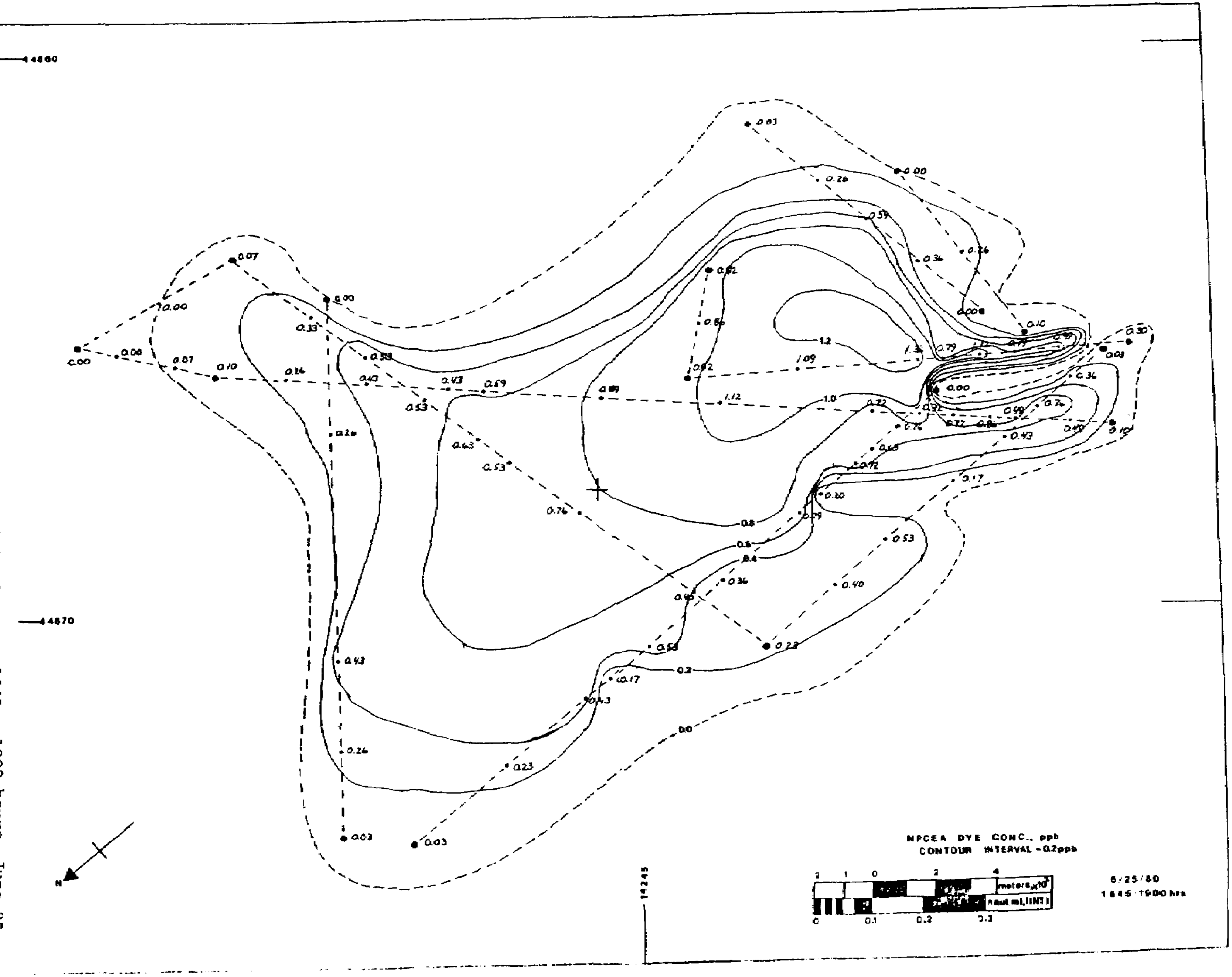


Figure 10. Isopleths showing configuration of dye between 1645 - 1900 hours, June 25, 1980.

Table 1. Loran coordinates of dye's final location on May 27, 1980 and coordinates of dye centers for five discrete sample locations in June.

Date	Time	Site	Loran Coordinates	
5-27-80	1850	I	14245.1	44877.4
6-24-80	1415-1507	I	14248.8	44869.1
6-24-80	1830-2033	II	14249.1	44868.5
6-25-80	0804-0953	III	14250.8	44871.4
6-25-80	1320-1503	IV	14246.2	44868.8
6-25-80	1654-1900	V	14245.1	44867.9

Table 2. Time, transect run, Loran coordinates (LOP) and dye concentration (ppb) for sample Location I on June 24, 1980 (1415-1501).

RUN #	TIME	LOP		VOLTAGE	SENSITIVITY	ppb
1	1415	14249.80	44867.30	0.00	3.16	0.00
		49.87	68.20	1.40	1	2.85
		49.90	68.49	>3.60	1	>7.14
		49.91	68.67	1.65	1	3.36
		50.03	70.00	.87	3.16	0.57
	1422	14250.10	44870.90	1.30	3.16	0.85
2	1422	14250.10	44870.90	1.30	3.16	0.85
		49.90	71.00	.25	3.16	0.16
		49.50	71.20	1.50	3.16	0.98
		49.38	70.76	2.10	3.16	1.38
		48.98	69.32	1.35	1	2.75
		48.77	68.56	>3.50	1	>7.14
	1434	14248.40	44867.20	.40	1	0.81
3	1436	14248.10	44868.20	0.00	3.16	0.00
		48.21	68.49	>3.50	1	>7.14
		48.51	69.24	2.35	1	4.79
		48.55	69.35	1.50	1	3.06
		48.78	69.93	.25	1	0.51
	1445	14249.00	44870.50	0.00	3.16	0.00
4	1459	14247.50	44869.80	.37	1	0.75
		47.56	69.80	2.50	3.16	1.64
		47.65	69.80	1.40	10	0.29
		47.68	69.80	.25	1	0.51
		47.73	69.80	1.40	3.16	0.92
	1501	14247.80	44869.80	1.75	10	0.36

Table 3. Time, transect run, Loran coordinates (LOP) and dye concentrations (ppb) for sample Location II on June 24, 1980 (1830-2033)

RUN #	TIME	LOP		VOLTAGE	SENSITIVITY	ppb
1	1830	14247.80	44870.20	.25	3.16	0.16
		48.12	68.98	1.80	3.16	1.18
		48.60	67.15	.80	1	1.63
		48.76	66.54	1.75	1	3.57
		49.08	65.32	.70	1	1.42
	1840	14249.40	44864.10	0.00	1	0.00
2	1843	14249.50	44865.70	0.00	1	0.00
	1844	14249.70	44865.90	0.00	1	0.00
3	1844	14249.70	44865.90	0.00	1	0.00
		49.74	65.84	1.80	3.16	1.18
		49.83	65.70	.75	3.16	0.49
		49.96	65.50	.15	3.16	0.09
	1847	14250.10	44865.30	0.00	3.16	0.00
4	1850	14249.80	44864.90	0.00	3.16	0.0
		49.75	64.94	.48	3.16	0.31
		49.63	65.03	.80	3.16	0.52
		49.55	65.10	.25	3.16	0.16
		49.50	65.14	.75	3.16	0.49
		49.43	65.20	1.00	3.16	0.65
	1853	14249.30	44865.30	1.65	3.16	1.08
5	1855	14249.00	44864.90	0.00	3.16	0.00
		49.04	65.31	3.40	3.16	1.08
		49.12	66.12	0.00	1	0.00
		49.24	67.33	1.12	1	2.28
		49.32	68.14	1.00	1	2.04
		49.40	68.95	.13	1	0.26
		49.48	69.76	0.00	1	0.00

Table 3. Continued. Time, transect run, Loran coordinates (LOP) and dye concentrations (ppb) for sample Location II on June 24, 1980 (1830-2033).

RUN #	TIME	LOP		VOLTAGE	SENSITIVITY	(ppb)
5	1855	49.68	71.79	1.60	3.16	1.05
		49.72	72.19	1.00	3.16	0.65
	1905	14249.80	44873.00	.40	3.16	0.26
6	1907	14249.70	44872.80	.10	3.16	0.06
		49.46	71.84	1.00	3.16	0.65
		49.22	70.88	1.75	3.16	1.15
		49.04	70.16	2.85	3.16	1.87
		48.86	69.44	.40	1	0.81
		48.68	68.72	.75	1	1.53
	1915	14248.50	44868.00	0.00	3.16	0.00
7	2028	14249.70	44868.00	.12	3.16	0.07
		49.82	68.08	.65	3.16	0.42
		49.94	68.16	4.90	3.16	3.22
		50.18	68.32	1.10	1	2.24
	2030	14250.30	44868.40	.60	1	1.22
8	2030	14250.30	44868.40	.60	1	1.22
		50.35	68.33	.25	1	0.51
		50.40	68.25	0.00	1	0.00
		50.47	68.15	0.00	1	0.00
	2033	14250.50	44868.10	.85	1	1.73

Table 4. Time, transect run, Loran coordinates (LOP) and dye concentrations (ppb) for sample Location III on June 25, 1980 (0804-0902)

RUN #	TIME	LOP		VOLTAGE	SENSITIVITY	ppb
1	0804	14251.10	44866.60	0.00	3.16	0.00
		51.43	68.96	1.10	3.16	0.72
		51.53	69.74	0.75	3.16	0.49
		51.62	70.40	0.35	3.16	0.23
		51.88	72.30	0.60	3.16	0.39
		52.01	73.25	0.30	3.16	0.19
		52.27	75.15	1.25	3.16	0.82
	0824	14252.40	44876.10	1.90	3.16	1.25
2	0824	14252.40	44876.10	1.90	3.16	1.25
		52.45	77.05	0.70	3.16	0.46
	0828	14252.50	44878.00	0.10	3.16	0.06
3	0828	14252.50	44878.00	0.10	3.16	0.06
		52.55	76.80	0.15	3.16	0.09
		52.58	76.20	0.85	3.16	0.55
	0834	14252.60	44875.60	1.75	3.16	1.15
4	0834	14252.60	44875.60	1.75	3.16	1.15
		52.25	75.19	1.60	3.16	1.05
	0842	14251.97	44874.86	1.10	3.16	0.72
5	0850	14251.40	44874.20	0.85	1	1.73
		51.05	73.02	0.25	1	0.51
		50.67	71.76	1.00	1	2.04
		50.30	70.50	1.25	1	2.55
		49.95	69.32	>3.50	1	>7.14
		49.75	68.65	0.00	1	0.00
	0902	14249.20	44866.80	0.00	1	0.00

Table 4. Continued. Time, transect run, Loran coordinates (LOP) and dye concentrations (ppb) for sample Location III on June 25, 1980 (0902-0953).

RUN #	TIME	LOP		VOLTAGE	SENSITIVITY	ppb
6	0902	14249.20	44866.80	0.00	1	0.00
		49.60	67.63	1.00	1	2.04
		50.00	68.45	2.10	1	4.28
		49.73	68.98	3.30	1	6.73
	0907	14250.80	44870.10	2.00	1	4.08
7	0907	14250.80	44870.10	2.00	1	4.08
		50.67	70.57	2.25	1	4.59
		50.46	71.30	0.95	1	1.93
		50.30	71.91	1.40	1	2.85
		49.95	73.15	0.65	1	1.32
	0915	14249.60	44874.40	0.15	1	0.30
8	0915	14249.60	44874.40	0.15	1	0.30
		49.50	73.50	0.00	1	0.00
		49.20	70.80	1.25	1	2.55
	0919	14249.10	44869.90	1.10	1	2.24
9	0919	14249.10	44869.90	1.10	1	2.24
		49.05	69.99	2.25	1	4.59
		48.94	70.16	1.35	1	2.75
		48.88	70.25	0.50	1	1.02
		48.82	70.36	0.00	1	0.00
		48.72	70.52	1.00	1	2.04
		48.68	70.58	2.00	1	4.08
		48.60	70.70	>3.50	1	>7.14
	0930	14248.50	44870.50	0.00	1	0.00
10	0932	14248.50	44870.50	0.10	1	0.20
		48.62	70.50	0.15	1	0.30
		48.74	70.50	0.00	1	0.00
	0937	14248.80	44870.50	0.15	1	0.30

Table 4. Continued. Time, transect run, Loran coordinates (LOP) and dye concentrations (ppb) for sample Location III on June 25, 1980 (0902-0953).

RUN #	TIME	LOP		VOLTAGE	SENSITIVITY	ppb
11	0937	14248.80	44870.50	0.15	1	0.30
		49.30	71.57	0.00	1	0.00
		50.02	73.16	0.60	1	1.22
	0946	14250.78	44874.80	0.15	1	0.30
12	0946	14250.78	44874.80	0.15	1	0.30
	0947	14250.63	44875.25	0.25	1	0.51
13	0947	14250.63	44875.25	0.25	1	0.51
	0948	14250.43	44875.35	0.25	1	0.51
14	0953	14250.30	44872.10	1.00	1	2.04

Table 5. Time, transect run, Loran coordinates (LOP) and dye concentrations (ppb) for sample Location IV on June 25, 1980 (1320-1456).

RUN #	TIME	LOP		VOLTAGE	SENSITIVITY	ppb
1	1320	14248.10	44869.80	0.85	3.16	0.55
		47.47	68.77	1.70	3.16	1.11
	1327	14247.00	44868.00	>3.20	3.16	>2.10
2	1353	14245.60	44870.80	0.00	3.16	0.00
		45.14	69.28	0.80	3.16	0.52
		45.04	68.95	0.40	3.16	0.26
		44.92	68.56	2.10	3.16	1.38
		44.83	68.26	1.90	3.16	1.25
		44.70	67.83	0.85	3.16	0.55
	1357	14244.60	44867.50	0.00	3.16	0.00
3	1401	14245.20	44865.40	0.00	3.16	0.00
	1403	14245.10	44865.60	0.10	3.16	0.06
		45.82	67.48	2.95	3.16	1.94
		46.94	70.03	1.20	3.16	0.78
		47.08	70.77	0.85	3.16	0.55
		47.48	71.80	0.35	3.16	0.23
		47.80	72.65	0.85	3.16	0.55
		48.09	73.40	0.80	3.16	0.52
	1420	14248.70	44875.00	0.30	3.16	0.19
4	1420	14248.70	44875.00	0.30	3.16	0.19
		48.80	74.34	0.00	3.16	0.00
		48.90	73.68	0.40	3.16	0.26
	1422	14249.00	44873.00	0.75	3.16	0.49

Table 5 . Continued. Time, transect run, Loran coordinates (LOP) and dye concentrations (ppb) for sample Location IV on June 25, 1980 (1320-1503).

RUN #	TIME	LOP		VOLTAGE	SENSITIVITY	ppb
5	1422	14249.00	44873.00	0.50	3.16	0.32
		48.95	71.60	0.70	3.16	0.46
	1425	14248.90	44870.20	0.30	3.16	0.19
6	1425	14248.90	44870.20	0.30	3.16	0.19
		48.45	68.86	0.20	3.16	0.13
		47.76	66.79	0.35	3.16	0.23
	1433	14247.30	4486.54	0.50	3.16	0.32
7	1433	14247.30	44865.40	0.50	3.16	0.32
		46.75	65.19	0.85	3.16	0.55
		46.45	65.08	1.45	3.16	0.95
		45.89	64.87	1.70	3.16	1.11
		45.45	64.70	1.20	3.16	0.78
		45.19	64.60	1.65	3.16	1.08
		44.75	64.43	1.20	3.16	0.78
		44.49	64.34	1.50	3.16	0.98
		44.19	64.22	1.20	3.16	0.78
		44.04	66.63	0.00	3.16	0.00
	1446	14243.60	44864.00	0.00	3.16	0.00
8	1451	14244.00	44864.30	0.10	3.16	0.06
		44.16	63.70	0.90	3.16	0.59
		44.26	63.31	1.80	3.16	1.18
	1454	14244.40	44862.80	0.65	3.16	0.42
	(Incidental point included to facilitate plotting dye perimeter)					
	(I)1455	14244.50	44862.00	0.05	3.16	0.03
9	1456	14244.50	44862.60	0.08	3.16	0.52
		44.27	63.29	1.40	3.16	0.92
		44.19	63.52	2.20	3.16	1.44
		44.04	63.99	2.90	3.16	1.90
		43.80	64.71	2.55	3.16	1.67
		43.53	65.50	1.40	3.16	0.92
	1503	14243.40	44865.90	0.40	3.16	0.26

Table 6. Time, transect run, Loran coordinates (LOP) and dye concentrations (ppb) for sample Location V on June 25, 1980 (1645-1900).

RUN #	TIME	LOP		VOLTAGE	SENSITIVITY	ppb
1	1645	14244.50	44864.00	1.40	3.16	0.92
		44.55	64.95	1.30	3.16	0.85
	1648	14244.60	44865.90	1.40	3.16	0.92
2	1648	14244.60	44865.90	1.40	3.16	0.92
		43.98	65.78	1.65	3.16	1.08
		43.30	65.64	2.00	3.16	1.31
		43.13	65.61	1.20	3.16	0.78
		42.95	65.57	1.70	3.16	1.11
		42.75	65.53	1.20	3.16	0.78
		42.50	65.48	1.50	3.16	0.98
	1703	14242.10	44865.40	.45	3.16	0.29
3	1705	14242.40	44865.70	0.05	3.16	0.03
		42.60	66.19	0.55	3.16	0.36
		42.80	66.68	1.15	3.16	0.75
		43.00	67.17	0.65	3.16	0.42
		43.30	67.91	0.25	3.16	0.16
		43.70	68.89	0.80	3.16	0.52
		44.00	69.62	0.60	3.16	0.39
	1715	14244.40	44870.60	0.35	3.16	0.23
4	1715	14244.40	44870.60	0.35	3.16	0.23
		44.79	69.59	0.60	3.16	0.39
		45.38	68.08	1.15	3.16	0.75
		45.74	67.14	0.80	3.16	0.52
		47.91	66.71	0.95	3.16	0.62
		46.19	65.99	0.80	3.16	0.52
		46.50	65.20	0.80	3.16	0.52
		46.78	64.48	0.50	3.16	0.32
	1737	14247.20	44863.40	0.10	3.16	0.06

Table 6. Continued. Time, transect run, Loran coordinates (LOP) and dye concentrations (ppb) for sample Location V on June 25, 1980 (1645-1900).

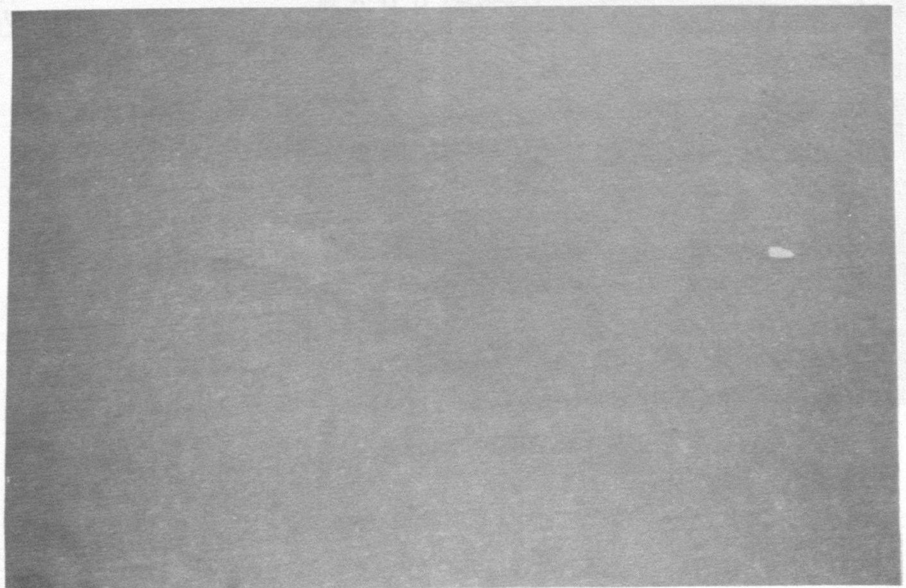
RUN #	TIME	LOP		VOLTAGE	SENSITIVITY	ppb
5	1737	14247.20	44863.40	0.10	3.16	0.06
		47.65	64.10	0.00	3.16	0.00
	1738	14248.10	44864.80	0.00	3.16	0.00
6	1738	14248.10	44864.80	0.00	3.16	0.00
		47.88	64.94	0.00	3.16	0.00
		47.53	65.16	0.10	3.16	0.06
	1740	14247.30	44865.30	0.15	3.16	0.09
7	1740	14247.30	44865.30	0.15	3.16	0.09
		46.90	65.30	0.40	3.16	0.26
		46.45	65.30	0.65	3.16	0.42
		46.00	65.30	0.65	3.16	0.42
		45.80	65.30	0.90	3.16	0.59
		45.15	65.30	1.35	3.16	0.88
		44.50	65.30	1.70	3.16	1.11
		43.65	65.30	1.10	3.16	0.72
		43.40	65.30	1.40	3.16	0.92
		43.20	65.30	1.10	3.16	0.72
		43.00	65.30	1.30	3.16	0.85
		42.85	65.30	0.75	3.16	0.49
		44.55	65.30		3.16	
	1800	14242.30	44865.30	0.15	3.16	0.09
8	1807	14242.90	44864.70	0.00	3.16	0.00
		43.26	63.75	0.55	3.16	0.36
		43.55	63.00	0.90	3.16	0.59
		44.75	62.29	0.40	3.16	0.26
	1814	14244.20	44861.30	0.05	3.16	0.03
9	1820	14243.40	44862.30	0.00	3.16	0.00
		43.75	63.75	0.40	3.16	0.26
	1824	14242.70	44865.20	0.15	3.16	0.09

Table 6. Continued. Time, transect run, Loran coordinates (LOP) and dye concentrations (ppb) for sample Location V on June 25, 1980 (1645-1900).

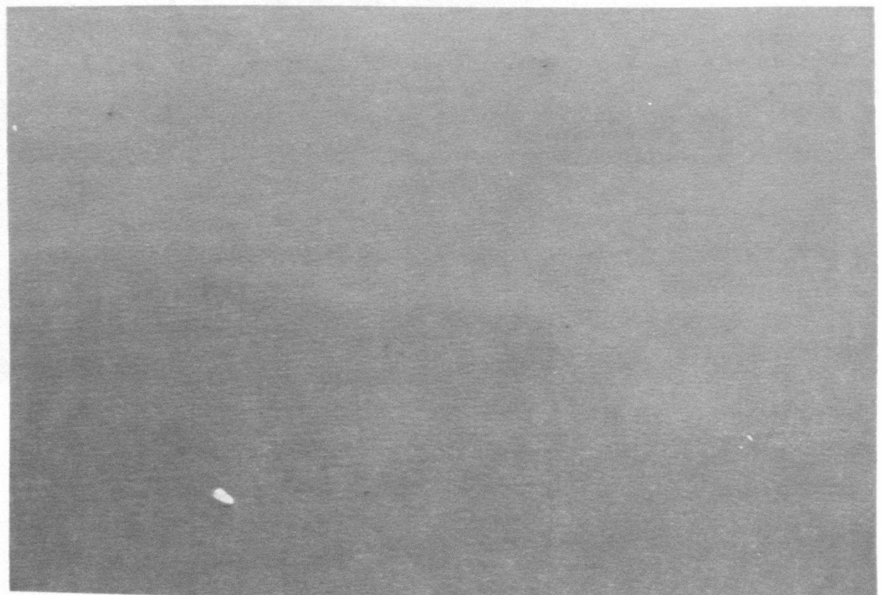
RUN #	TIME	LOP		VOLTAGE	SENSITIVITY	ppb
10	1827	14243.20	44866.30	0.00	3.16	0.00
		43.46	66.97	1.15	3.16	0.75
		43.62	67.39	0.95	3.16	0.62
		43.71	67.64	1.10	3.16	0.72
		43.94	68.23	0.30	3.16	0.19
		44.06	68.59	1.20	3.16	0.78
		44.54	69.83	0.55	3.16	0.36
		44.99	71.00	0.80	3.16	0.52
		45.22	71.59	0.25	3.16	0.16
		45.38	72.01	0.65	3.16	0.42
		45.86	73.27	0.35	3.16	0.23
	1845	14246.40	44874.70	0.05	3.16	0.03
11	1848	14246.80	44873.80	0.05	3.16	0.03
		46.64	72.26	0.40	3.16	0.26
		46.47	70.63	0.65	3.16	0.42
		46.05	66.60	0.40	3.16	0.26
	1900	14246.70	44864.20	0.00	3.16	0.00

Aerial Photo 1. Showing dye patch three minutes after being released on May 27th (Altitude 400 ft).

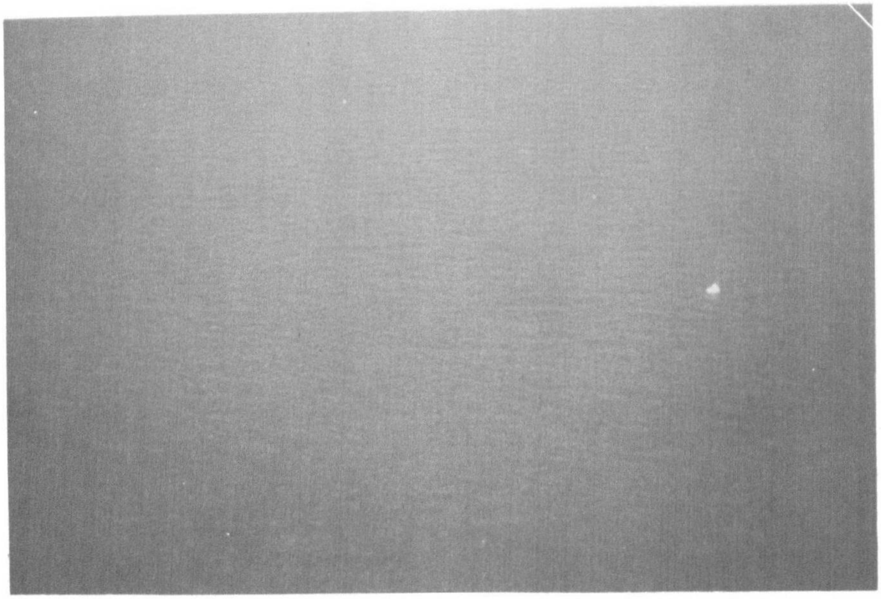
Aerial Photo 2. Dye patch eleven minutes after being released on May 27th (Altitude 800 ft).



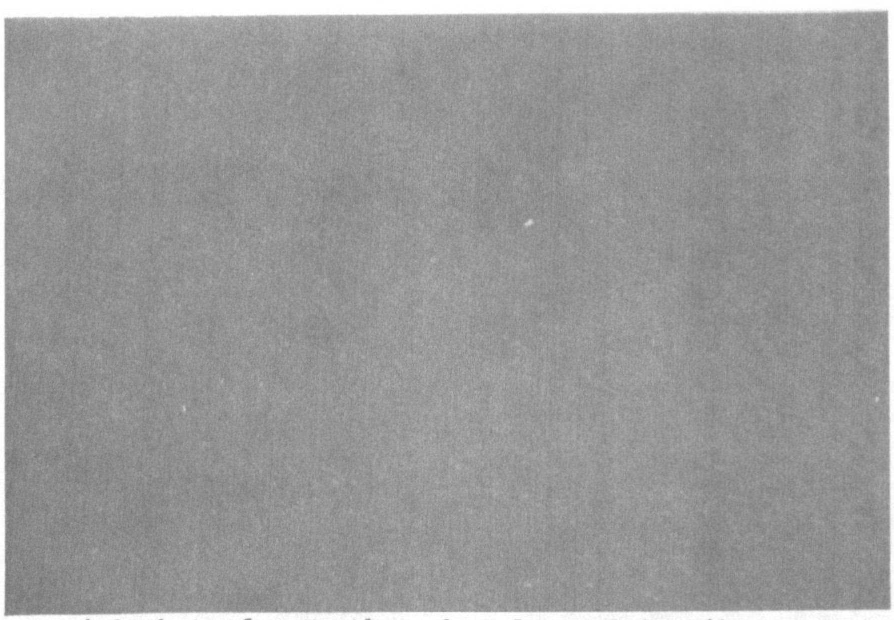
Aerial Photo 3. Characteristic ball and comet-like tail developed 20 minutes after dye drop on May 27th (Altitude 1,000 ft).



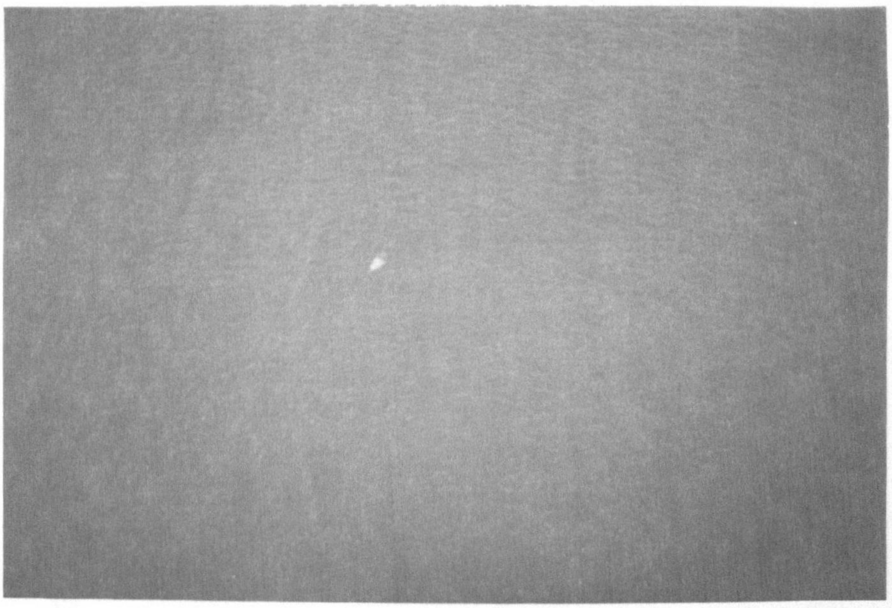
Aerial Photo 4. Leading edge of most concentrated dye and long comet-like tail, two hours and seven minutes after May 27th release (Altitude 800 ft).



Aerial Photo 5. Dye is a relatively small patch four hours and twenty-eight minutes after the June dye drop - 0755 hours (Altitude 1,700 ft).



Aerial Photo 6. Southern boundary of dye (lower part of picture) is much sharper thatn diffuse northern boundary at 1610 hours, June 24th (Altitude 2,300 ft).



Aerial Photo 7. Showing loss of sharp southern boundary and more diffuse dye at 1956 hours (Altitude 1,700 ft).

☆ U.S. GOVERNMENT PRINTING OFFICE 1984—752-340/19064