Environment Canada Environnement Canada

A Remote Sensing Survey of the Chedabucto Bay Oil Spill

K. P. B. Thomson and W. D. McColl

SCIENTIFIC SERIES NO. 26
(Résumé en français)

CANADA CENTRE FOR INLAND WATERS
BURLINGTON, ONTARIO, 1972

Environment Canada
Environnement Canada

A Remote Sensing Survey of the Chedabucto Bay Oil Spill

K. P. B. Thomson and W. D. McColl

SCIENTIFIC SERIES NO. 26
(Résumé en français)

CANADA CENTRE FOR INLAND WATERS
BURLINGTON, ONTARIO, 1972

Contents

Illustrations

Illustrations (cont'd)

Page

Tables

Abstract

The effectiveness of the infrared line scanner, a modified Reconofax IV, as a tool for detecting oil spills was tested at the time of the grounding and subsequent breakup of the oil tanker "Arrow" in Chedabucto Bay, Nova Scotia, February 1970. For photographic surveillance of the spill, a variety of film/filter combinations were used.

Results indicated that the infrared line scanner is useful only when there is a significant temperature difference between the oil and the water. Identification of oil on infrared imagery would be facilitated by the use of a quantitative line scanner. For simple surveillance, photographic imagery is superior, especially when optimum film/filter combinations are used. Photography is limited to daytime observations.

Although either technique can be used to delineate and monitor an oil slick, neither can positively identify oil.

The report includes illustrated examples.

Résumé

L'efficacité du détecteur à radiations infrarouges, un appareil Reconofax IV modifié, comme moyen de scruter les nappes de mazout répandu, a été vérifiée lors de l'échouement et du démembrement qui s'ensuivit du pétrolier "Arrow" dans la Baie de Chedabucto, en Nouvelle-Écosse, en février 1970. Pour l'observation photographique de la nappe de mazout, plusieurs combinaisons de pellicules et de filtres ont été utilisées.

Les résultats ont indiqué que le détecteur à radiations infrarouges n'est utile que s'il existe alors une différence appréciable entre la température du mazout et celle de l'eau. L'identification du mazout sur les images obtenues par radiations infrarouges serait facilitée par l'emploi d'un détecteur "quantitatif". Dans le but de simple observation, l'image photographique est supérieure, surtout si des combinaisons optimum de pellicules et de filtres sont employées. La photographie se limite aux heures du jour.

Quoique l'une ou l'autre des techniques utilisées peut servir à délinéer et observer le mouvement d'une nappe de mazout, aucune d'elles ne peut identifier d'une façon certaine le mazout.

Le rapport présente des exemples au moyen d'illustrations.

A Remote Sensing Survey of the Chedabucto Bay Oil Spill

K. P. B. Thomson and W. D. McColl

INTRODUCTION

On February 4, 1970, the oil tanker ARROW, carrying a cargo of 108,000 barrels of Bunker C fuel oil, went aground on Cerebrus Rock in Chedabucto Bay, Nova Scotia. On February 9, 1970, the wreck broke into two sections. The stern section sank into 90 feet of water on February 12. It has been estimated that by February 12, one half of the total cargo of fuel oil had been released into the environment causing a serious pollution problem. A full account of the ARROW disaster and the clean-up efforts is contained in a recent report: "Task Force Operation Oil", Volumes I, II, and III, issued by the Ministry of Transport.

At the time of the ARROW disaster, the Great Lakes Division, Inland Waters Branch, Department of Energy, Mines and Resources, (now Lakes Research Division, Environment Canada) was in the process of establishing an extensive remote sensing facility for lake research programs (Lane, McColl, and Thomson, 1972). The remote sensing program involved the evaluation of an infrared line-scanning device as well as photographic techniques.

One further aspect of the Lakes Research Division's research program which at that time was purely in the planning stage, was research into the physical and chemical properties of oil on lakes. The detection and delineation of oil patches or plumes through aerial surveillance was considered to be an important aspect of this program. As a result, it was decided that advantage should be taken of the ARROW incident to evaluate the infrared line scanner as a tool for detecting oil spills. In addition, a variety of film/filter combinations were selected for photographic surveillance. This report summarizes and comments on the results of this evaluation experiment.

INSTRUMENTATION

The infrared line scanner used for the experiment was a modified Reconofax IV. The scanner was equipped with a HG Ge detector which is sensitive to radiation in the 8-14 micron spectral band. The data output from this particular scanner provides only a qualitative image of the lake or sea surface temperature structure (Lane, McColl, and Thomson 1972).

The remaining sensors on the aircraft consisted of two 70 mm Vinten cameras, one 35 mm camera with a wide angle lens, and a Barnes PRT - 5 radiometer to provide measurements of sea surface temperatures.

The aircraft used for the mission was a NORTH STAR operated by the National Aeronautical Establishment.

THE REMOTE SENSING SURVEYS

The remote sensing surveys were planned so that a wide variety of imaging conditions would be encountered. The response of the infrared scanner and its ability to image the oil pollutant could be tested and compared, where possible, to simultaneous visual imagery. Flights were scheduled for daytime and nighttime, at both high and low levels. It was hoped that a comparison of the daytime and nighttime imagery would determine the effect of solar illumination of the oil slick and the feasibility of nighttime oil reconnaissance.

The flight lines for each day, February 13 - 15, 1970, are shown in Figures 1 to 4. Table 1 lists the times of flight, general weather conditions, tide levels, and instruments used on each flight. The locations of the first flight lines were determined by visual observations from the aircraft. The high-level lines were flown parallel, with sufficient lateral overlap to mosaic the imagery from the scanner and the wide angle 35 mm camera. This provided a near-synoptic presentation of the distribution of oil over most of the bay area.

During the flights on February 13, it was apparent that oil was still leaking from the two portions of the ship. Several passes at low level were flown over the two long oil plumes streaming from the broken sections. Seven lines were flown at a higher altitude to produce an image mosaic of the area. The visibility deteriorated considerably during the afternoon and a light snowfall made it impossible to attempt a night flight on the 13th. On February 14, the weather was clear and a repeat of the previous day's flights was made. However, it was observed that much less oil was emanating from the two portions of the ship than was observed on the 13th. A reconnaissance flight of the perimeter of the bay was completed and 35 mm colour

Table 1. Summary of remote sensing flights

Flight No.	Date and Time A.S.T.	Weather	Tide			Sensors
			Da.	Time A.S.T.	Ht. in ft.	
1.	Feb. 13/70 10:30 – A.S.T. 13:00	Clear at 10:30 Cloud and haze increasing to cause poor visibility by 13:00	13.	0040 0735 1310 2010	6.2 2.6 6.0 3.0	I.R. Scanner Radiation Therm. 2 Vinten 70 mm Cameras 35 mm wide angle Tracking camera*
2.	Feb. 14/70 11:30 – 13:00 A.S.T.	Clear at 11:30. Some haze and high cloud forming during flight	14.	0130 0835 1410	5.8 2.9 5.7	All sensors on each flight line except cameras not used on night flight
3.	Feb. 14/70 19:30 – 20'30 A.S.T.	Clear, less than 1/10 cloud. Partial moon		2115	3.2	
4.	Feb. 15/70 11:30 – 12:30 A.S.T.	Clear, some haze and high cloud	15.	0230 0935 1535	5.4 3.0 5.6	* wide angle Feb. 13/70 only 35 mm Hand Held Pentax on all daylihgt flights

oblique photos were taken. Infrared imagery and 70 mm colour and false colour vertical photos were taken over areas of heavy oil contamination. On the evening of the 14th, the scheduled nighttime flight was attempted. Navigation was visual, using available moonlight and recognizable lights from the small villages. The two oil slicks that were seen in the daylight were not visible. The low-level lines were flown from Moyac Point at a fixed, predetermined heading in an attempt to image the area of the sunken ship. The infrared scanner was the only imaging instrument that could be employed on the nighttime flights.

On Sunday, February 15, the flow of the oil from the ARROW was reported to be very low. All the remaining lines were flown over oil-fouled beaches and nearshore bays contaminated with heavy oil slicks. The main interest in this flight was to image the oil in an area where fresh ice was formed so that the relative contrasts of the oil, water and ice could be investigated. Auxiliary measurements consisting of 35 mm colour photos and infrared thermometer records were gathered shortly after the flights on the 15th in the vicinity of West Arichat, Crichton Island, and Janvrin Island. The infrared thermometer was used to determine whether a radiation difference could be detected between the heavy oil and the water background from a closeup observation point. No radiation difference between the oil and the water was detectable with the radiation thermometer.

INFRARED IMAGERY

The infrared imagery showing the greatest contrast between the oil and water was obtained on February 13, 1970. Imagery from subsequent flights yielded rather poor contrast which made positive identification of the oil difficult. Figures 5 and 6 show a portion of the infrared imagery taken over the wreck on February 13. The dark patches, indicative of a lower temperature, coincide with the central portions of the oil plumes emanating from the wreck. Away from the central portions of the plume the oil becomes more difficult to identify.

The sharp contrast present in the imagery must be due to differences in emissivity between the oil-water mixture and the bay water. Real temperature differences must be excluded on the basis of the isothermal temperature conditions present in Chedabucto Bay in mid-February.

Radiation thermometer measurements also indicated that the temperature of the oil was the same as the surrounding temperatures. Similar phenomena were observed during the Santa Barbara oil spill (Chandler, 1970).

The oil plumes were not detectable on the infrared imagery taken during the night flight of February 14. This was due to the lack of any significant temperature difference between the oil and water and also the decrease, observed during the daytime survey, in the amount of oil leaking from the wreck.

Figure 7 shows a section of infrared imagery taken along the shore on February 13th. The dark streaks and apparent thermal boundary on the water give some indication of oil. However, this can only be confirmed with reference to the high altitude photographs. The corresponding aerial photographs of this region do show the presence of oil penetrating towards the shore. The dark (cold) areas on the infrared imagery correspond to patches of ice in pools and inlets.

PHOTOGRAPHIC IMAGERY

The most successful film/filter combination for the delineation of the oil slick was the Kodak "Plus X" with a Wratten 39 filter. Figure 8 shows a mosaic of Chedabucto Bay prepared from the February 13 survey. The oil slicks show up very clearly and are directed eastwards by the tidal currents. It is interesting to note that the surface oil has formed wind streaks (note the smoke from the vessel just south of the plume) that are almost normal to the main flow. At the eastern edge, the oil streaks become more elongated and the identity of each plume becomes lost. The apparent remnants from earlier flow appear in the bays along the north shore. Figure 9 shows an enlargement of the main oil plume portion of the large mosaic taken with the same film/filter combination. Penetration of the slick into the bays and shore areas is shown in Figure 10.

Figures 11 and 12 show some examples of photography, using colour and colour infrared film, over the heavily oil-fouled beaches. To some extent the colour infrared (Figure 11A) gives a better definition of the oil along the beach. Trees and seaweed are also better defined with the colour infrared film (Figure 12A). However, in Figure 12A, the colour infrared film gives the false impression that water away from the beach is clear of oil. The same area viewed with ordinary colour film (Fig. 12B) shows a dirty brown colour in the waters close to the shore.

Figures 13, 14, and 15 show the two sections of the wreck taken from different altitudes during the February 13th survey. The main concentration of the oil plumes show very clearly. A comparison of these photographs with the simultaneous infrared imagery (Figures 5 and 6) is a good indication of the problems in the interpretation of infrared imagery of this type of oil spill.

CONCLUSIONS

The most important conclusion to be made from this experiment is that the infrared line scanner can be used to advantage only when certain conditions prevail. This instrument is useful for oil spill surveillance only when there is a significant temperature difference between the oil and the water, a condition that is only likely to persist close to the source of the oil slick. Identification of oil on infrared imagery would be facilitated by the use of a quantitative line scanner. In this instance, small temperature changes could be more easily related to the grey tones of the imagery.

For simple surveillance, the photographic imagery is much superior especially when optimum film/filter combinations are used. Of course, the photography is limited to daytime observation.

It must be remembered that while both the infrared and photographic sensors can be used to delineate and monitor an oil slick, neither technique can positively identify oil. Any operation that requires such positive identification must look to other techniques.

ACKNOWLEDGMENTS

The authors would like to express their thanks to Dr. R. K. Lane, Head, Lake Resources Subdivision, Canada Centre for Inland Waters, who initiated the Chedabucto Remote Sensing Survey. We would also like to express our thanks to the National Aeronautical Establishment for providing the aircraft for this experiment.

REFERENCES

Chandler, P.B., 1970. Remote Sensing of Oil Polluted Sea Water. North American Rockwell Corporation Report.

Lane, R.K., W.D. McColl, and K.P.B. Thomson. Report on Remote Sensing at Canada Centre for Inland Waters. In press.

APPENDIX

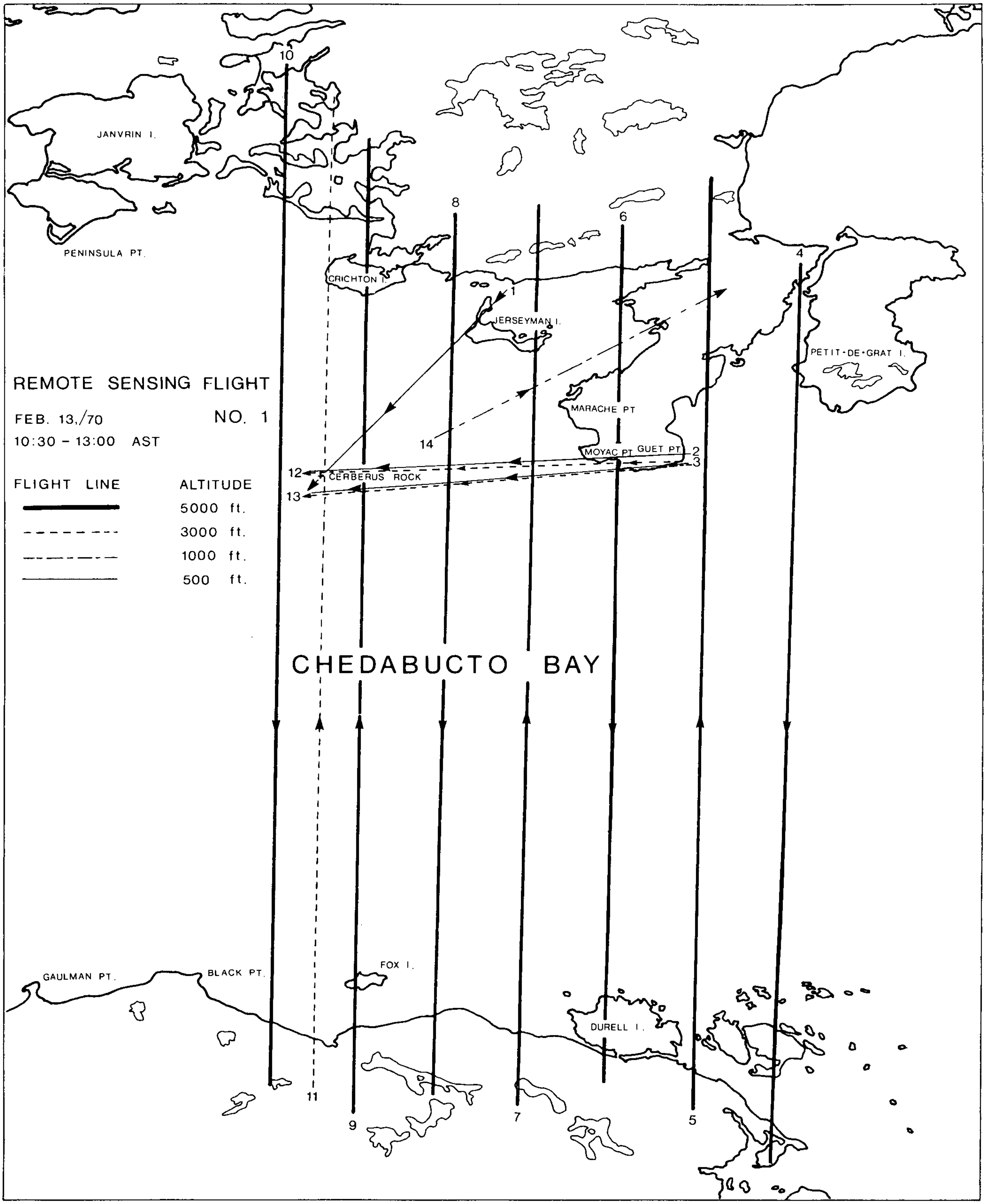


Figure 1. Chedabucto Bay, remote sensing flight no. 1, February 13, 1970.

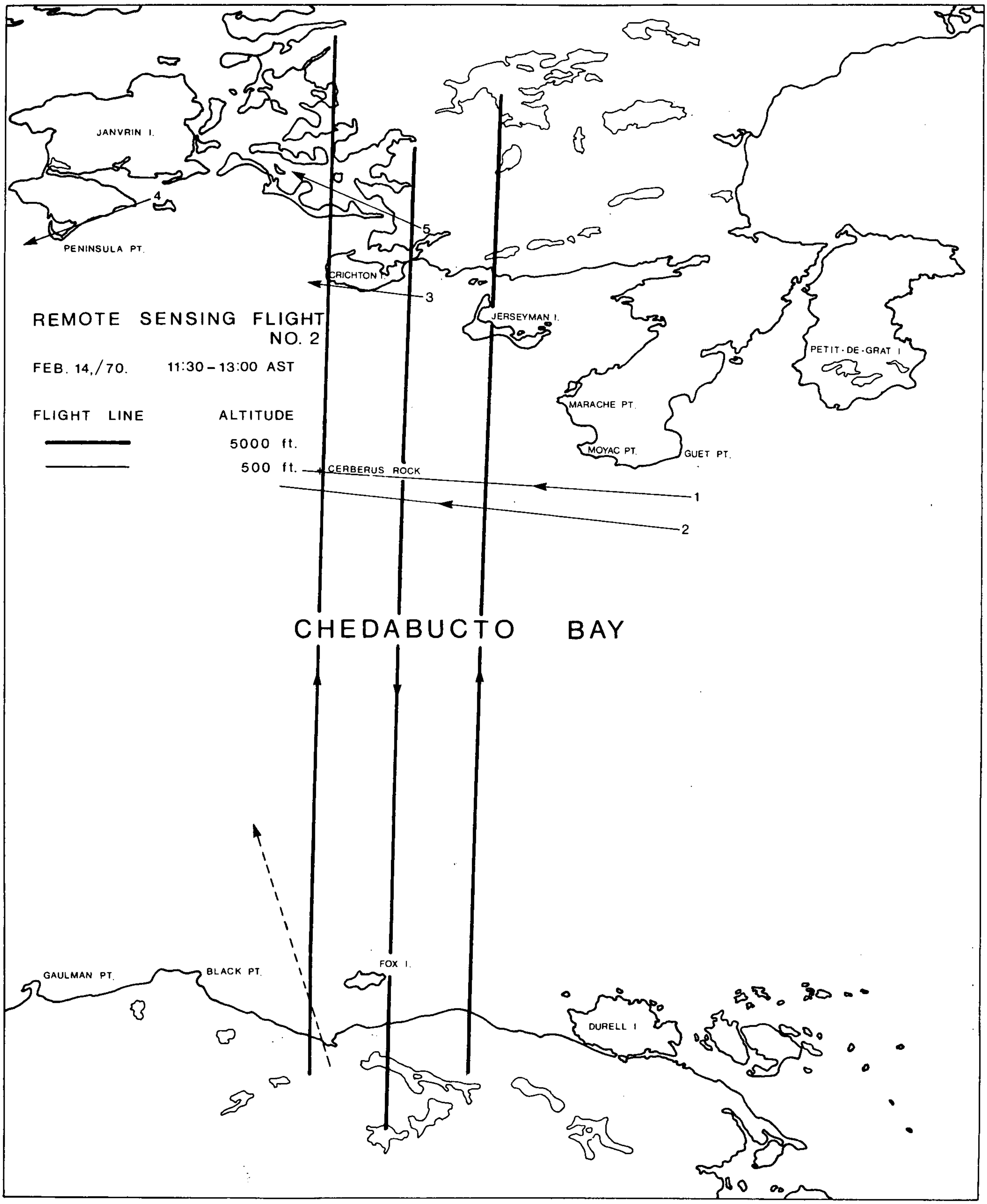


Figure 2. Chedabucto Bay, remote sensing flight no. 2, February 14, 1970.

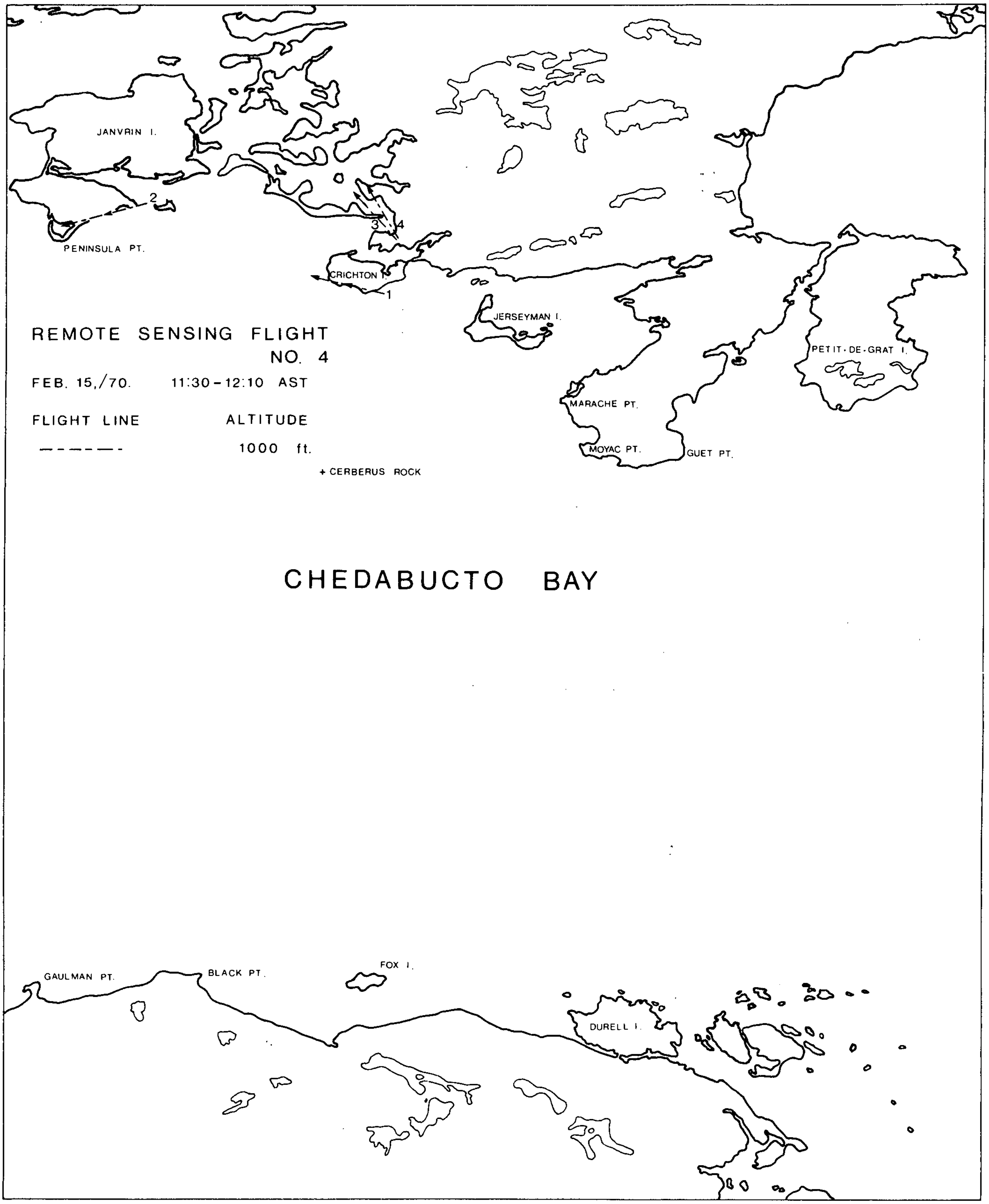


Figure 4. Chedabucto Bay, remote sensing flight no. 4, February 15, 1970.

Figure 5. Infrared imagery of the oil slicks emanating from all the stern section of the Arrow, taken on February 13, 1970 on flight line 3.

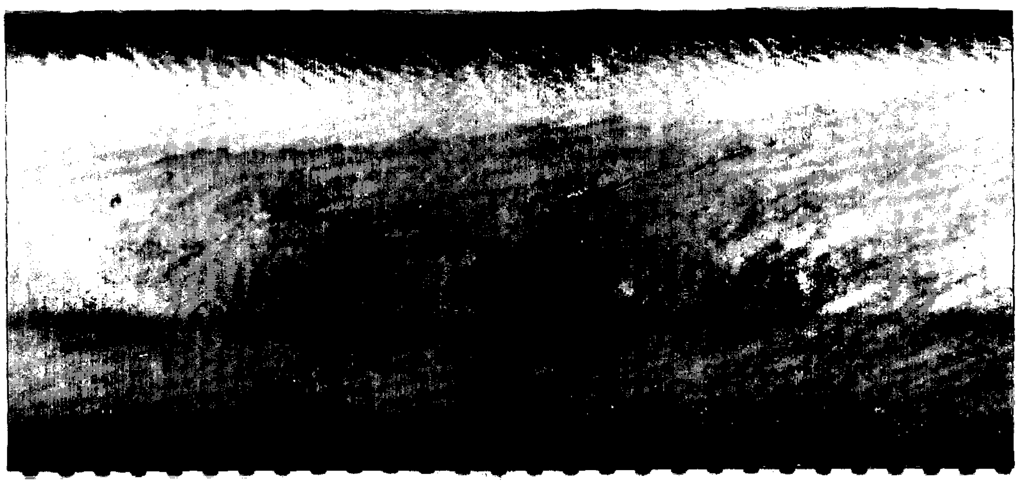


Figure 6. Infrared imagery of the oil slick emanating from the bow section of the Arrow, taken on February 13, 1970.

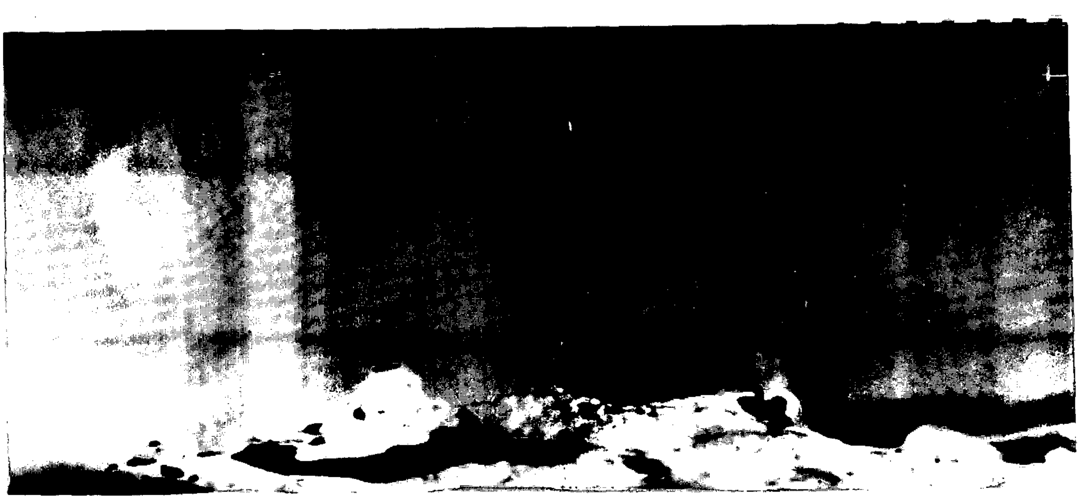


Figure 7. Infrared imagery of shore areas taken on February 13, 1970, flight line 14.

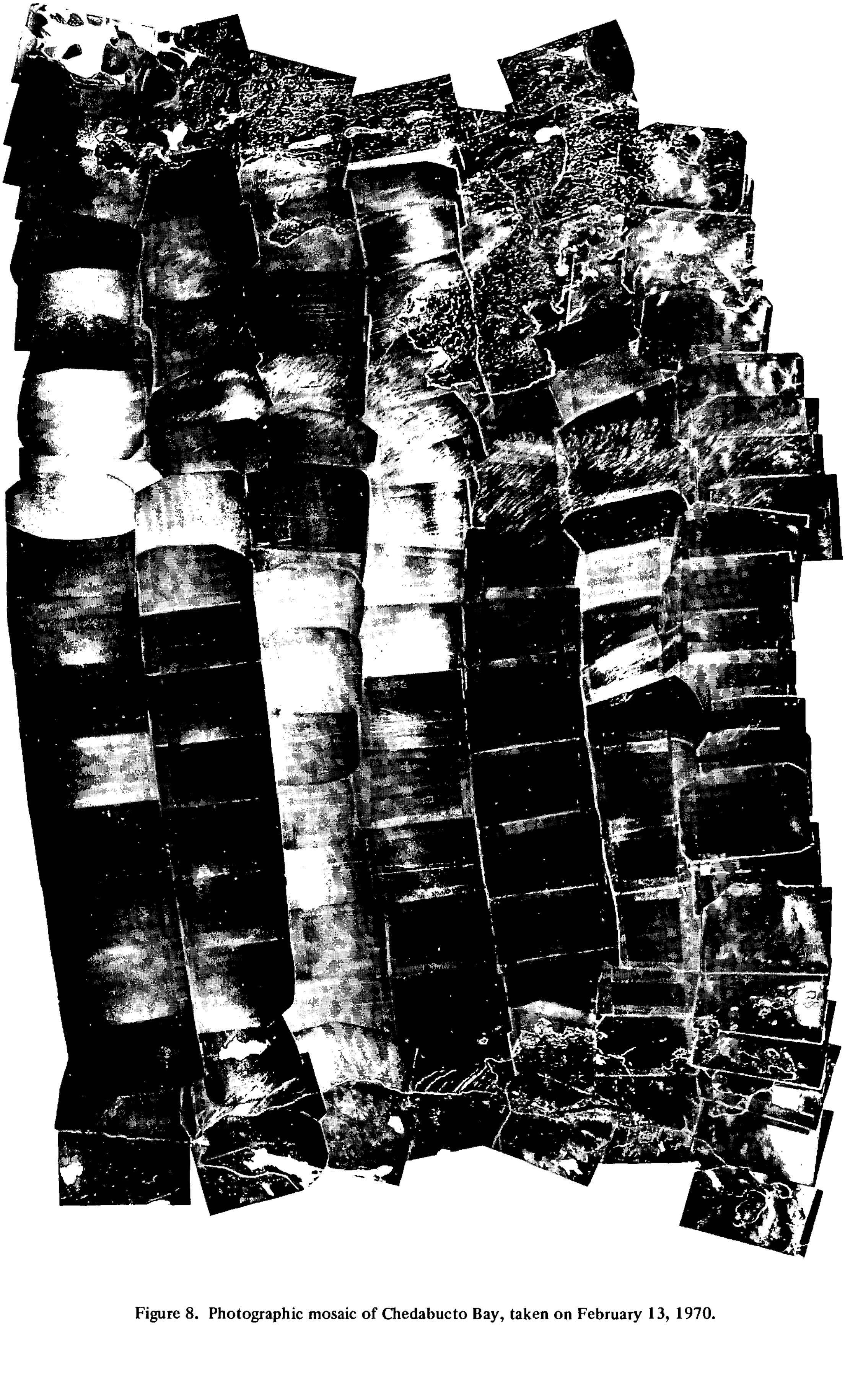


Figure 8. Photographic mosaic of Chedabucto Bay, taken on February 13, 1970.

Figure 9. Photographic mosaic showing the extent of the two oil plumes emanating from the wreck, taken on February 13, 1970.

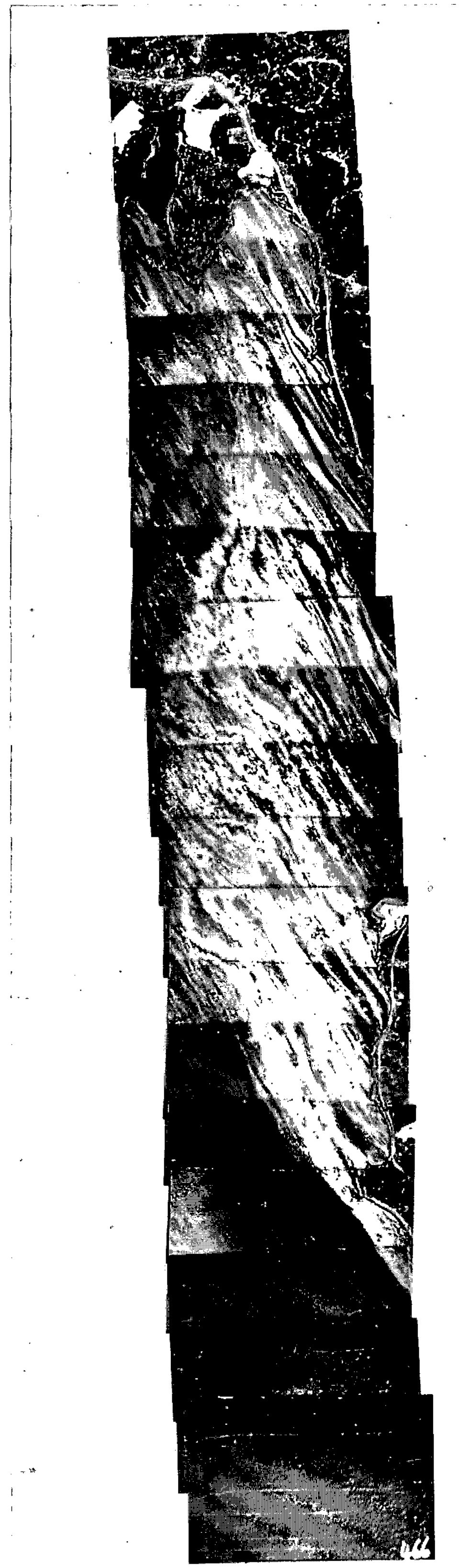
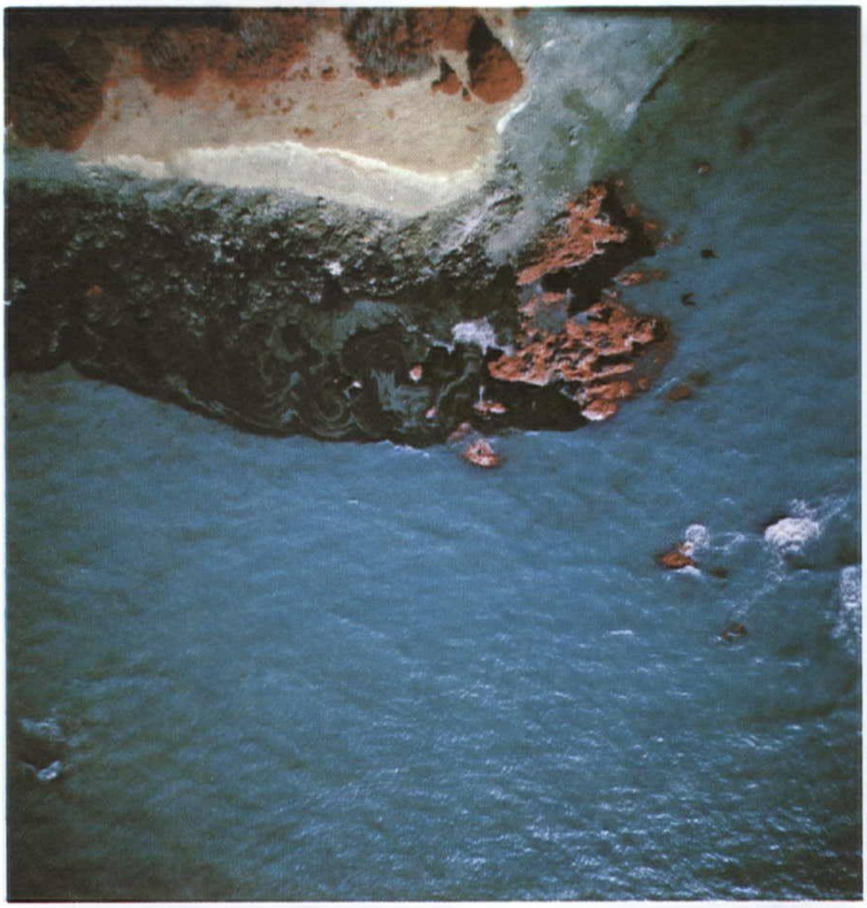
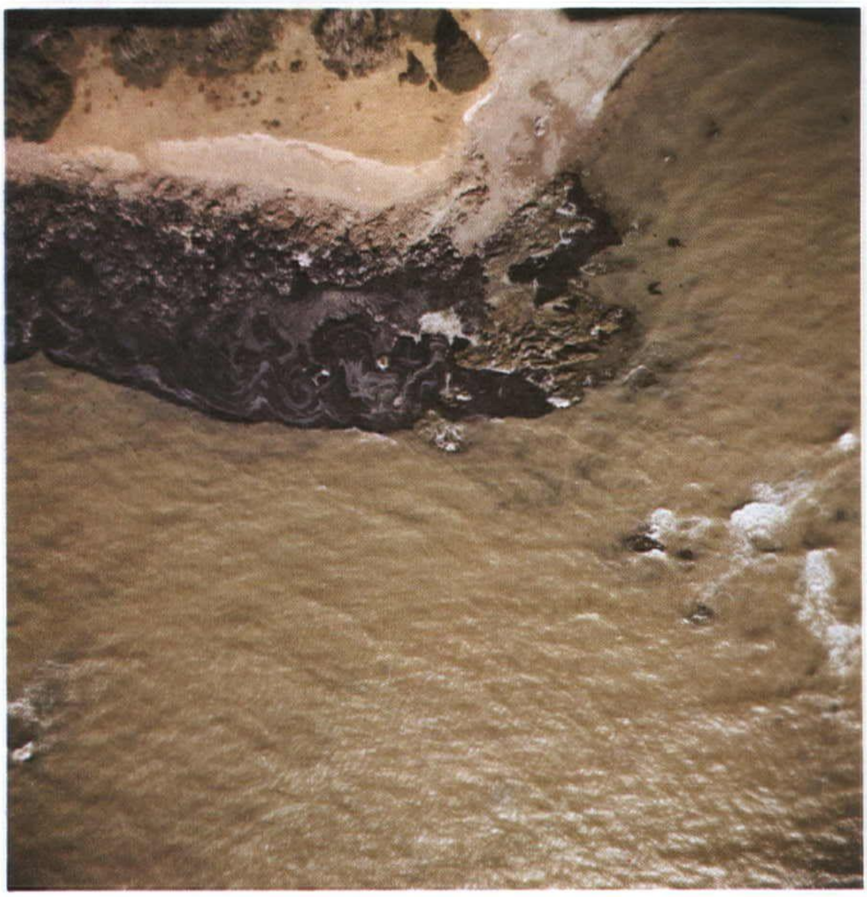


Figure 10. Photographic mosaic showing incursion of the oil plumes along the beach areas, taken on February 13,1970 on flight line 14.



A



B

Figure 11. Photographic imagery of oil-fouled beach areas, taken on February 15, 1970; (A) colour infrared film, (B) colour film.

A

B

Figure 12. Photographic imagery of oil-fouled beach areas, taken on February 15, 1970; (A) colour infrared film, (B) colour film.

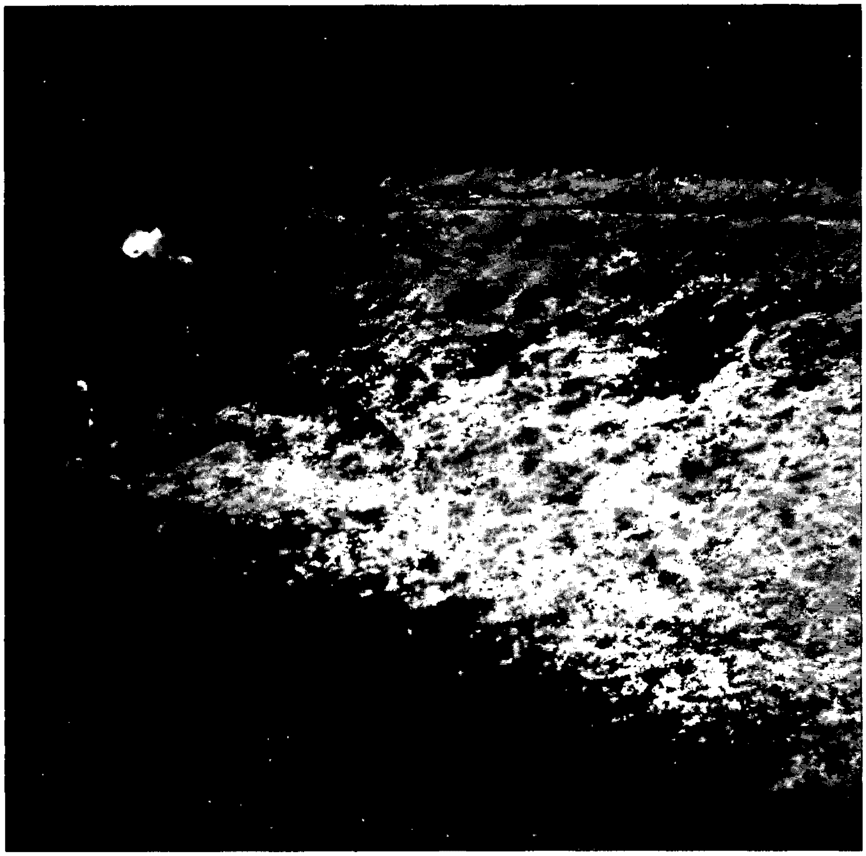


Figure 13. Photographic imagery of the stern section of the wreck, taken on February 13, 1970 from an altitude of 500 feet.

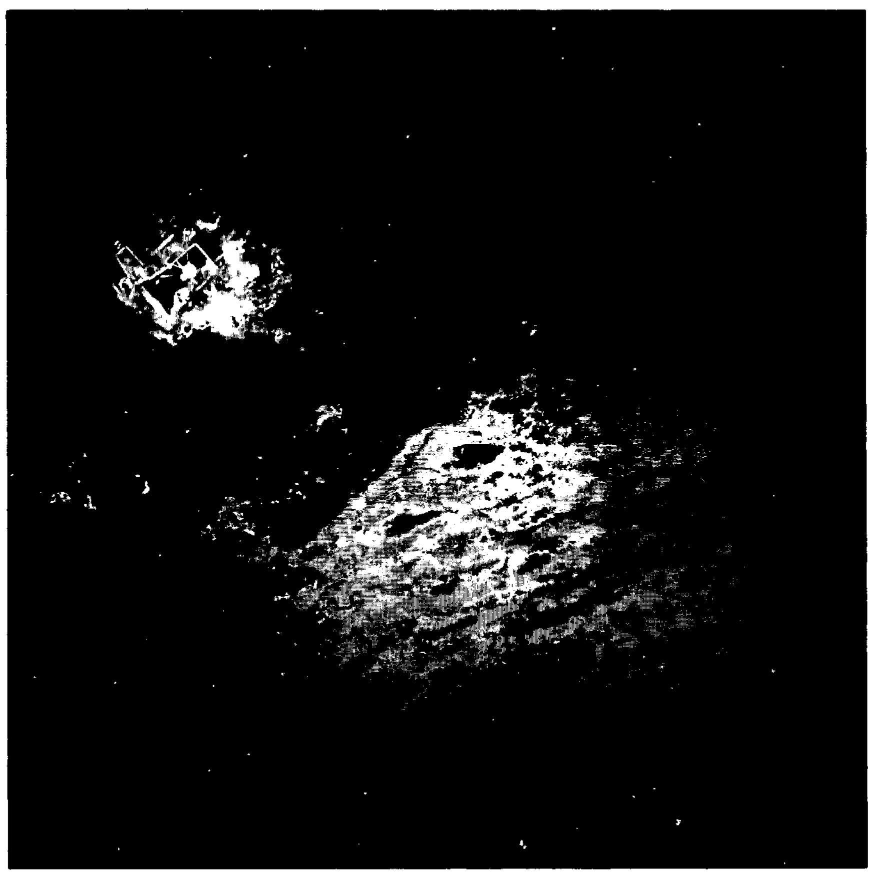


Figure 14. Photographic imagery of the bow section of the wreck, taken on February 13, 1970 from an altitude of 500 feet.

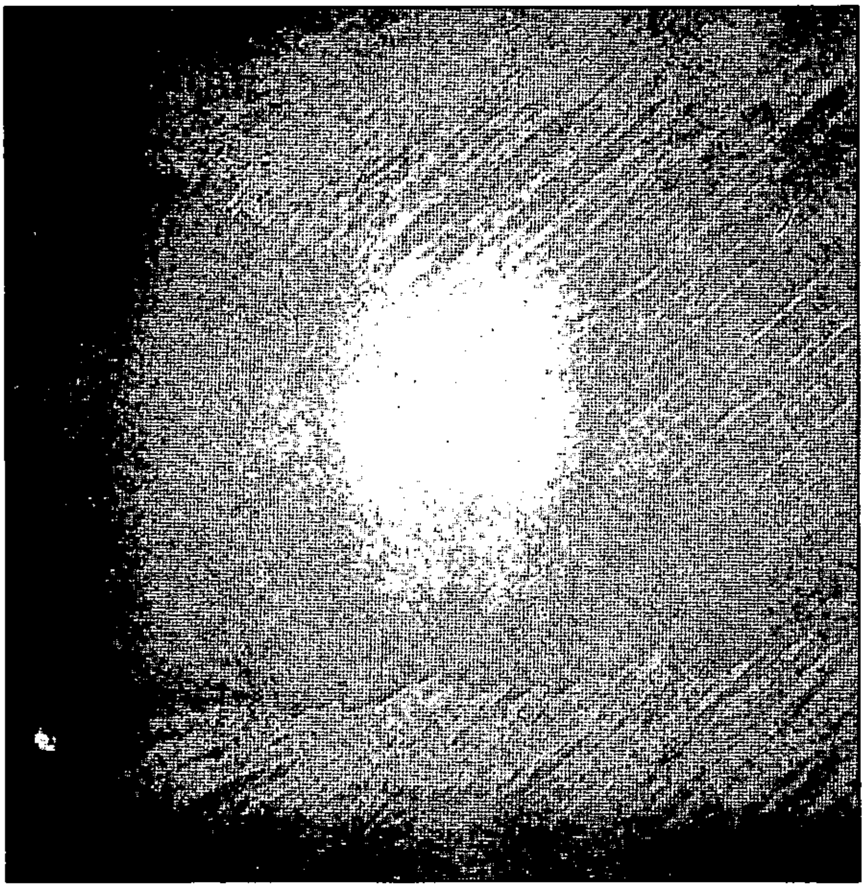


Figure 15. Photographic imagery of the two sections of the wreck, taken on February 13, 1970 from an altitude of 3,000 feet.