PRELIMINARY RESULTS OF REMOTE SENSING OVERFLIGHTS DURING THE KURDISTAN OPERATION

M.F. Fingas
Environmental Emergency Branch
Environmental Protection Service
Hull, Quebec.

R.A. O'Neil
Canada Centre for Remote Sensing
Department of Energy, Mines and Resources
Ottawa, Ontario.

V. Thomson and R.A. Neville
Intera Environmental Consultants
Ottawa, Ontario.

Background to the EPS Scientific Studies of the KURDISTAN Spill

What year? 1979

On the fifteenth of March, the KURDISTAN reported that it had suffered structural damage in the approaches to Cabot Strait. By the night of the same day, with a Canadian Coast Guard ship nearby, she broke in two. The Coast Guard ship reported seeing oil in the vicinity and after discussing the matter with the ship's crew determined that at least 3 tonnes of oil had been lost. Subsequent calculations put the loss of oil at closer to 7K to 9K tonnes.

On the 16th of March overflights by Tracker aircraft, the AES ice reconnaissance Electra and Coast Guard helicopters failed to turn up any trace of the oil. EPS personnel obtained emergency funding under the aegis of the AMOP program for a contract to CCRS to overfly the area for the purpose of searching for the oil and also to test a remote sensing package that had been developed for the AMOP program. CCRS personnel were able to assemble the instruments, mount these on the aircraft, and fly to Halifax on the night of the 16th and the morning of the 17th of March.

On the 16th of March discussions were held with C-CORE personnel about the possibility of initiating a study on the behaviour of the KURDISTAN spill in the ice-infested environment. A contract was subsequently let to C-CORE with FENCO as a sub-contractor when the oil was found. A contract was also let to assess the feasibility of employing existing satellite data to detect the oil spill. The focus of this study would be to examine Landsat and Tiros-N data to determine whether known oil locations could be detected.

These studies continued until 31 March, 1979, and shortly after this time proposals were put forward to the AMOP Management Committee to continue these studies. Funding was obtained from the AMOP program to initiate a new contract to C-CORE with subcontracts to FENCO and NORDCO to study the macro and micro behaviour of the oil in the ice and other related aspects of the spill. Unsuccessful attempts were also made to acquire the assistance of BIO to study the oil in the water column using a vessel such as the HUDSON. CCRS was again requested to provide overflights. The funding devoted to these studies totalled approximately $200,000. In retrospect, more has been learned from this spill - especially as applied to spills in ice-infested waters - than from most other spills which occurred in Canadian waters. I am sure that the papers which follow will make this evident.

The Remote Sensing Studies

The remote sensing missions were initially activated to locate and map the oil spill, which at that particular point in time was a mystery both as to the extent and the location. In addition, the spill afforded a unique opportunity to test the AMOP sensor package on a spill in ice-infested waters, on heavy oil and on a "real" spill. In the later phases of the study, another objective of the program was to provide imagery to those groups studying the behaviour of oil in ice.

Remote Sensing Instrumentation

The sensor packages that were used on the KURDISTAN mission included:

(a) Sensors mounted on the DC-3 (C-GRSB)

(i) Multi-Spectral Scanner
The ultra-violet and infra-red channels were primarily used to produce final imagery. The instrument employed actually produced 10 channels of imagery.

(ii) Low-Light Level Television

(iii) Two 70mm Cameras
One was mounted forward and used UV-sensitive film, the other was mounted to view the nadir (look directly downward) and was loaded with colour film.

(iv) MEIS
The MEIS is an experimental sensor employing an electronically scanned diode array. The sensor detects radiation in the 300 - 395 mm and 705-750 mm ranges on two channels, one polarized horizontally, the other vertically.

(b) Sensors mounted on the Falcon Jet (C-GRSD)

(i) DCLS (Dual Channel Line Scanner)
This line scanner selected imagery in the IR and UV regions.

(ii) Two RC-10 Cameras
Both were mounted nadir-looking; one was used with colour film, the other with IR false colour film.

The prime oil sensor, the laser fluorosensor, was not employed in these missions as it was in Rexdale, Ontario for repairs. That is unfortunate since this instrument is capable of providing fairly definitive indications of the presence and absence of oil and can even distinguish between type of oil.

The Overflights

A summary of the sorties conducted during the KURDISTAN spill appear in Table 2. Oil found on these missions appear on the charts below. In total 15,774 kms were flown by the two aircraft employed of which 5,360 kms were in the target area. A total of 1,676 sensor kilometers were accumulated between the two aircraft, of this distance 292 kilometers were immediately over oil or oil-contamination. This massive program has, needless to say, resulted in a considerable accumulation of data. Thus, it will not be possible in this paper even to summarize all the flights, locations or results of the program. Sets of data (weighing almost 80 pounds) have been provided to C-CORE and EPS, Halifax. The data will be used by C-CORE in compiling a final report on the behaviour of the oil from the KURDISTAN spill.

The major problem encountered during the overflights was the vast areas that could possibly be contaminated. The DC-3 has a "safe" range of approximately 500 miles over water and to cover an area in detail a track spacing of one or two miles is required depending on the altitude. It can be seen that only "bits" of areas such as the Atlantic can be covered in one single day. It was for this reason that the Falcon Jet (although it has weight limitations) was used in the latter stages of the remote sensing.

Another problem that did occur was the poor weather encountered during the first few days of the spill. On several days it was not possible to fly at all. On other days the ceiling restricted flying to lower altitudes - thus lowering the areal coverage.

The Imagery and Results

Summaries of the locations of the oil and oil contaminated shoreline and ice are given in Tables 1 and 2 as well as illustrated in Figures 1 through 6 as segments or points along flight lines. Rather than review in detail these locations, we will attempt to summarize the visual appearance of the oil from the air in the various situations.

Oil on the ice appeared to be black, grayish or brownish and appeared in large swirls or streaks. The fluid motion of the ice surface under the streaks appears to be quite evident. Much of the oil especially in the early stages of the spill was paler colored because it was mixed with slush ice or snow. As could be expected when melting proceeded, the oil became darker in colour on the ice.

Oil on the ice appeared in several different forms. Chocolate mousse was found in several locations and on several days. It was a bright chocolate brown on all sightings. The chocolate mousse was distributed in small pans (i.e. of a few meters in diameter) which were of circular shapes. The chocolate mousse was generally widely distributed; that is, large numbers of pans (50 or more) were never found in a small area although the presence of pans was usually quickly established by locating a number of them in a given area.

Thin sheens of oil were observed on occasion. On the 23rd of March a large area covered by sheens was observed. On this occasion the eastern portions of the area appeared to be fairly continuously covered with a thin sheen broken only occasionally by wind or waves. On the western portion of this particular area the slicks were not continuous and areal coverage was estimated to be only 20% in some areas.

The most interesting observation of the oil in the remote sensing program was that looking straight down (visually) one could see dark regions which appeared to be pans of oil floating just below the surface. the color of these pans was black and thus would have been unemulsified oil. These areas were observed primarily in the regions where oil sheens were found on the surface such as on the remote sensing mission of March 23, although the general search for these was not conducted in areas not close to slicks. It is unfortunate that resources were not available to ground truth these areas to determine if indeed this was submerged oil and if it was - to determine the thicknesses of these sheets and their distance to the surface. During the course of this spill there was much speculation that the oil was submerging and resurfacing, however, to our knowledge this was never actually observed or documented.

Evaluated Sensors

The output of the sensors from the missions over the Kurdistan spill in areas of open water did not yield any surprises. Reviews of the applicability, merits, etc. of various sensors for the detection of oil on water has become a common practise (vis. Spill Technology Newsletter Vol. 4 No. 2). Of greater interest was the detection of oil on or with ice. It is felt that the most useful of the sensors employed for this purpose were the IR and UV line scanners. The oil on the ice appeared grey to black on the UV scanner imagery (depending on density of oil on the ice) whereas the ice appears featureless and white. This indicates that oil, as on water, has a much higher UV absorbance than ice and can easily be distinguished. The color of the oil was usually grey compared to the "black" water allowing one to distinguish between these as well.

Oil on ice absorbs much more solar radiation than the ice around it and has a high emissivity of IR. Thus the oil on ice appears as white on a black background on IR scanner imagery. Comparison of IR and UV imagery can be very useful to ascertain what is oil and not some other phenomenon. It is unfortunate that the laser fluorosensor was not available for these missions to ascertain its response to the oil on the ice, since it is anticipated that this instrument will be used as the primary "yes - no" device to determine the presence of oil, and that standard techniques such as IR or UV will be employed for mapping the distribution of the oil.

The use of IR and UV are not free of problems. In the ice situation, little research has been done on the responses, properties, etc. of oil and interfering materials. For example, it is known that soils will behave similar to oil i.e. high absorbance in UV and IR emissivity and thus could be mistaken for oil. In addition the distribution patterns of soil appear to be similar to that of oil and also much of the ice in the Cape Breton vicinity was soiled.

In the case of the KURDISTAN spill, ground truthing was performed for oil in ice, establishing oil and densities of oil in particular areas so that it will be possible in most cases to accurately map the distribution of the oil in the top layer of the ice. Perhaps future tests will show that the fluorosensor can take the place of this ground truthing.

Summary

A large amount of valuable data has been collected. It will be possible to map, to a certain extent, the distribution and movement of oil on ice from the KURDISTAN spill. This should prove to be invaluable as far as examining the fate and behaviour of the oil in this environment. The data on the distribution of oil on the water should be valuable in assessing the overall oil budget of the KURDISTAN spill as well as modelling the movement of oil along the coast.

The remote sensing study has also been very valuable for determining the requirements, problems etc., of sensing oil on ice. Further analysis of the mission is planned and results of this will be incorporated into a report being prepared by CCRS for AMOP to recommend on a sensor system for use in ice-infested waters. As noted before, a data set has also been provided to C-CORE for analysis and incorporation into a major report on the behaviour of oil in the KURDISTAN spill.

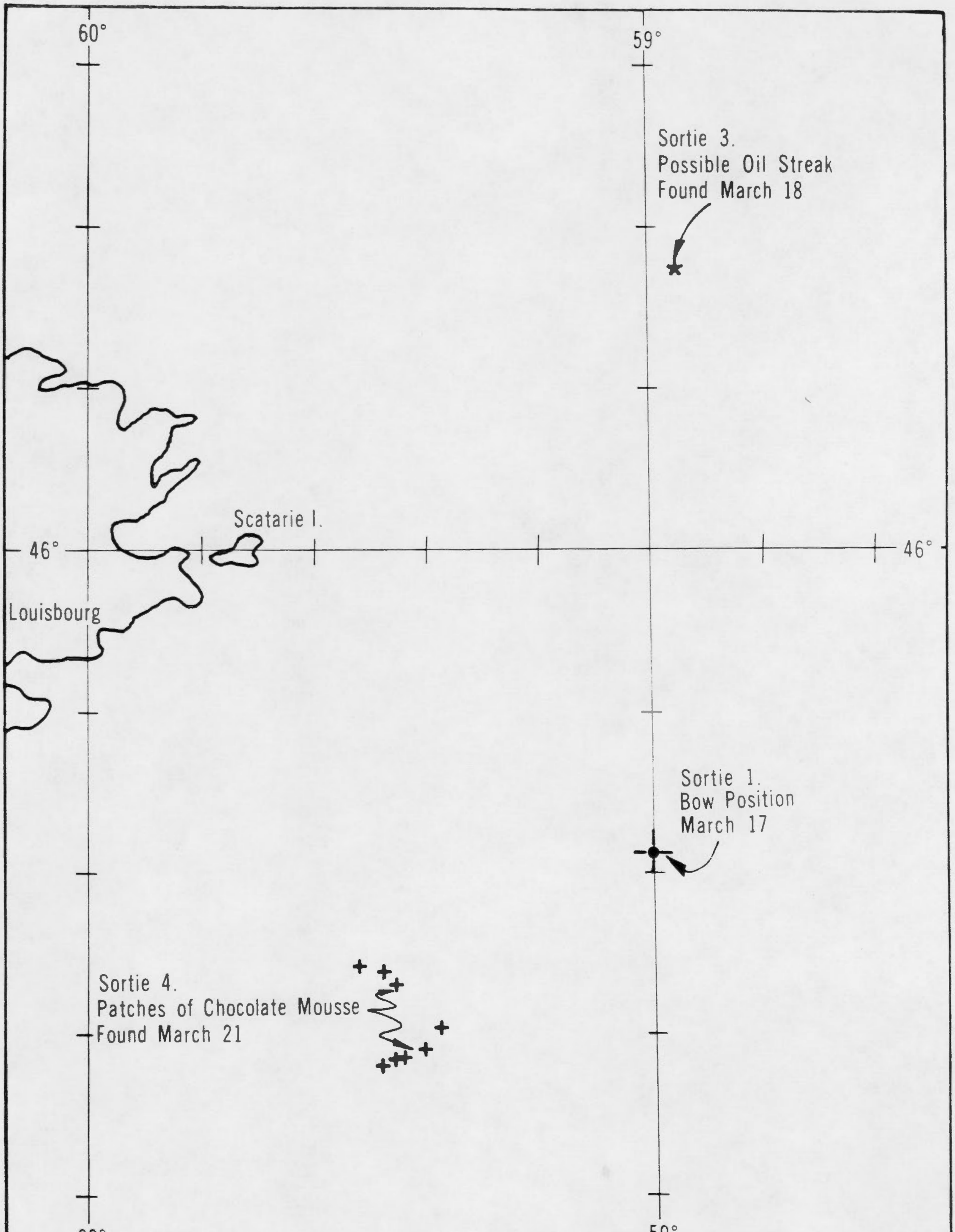

Fig.1 - Oil Found by Remote Sensing Mission
Sorties 1-4, 17-21 March 1979

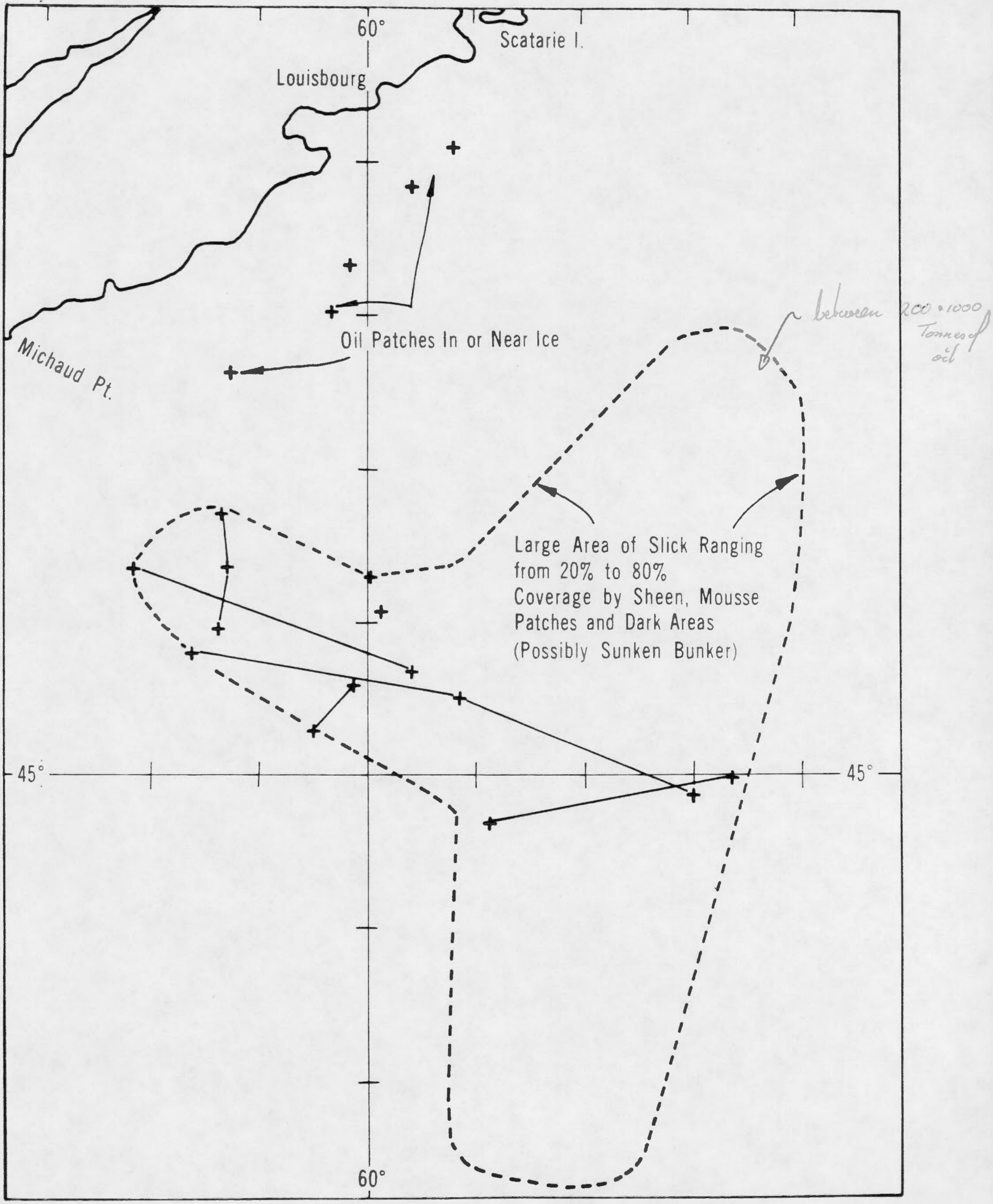

Fig.2 - Oil Found by Remote Sensing Mission
Sortie 5, 23 March 1979

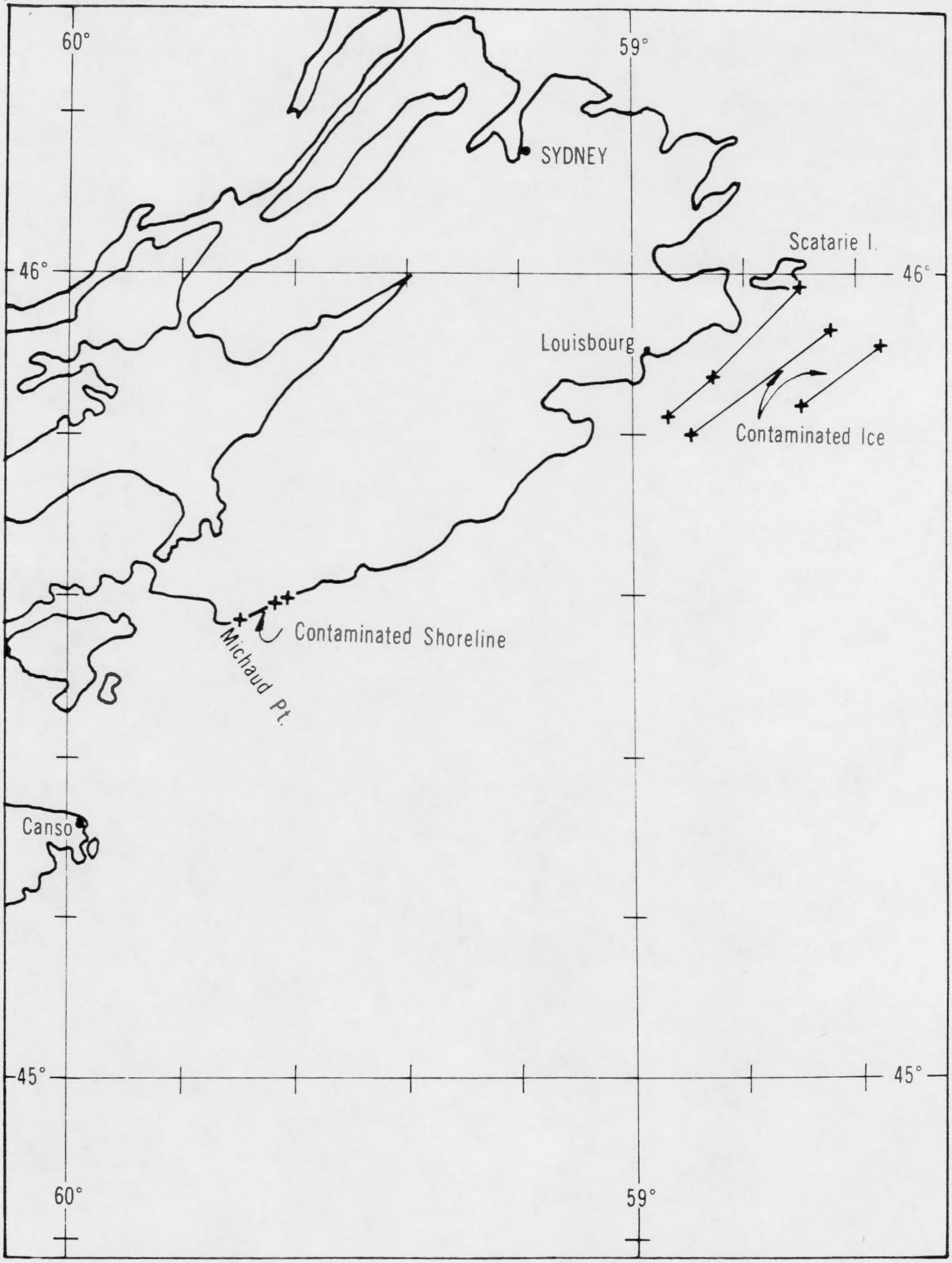

Fig.3 - Oil Found by Remote Sensing Mission
Sortie 6, 29 March 1979

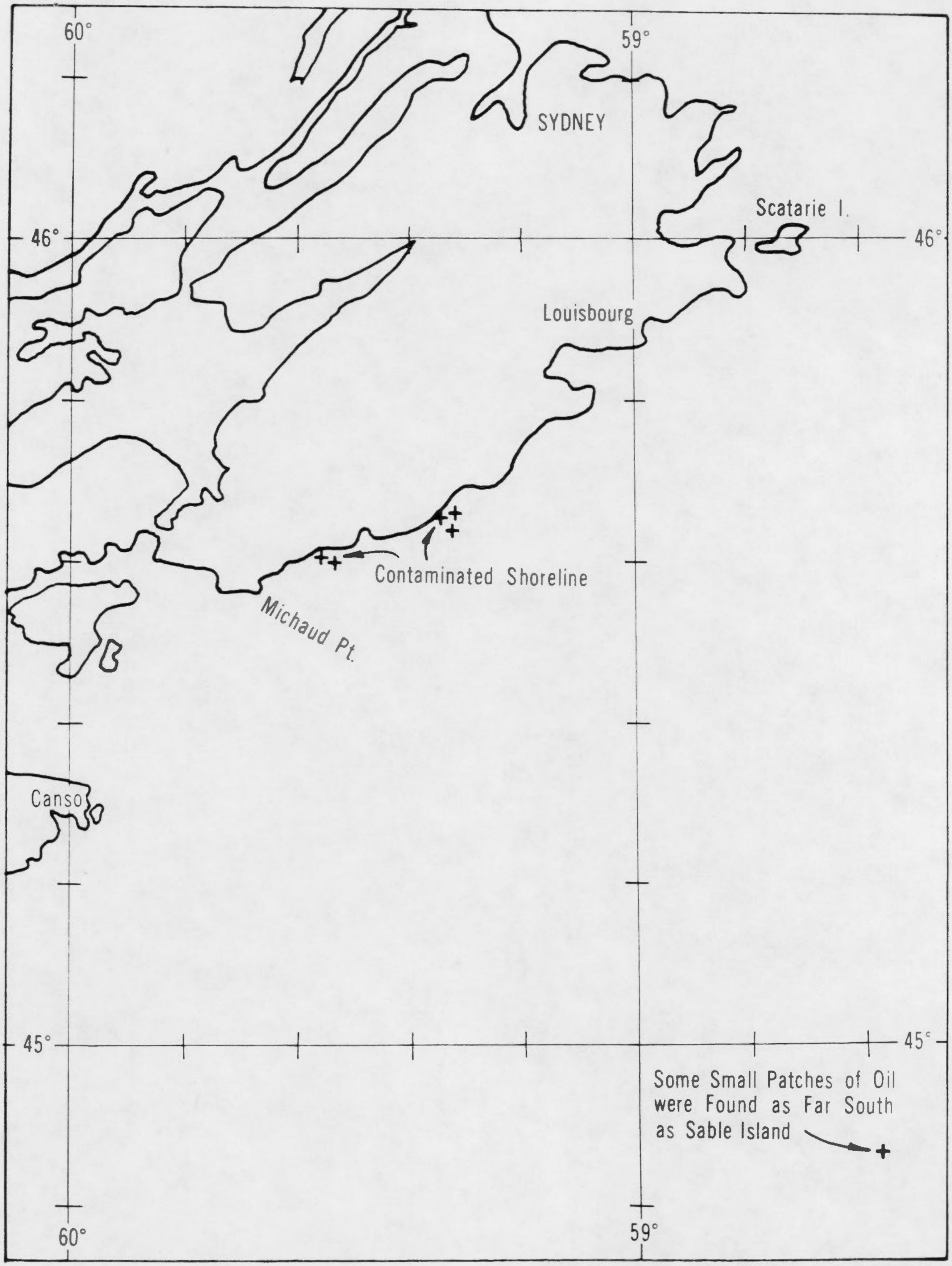

Fig.4 - Oil Found by Remote Sensing Mission

Sortie 7, 29 March 1979

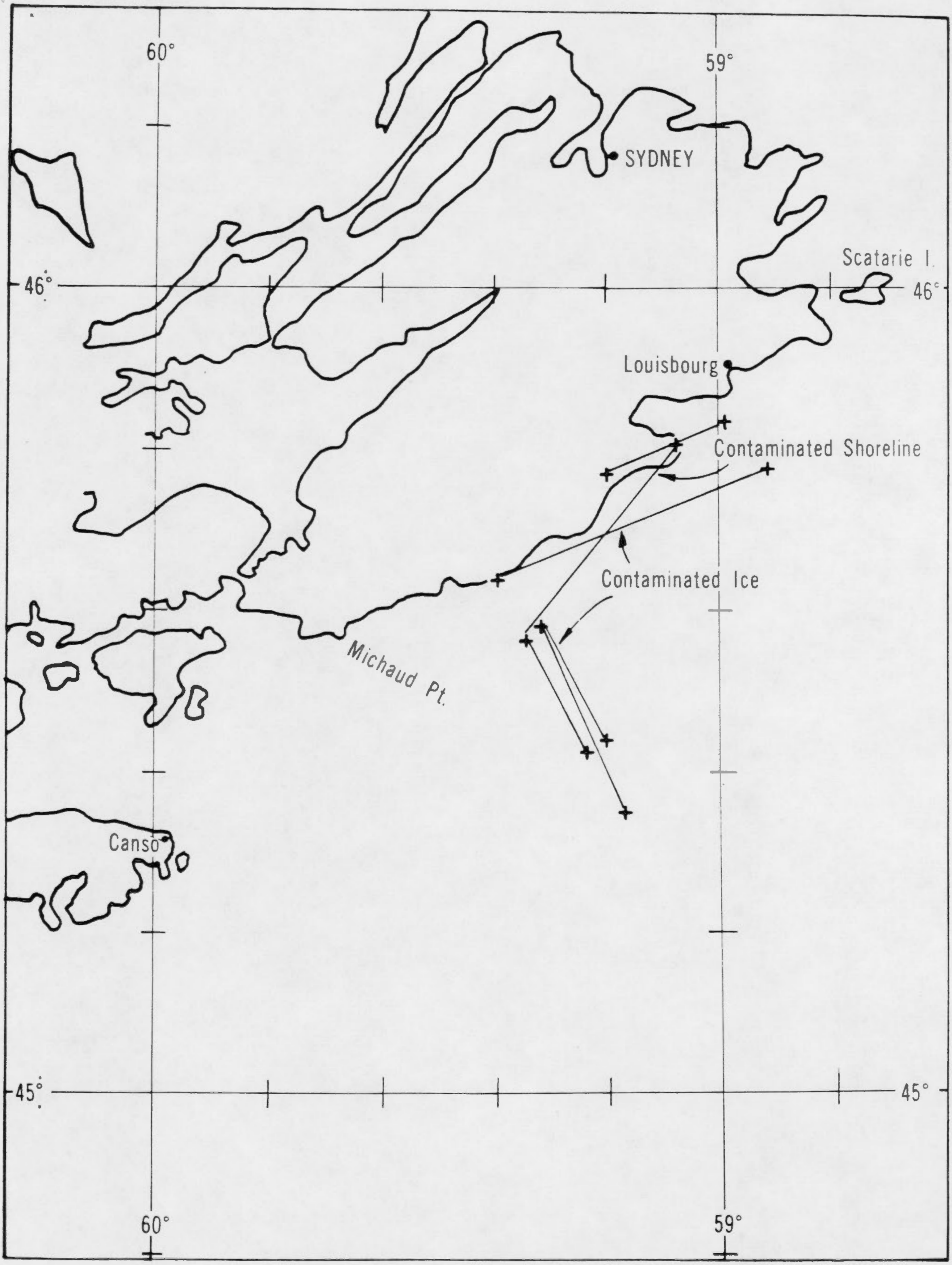

Fig.5 - Oil Found by Remote Sensing Mission
Sortie 8, 2 April 1979

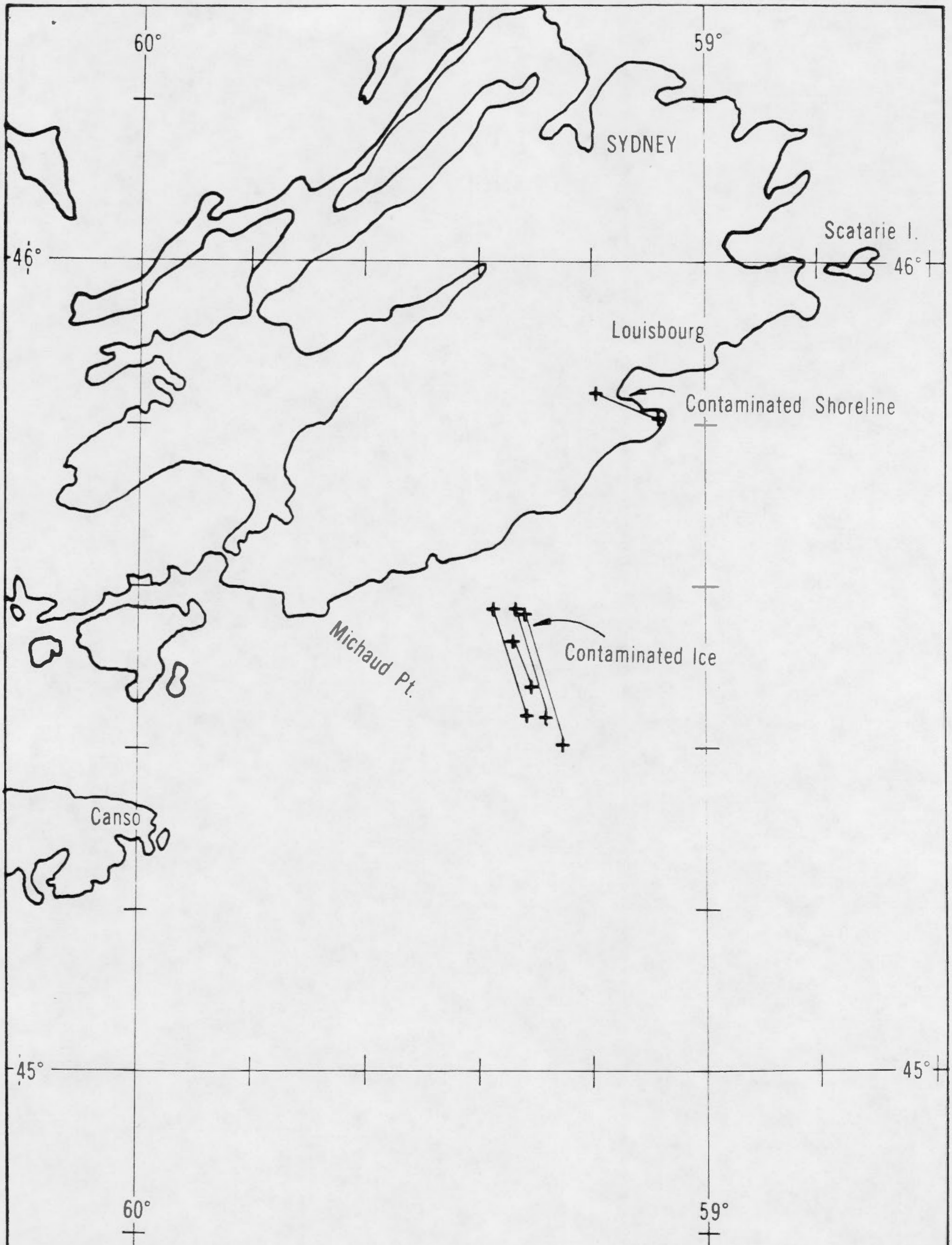

Fig.6 - Oil Found by Remote Sensing Mission
Sortie 9, 2 April 1979

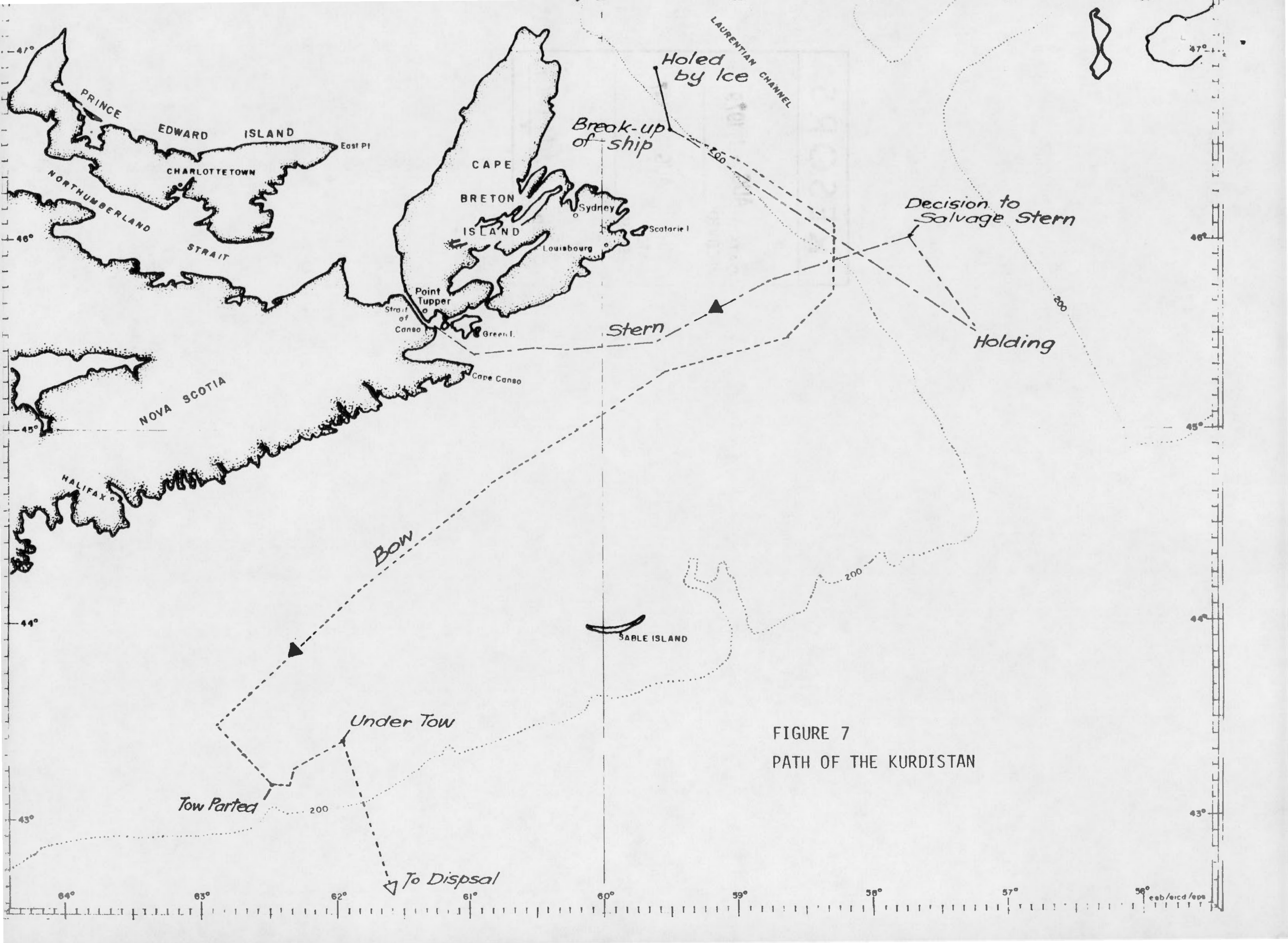

FIGURE 7

PATH OF THE KURDISTAN

TABLE 1 (cont'd)

SUMMARY OF EVENTS AND OIL OBSERVATIONS
KURDISTAN SPILL

Date	Basic Events	Visual Sightings of oil	CCRS Remote Sensing Observations
March 27		Oil comes ashore at several points on Cape Breton Coast	
March 29			Contaminated ice and shoreline mapped. Small patches of oil found as far south east as Sable Island.
April 1	Bow section is sunk at approx. noon AST at 41@55.2'N 60@58'W		
April 2			Contaminated ice and shoreline mapped, south portions of several bays are contaminated.

TABLE 2

SUMMARY OF REMOTE SENSING MISSIONS OVER THE KURDISTAN SPILL

Day	Aircraft	Sensor Time & Distance total (Hrs/min/sec,km)	Sensor Time & Distance over oil (Hrs/min/sec,km)	Sortie	Oil found
March 17	DC-3	0:1:50 2.25 km	0:00:00	1,2	Preliminary flight over bow and suspected areas - no oil found
March 18	DC-3	1:20:47 308 km	0:00:00 (.25 km)	3	A reddish-colored streak was discovered at 46:24.6N 58:58.2W, later suspected to be an oil "streak"
March 21	DC-3	0:43:01 170 km	0:00:10 0.7 km	4	Area between the bow and stern was searched approx. midway between these two areas, (45:37.5N 59:01.0W and 45:14.1N 59:43.2W) patches of chocolate mousse were found
March 23	DC-3	1:29:32 360 km	0:30:51 134 km	5	Large area (approx. 130 X 45 km) of oil found directly east of Port Hawkesbury. Large area consisted of surface sheen, patches of mousse and darker areas (possibly submerged oil). Percentage of surface coverage varied. Patches of oil or oil contaminated ice found parallel to the Nova Scotia Coast as well.
March 29	Falcon	0:28:45 305 km	0:06:36 63 km	6	Large areas of contaminated ice were found offshore between Scaterie Island and Louisburg. Some contaminated shoreline was also found near Michaud Point.

TABLE 2 (cont'd)

SUMMARY OF REMOTE SENSING MISSIONS OVER THE KURDISTAN SPILL

Day	Aircraft	Sensor Time & Distance total (Hrs/min/sec,km)	Sensor Time & Distance over oil (Hrs/min/sec,km)	Sortie	Oil found
March 29	Falcon	0:13:30 108 km	0:00:20 2.7 km	7	Contaminated shoreline was found on several portions of the Cape Breton Island. Several small patches of oil were tentatively identified on the open water as far south as Sable Island.
April 2	Falcon	0:30:14 292 km	0:19:17 187 km	8	The shoreline and ice contamination as noted in sortie 7 was observed to have generally drifted southwards - shoreline contamination was evident in the Southern portion of many bays. Extensive shoreline and ice contamination was mapped.
April 2	Falcon	0:19:26 131 km	0:05:40 39 km	9	The extensive shoreline and ice contamination noted above was mapped in slightly different areas than noted above.