Exxon Valdez Oil Spill
State/Federal Natural Resource Damage Assessment Annual Report

Undersea Observations of Submerged Oil

Fish/Shellfish Study Number 20
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

Daniel C. Huttunen
Paul A. Skvorc, II

Alaska Department of Fish and Game
Oil Spill Impact and Restoration Division
333 Raspberry Road
Anchorage, Alaska 99518

January 1989

Exxon Valdez Oil Spill
State/Federal Natural Resource Damage Assessment Annual Report

Undersea Observations of Submerged Oil

Fish/Shellfish Study Number 20
Annual Report

This annual report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

Daniel C. Huttunen
Paul A. Skvorc, II

Alaska Department of Fish and Game
Oil Spill Impact and Restoration Division
333 Raspberry Road
Anchorage, Alaska 99518

January 1989

Undersea Observations of Submerged Oil

Fish/Shellfish Study Number 20
Annual Report

Study History: Fish/Shellfish Study Number 20 was initiated as part of a detailed study plan in 1989. The study was intended to support Fish/Shellfish Studies 14 (brown king crab), 15 (spot shrimp), 17 (rockfish) and 23 (rockfish, lingcod, halibut) in providing direct observation of seafloor conditions and in establishing sampling areas for these demersal species.

Abstract: A remotely operated vehicle (ROV) was deployed in Fall 1989 in 34 locations throughout Prince William Sound and Kachemak Bay, many of which had been identified as contaminated in an earlier study. The dives were conducted in areas with the greatest probability of contamination with North Slope crude oil to ground truth the technique of visually detecting subsurface oil using video cameras. Sealed (at depth) sediment samples were simultaneously collected to verify the oil presence or absence. If viable, the technique would be employed on a large scale to map oiled and non-oiled areas of the benthos to facilitate pair-wise studies of injury to brown king crab, spot shrimp, and rockfish in Prince William Sound, and along the lower Kenai Peninsula. No other subsurface oil or oil byproducts were detected via video camera during this study. One small (0.4 cm^2) sheen was detected on each of two physical sediment samples. No other evidence of subsurface oiling was found during the field portion of this study; however, the sediment samples have not been thoroughly analyzed. Results indicate that if subsurface oil was present at these locations, it could not be detected visually on video cameras mounted in an ROV.

Key Words: Crude oil, *Exxon Valdez* oil spill, Kachemak Bay, oil sheen, Prince William Sound, remotely operated vehicle (ROV), subsurface oil, video photography.

Project Data: *Description of data* - Report data is presented in Tables 2 and 3. *Format* - Tables 2 and 3 are Word files. *Custodian* - Celia Rozen, Librarian, Alaska Department of Fish and Game, Habitat and Restoration Division, Anchorage, Alaska, 99518, (907) 267-2314. *Availability* - upon request.

Citation:

Huttunen, D.C., and P.A. Skvorc, II. 1989. Undersea observations of submerged oil, *Exxon Valdez* Oil Spill State/Federal Natural Resource Damage Assessment Annual Report (Fish/Shellfish Study Number 20), Alaska Department of Fish and Game, Oil Spill Impact and Restoration Division, Anchorage, Alaska.

TABLE OF CONTENTS

STUDY HISTORY/ABSTRACT/KEY WORDS/PROJECT DATA/CITATION i

LIST OF TABLES iii

LIST OF FIGURES iii

LIST OF APPENDICES iv

EXECUTIVE SUMMARY 1

INTRODUCTION 1
- Project Background 2
- ROV Description 2

OBJECTIVES 2

STUDY METHODOLOGY 3
- Experimental Design 3
- Sample Collection 4
  - Visual Samples 4
  - Physical Samples 4
  - Data Recording 4

RESULTS 5
- Prince William Sound 5
- Kachemak Bay 5

STATUS OF INJURY ASSESSMENT 5

LITERATURE CITED 7

LIST OF TABLES

Tables — Page

1. List of proposed sampling sites to ground truth visual observations of benthic oiling via Remotely Operated Vehicle (ROV), 1989. 9

2. List of sealed (at depth) sediment samples collected in Prince William Sound during VCR filming via Remotely Operated Vehicle (ROV) by location and date, 1989 10

3. List of bottom trawls conducted in Kachemak Bay before VCR filming via Remotely Operated Vehicle (ROV) by location and date, 1989 11

LIST OF FIGURES

Figure — Page

1. General areas of proposed sampling for benthic oiling via Remotely Operated Vehicle (ROV) in Prince William Sound, Alaska, 1989 12

2. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons in the Upper Knight Island group, Prince William Sound, Alaska, 1989 13

3. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons near Perry Island, Prince William Sound, Alaska, 1989 14

4. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons near Evans and Latouche Islands, Prince William Sound, Alaska, 1989 15

5. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons along lower Knight Island, Prince William Sound, Alaska, 1989 16

6. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons along Green Island, Prince William Sound, Alaska, 1989 17

7. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons in Kachemak Bay, Alaska, 1989 18

LIST OF APPENDICES

APPENDIX A: KACHEMAK BAY

Page

A.1 - Exact ROV track during dive ROVK01 in Kachemak Bay, Alaska on 3 October 1989 20

A.2 - Exact ROV track during dive ROVK02 in Kachemak Bay, Alaska on 4 October 1989 21

A.3 - Exact ROV track during dive ROVK03 in Kachemak Bay, Alaska on 5 October 1989 22

A-4. - Exact ROV track during dive ROVK04 in Kachemak Bay, Alaska on 5 October 1989 23

EXECUTIVE SUMMARY

A Remotely Operated Vehicle (ROV) was deployed in 34 locations throughout Prince William Sound and Kachemak Bay, Alaska, from 19 September through October 6, 1989. The dives were conducted in areas with the greatest probability of contamination with North Slope crude oil to ground truth the technique of visually detecting subsurface oil using video cameras. Many of the sample locations were identified as contaminated during an earlier study. Sealed (at depth) sediment samples were collected at the same time to verify the presence or absence of oil. If viable, the technique would be employed on a large scale to map oiled and non-oiled areas of the benthos to facilitate pair-wise studies of injury to brown king crab (Fish/Shellfish Study Number 14), spot shrimp (Fish/Shellfish Study Number 15), and rockfish (Fish/Shellfish Study Number 17) in Prince William Sound, and along the lower Kenai Peninsula (Fish/Shellfish Study Number 23).

No subsurface oil or oil byproducts were visually detected on video camera during any portion of this study. One small (0.4 cm^2) sheen was noticed on each of two physical sediment samples as they were transferred to certified sample storage containers. No other evidence of subsurface oiling was found during the field portion of this study, although the sediment samples have not been thoroughly analyzed. The result of this investigation is that if subsurface oil was present at any of the study locations, it could not be detected visually on video cameras mounted in an ROV.

INTRODUCTION

Following the grounding of the *F/V Exxon Valdez* on Bligh Reef on 24 March 1989, an estimated 10.8 million gallons of North Slope crude oil spilled into the waters of Prince William Sound. Of that amount, less than half has been accounted for; approximately 1.4 million gallons were recovered and an additional 3.2 million gallons are estimated to have evaporated (AOG, 1989). The fate of the remaining 6.2 million gallons remains largely unknown.

Ancillary information from this and other large oil spills suggests that some fraction of the spilled oil may have entered the benthos of Prince William Sound and Kachemak Bay. Oiled dungeness crab (*Cancer magister*) were reported from a large spill along the coast of British Columbia (Glen Jameson, DFO, British Columbia, personal communication) and early reports of oil and tar balls on anchors were tendered by fishermen and others in embayments within Prince William Sound. However, the extent, distribution, and patchiness of submerged oil or oil byproducts remains unknown due to a paucity of viable techniques capable of sampling large areas of the ocean bottom in a timely fashion. Information detailing subsurface oil distribution was needed to identify control and experimental sampling areas for pair-wise analysis of the effects of oil contamination on commercially important demersal species including brown king crab (*Lithodes aeuispina*), spot shrimp (*Pandalus platyceros*), rockfish (*Sebastes* spp.) and Pacific halibut (*Hippoglosus stenolepis*).

Project Background

Visual observation was the sampling method specified in this study because it represented the only possible means of sampling a large area of the ocean floor completely. However, no oil spill related investigators reported visual observations of submerged oil. National Oceanic and Atmospheric Administration (NOAA) researcher Mr. Ken Krieger failed to observe any substance he could identify as probable petroleum hydrocarbon during several hundred hours he spent in a manned submersible in heavily oiled areas of Prince William Sound and the Gulf of Alaska shortly after the spill (personal communication). Additionally, NOAA scientist Mr. Chuck O'Claire failed to see any oil or oil byproducts while swimming marked transects in the intertidal zones of several heavily oiled Prince William Sound beaches at high tide in SCUBA gear. Alaska Department of Fish and Game (ADF&G) researchers Fritz Funk, Hal Geiger, and Evelyn Biggs also reported no sightings of submerged oil during SCUBA diving activities associated with other oil spill related studies in the area. Canada Department of Fisheries and Oceans (DFO) researcher Mr. Glen Jameson reported oiled Dungeness crab from the Nestucca spill in British Columbia, but found only indirect evidence of subtidal oiling (personal communication). Therefore, the focus of the initial portion of this project was modified to ground truth the technique of visually observing submerged oil via Remotely Operated Vehicle (ROV) in areas of Prince William Sound and Kachemak Bay which had the highest probability of contamination. Plans detailing future project direction were to be developed subsequent to results of the ground truth experiments.

ROV Description

The method initially identified as the most cost-effective method and likely capable of visually sampling large areas of the ocean bottom for benthic oiling was ROV. An ROV is an unmanned submersible which is controlled by an operator aboard a support vessel. Observations are made through one or more video and/or still cameras mounted in the vehicle, and all visual and control signals are transmitted through an attached umbilical cable. Images are displayed in real time on ordinary color televisions aboard the support vessel, and all observations can be permanently recorded on video tape. ROVs can be fitted with one or more manipulator arms capable of collecting physical samples within the field of view. In addition, smaller vehicles - those capable of operating in depths of less than 330m - are portable, moderately maneuverable, and significantly cheaper, safer and more readily available than manned submersibles.

OBJECTIVES

This portion of the Undersea Observation Study (Fisheries/Shellfish Study Number 20) was tasked to determine if submerged oil could be detected visually using video and/or still frame cameras transported about the benthos in an ROV. Specific sample collection goals included:

1. Collecting at least 50 coincident visual (video-taped) and physical (sealed scoop) samples of the ocean floor in selected heavily oiled embayments of Prince William Sound, Alaska.

2. Collecting at least 20 coincident visual (video-taped) and physical (drag) samples of the ocean floor in selected areas of Kachemak Bay, Alaska.

STUDY METHODOLOGY

The ground truth of this technique was accomplished by remotely observing the bottom sediment with an ROV, and simultaneously collecting physical samples of that sediment for subsequent analysis to determine total petroleum hydrocarbon content and to establish its origin.

Experimental Design

We identified 27 areas in Prince William Sound and Kachemak Bay which were heavily oiled and which represented the greatest probability of benthic contamination with North Slope crude oil (Table 1). Using maps prepared by the Alaska Department of Environmental Conservation (ADEC), Exxon, and private contractors, we established transects within embayments where pools of sunken oil were likely to have settled (Figure 1). Transects were selected to allow visual examination of both the subtidal slope region and the deeper areas of each bay where sunken oil might have accumulated (Figures 2-7). Whenever possible, we duplicated transects sampled during an earlier study which found preliminary evidence of oiling at depth in grab samples (Malin Babcock, National Marine Fisheries Service, Auke Bay, personal communication).

Potential sampling areas included bays oriented in many different directions so that sampling was possible somewhere regardless of prevailing winds. We conducted all sampling within embayments because the heaviest distillate fraction of North Slope crude oil is characterized by a specific gravity of 0.9, or less than that of fresh water (S. Ede, Head Chemist, Chemical and Geological Laboratories of Alaska, personal communication). It follows that since almost no dispersants were used on the spill, the mechanism causing oil to sink in salt water must be one where oil becomes mixed with a heavy substance such as gravel or rocky sediment along shorelines. Clumps of the resulting mixture could roll and collect along the subtidal slope, eventually settling in deeper embayment areas.

In practice, several independent dives were conducted along each embayment transect in Prince William Sound because the ROV required a stable platform from which to operate; the maximum speed differential between the support vessel and the ROV (at depth) may not exceed 2.0 knots. Therefore, the vessel was anchored for all dives conducted within small embayments, and free-boated or drifted during dives conducted in Kachemak Bay. During each anchored dive the ROV was manually deployed to within one meter of the bottom as quickly as practical, maneuvered in a radius of approximately 50m, a double scoop sample obtained, and manually retrieved. A 23 kg lead weight attached to the umbilical expedited deployment. During each free-boated dive, the ROV was manually deployed to within one meter of the bottom, maneuvered in a radius of approximately 100m of the drifting boat track for approximately 1.6 km, and manually retrieved.

Sample Collection

Visual and physical samples were collected with high quality, precision equipment. We used a Benthos "Mini Rover Mark I" (ROV) to collect data in Prince William Sound, and a Deep Ocean Systems Phantom 500 in Kachemak Bay.

Visual Samples

We used high (at least 340 line per inch) resolution, low light capable color and black and white video cameras mounted in the hull of the ROV to collect all visual samples. The color camera was oriented forward, while the black and white camera was mounted in a downward orientation. Both cameras were mounted behind clear hemispherical windows; the forward mount allowed a +55° omnidirectional pan while the downward-looking camera was stationary. Two forward facing 150 watt lights provided illumination at depth and during night dives.

Physical Samples

All sediment samples from Prince William Sound were collected within the field of view, sealed at depth, and retrieved with the ROV. Special devices were manufactured to collect these samples and prevent contamination during retrieval. They consisted of two 8 cm by 12 cm cylinders mounted on the bottom of the vehicle frame with caps which could be cycled remotely by the operator. Disposable internal sleeves held the samples The samples were transferred from the sleeves to certified clean 4 oz or 8 oz jars once the ROV was on board the vessel, and the internal sleeves were removed and discarded, eliminating the need to repeatedly clean the sample devices in the field. We carefully followed all prescribed sample handling procedures to prevent accidental contamination, and all samples were immediately sealed, uniquely labeled, and frozen.

Drag samples from Kachemak Bay were collected immediately after ROV sampling along precisely the same track the vessel had taken. The absolute presence or absence of oil in sediments was determined *in situ* by inspecting sediments on deck, and no physical samples were collected for further analysis.

Data Recording

We recorded all visual observations on master quality VHS format video tapes. Data collected and transcribed onto video tape during each dive included: 1) date; 2) exact latitude and longitude (to seconds) as determined by the vessel LORAN; 3) depth at each anchored station and periodically during each free-boated dive; and 4) presence or absence of any observable substance which might be oil or an oil byproduct. A peripheral character generator and a microphone patch allowed us to record supplementary information directly onto tape in real time as necessary. All data which were recorded on tape, exact time, and presence or absence (binary) of oil or petroleum byproducts in visual and physical samples were also recorded in a field notebook immediately after each dive.

RESULTS

Prince William Sound

Data collection in Prince William Sound commenced on 19 September and continued through 22 September 1989. A total of 49 physical scoop samples and roughly 6 hours of video taped observations were collected during 25 dives conducted during approximately 2.5 days of sampling (Table 2). Depths ranged from 13 m to 46 m. Sampling was interrupted by severe weather and the rescue of victims from an aircraft accident at one sampling site.

Kachemak Bay

A total of eight dives was conducted in Kachemak Bay from 4 - 6 October 1989. Approximately five hours of video taped observations and nine drag samples were collected at depths ranging from 26 m to 168 m (Table 3). Weather also hindered data collection during the second phase of the project.

No submerged oil or oil byproducts were observed during visual sampling of the benthos in any phase of the ground truth experiment. One small ($0.4cm^2$) sheen was observed in each of two sediment samples during transfer from the disposable sampling container to the certified sample jar (Table 2). No other olfactory or visual evidence of subsurface contamination with petroleum hydrocarbons was evident during any phase of the project, including dives conducted through a 0.5 km^2 surface slick of sheen and mousse in Northwestern Bay.

STATUS OF INJURY ASSESSMENT

No subsurface oil was detected visually during this study in areas processing a high probability of petroleum hydrocarbon contamination. Additionally, no investigators participating in juxtaposed or distant oil spill studies have reported visual observations of submerged oil in areas with heavy surface contamination and ancillary evidence of contamination. While lab analyses of physical samples have not yet been completed, the salient result of this study remains that no benthic oil was visually observed *in situ* via ROV or any other method. With a single exception, reports of oil on anchors, etc. could not be verified as to source (of the report) or location. Without exception, we noticed no indications of petroleum contamination or unusual behavior exhibited by any species of fish or shellfish observed during any dives. Therefore, it appears that questions regarding the presence, extent, and/or location of visually or olfactorily detectable quantities of sunken oil will not be answered through use of an ROV.

An additional finding of this study relates to limitations imposed by using ROVs as platforms for conducting benthic research activities. Current ROV technology requires direct connection to the support vessel at all times. This absolute requirement limits the scope and manner in which operations may successfully be conducted, including: 1) the support vessel must be anchored or free-floating; it may generally not be operated under power; 2) the relative speed between the support vessel and the ROV may not exceed two to three knots; 3) under optimum conditions

the field of vision is 10 m to 20 m at depths greater than euphotic; 4) seas must be less than 1 m; and 5) extreme caution must be exercised in areas likely to house wrecks or abandoned fishing gear which would damage or entangle the umbilical cable. For all of these reasons, it is our opinion that ROVs may have limited application as broadscale exploratory tools of the ocean floor in Alaskan waters.

LITERATURE CITED

AOG (Alaska Office of the Governor). 1989. *Exxon Valdez* oil spill information packet. Juneau, Alaska.

PERSONAL COMMUNICATION

Babcock, Malin, National Marine Fisheries Service, Auke Bay.

Ede, S, Head Chemist, Chemical and Geological Laboratories of Alaska.

Jameson, Glen, Department of Fisheries & Oceans, British Columbia.

Krieger, Ken, National Oceanic and Atmospheric Administration.

TABLES AND FIGURES

Table 1. List of proposed sampling sites to ground truth visual observations of benthic oiling via Remotely Operated Vehicle (ROV), 1989.

General Location	Specific Location	No. of Transects
Perry Island	East Twin Bay	1
Eleanor Island	Northwest Bay	3
Knight Island	Louis Bay	2
Knight Island	Herring Bay	4
Knight Island	Bay of Isles	2
Knight Island	Snug Harbor	3
Evans Island	Shelter Bay	2
Latouche Island	Sleepy Bay	1
Green Island	North Side	1
Kachemak Bay	Outside the Spit	4
Kachemak Bay	Inside the Spit	1
Kachemak Bay	Tutka Bay	3
Total		27

Table 2. List of sealed (at depth) sediment samples collected in Prince William Sound during VCR filming via Remotely Operated Vehicle (ROV) by location and date, 1989

Date	Sample No.	Location Name	Latitude	Longitude	Depth (m)	Oil Observed via: ROV	Sample
09/19	ROVP001A	Sleepy Bay	60°02.10N	147°50.05W	22	No	No
09/20	ROVP002A	Herring Bay	60°26.20N	147°42.90W	16	No	No
09/20	ROVP002B	Herring Bay	60°26.20N	147°42.90W	16	No	No
09/20	ROVP003A	Herring Bay	60°26.00N	147°55.45W	38	No	No
09/20	ROVP003B	Herring Bay	60°26.00N	147°55.45W	38	No	No
09/20	ROVP004A	Herring Bay	60°25.18N	147°47.45W	18	No	Yes
09/20	ROVP004B	Herring Bay	60°25.18N	147°47.45W	18	No	No
09/20	ROVP005A	Herring Bay	60°25.45N	147°47.10W	26	No	No
09/20	ROVP005B	Herring Bay	60°25.45N	147°47.10W	26	No	No
09/20	ROVP006A	Herring Bay	60°25.69N	147°46.92W	24	No	No
09/20	ROVP006B	Herring Bay	60°25.69N	147°46.92W	24	No	No
09/20	ROVP007A	Herring Bay	60°26.03N	147°46.81W	29	No	No
09/20	ROVP007B	Herring Bay	60°26.03N	147°46.81W	29	No	No
09/20	ROVP008A	Herring Bay	60°26.45N	147°46.60W	31	No	No
09/20	ROVP008B	Herring Bay	60°26.45N	147°46.60W	31	No	No
09/20	ROVP009A	Herring Bay	60°26.72N	147°46.95W	24	No	No
09/20	ROVP009B	Herring Bay	60°26.72N	147°46.95W	24	No	No
09/20	ROVP010A	Herring Bay	60°28.66N	147°42.80W	13	No	No
09/20	ROVP010B	Herring Bay	60°28.66N	147°42.80W	13	No	No
09/20	ROVP011A	Herring Bay	60°28.72N	147°43.11W	27	No	No
09/20	ROVP011B	Herring Bay	60°28.72N	147°43.11W	27	No	No
09/20	ROVP012A	Herring Bay	60°28.80N	147°43.49W	40	No	No
09/20	ROVP012B	Herring Bay	60°28.80N	147°43.49W	40	No	No
09/20	ROVP013A	Knight Island	60°30.34N	147°42.68W	22	No	No
09/20	ROVP013B	Knight Island	60°30.34N	147°42.68W	22	No	No
09/20	ROVP014A	Knight Island	60°30.58N	147°42.68W	42	No	No
09/20	ROVP014B	Knight Island	60°30.58N	147°42.68W	42	No	No
09/21	ROVP015A	Louis Bay	60°28.40N	147°40.50W	22	No	No
09/21	ROVP015B	Louis Bay	60°28.40N	147°40.50W	22	No	No
09/21	ROVP016A	Louis Bay	60°28.38N	147°40.71W	15	No	No
09/21	ROVP016B	Louis Bay	60°28.38N	147°40.71W	15	No	No
09/21	ROVP017A	Louis Bay	60°28.36N	147°40.92W	29	No	No
09/21	ROVP017B	Louis Bay	60°28.36N	147°40.92W	29	No	No
09/21	ROVP018A	Louis Bay	60°28.58N	147°39.81W	42	No	No
09/21	ROVP018B	Louis Bay	60°28.58N	147°39.81W	42	No	No
09/21	ROVP019A	Northwestern Bay	60°32.25N	147°34.68W	16	No	No
09/21	ROVP019B	Northwestern Bay	60°32.25N	147°34.68W	16	No	No
09/21	ROVP020A	Northwestern Bay	60°33.47N	147°34.82W	27	No	No
09/21	ROVP020B	Northwestern Bay	60°33.47N	147°34.82W	27	No	No
09/21	ROVP021A	Northwestern Bay	60°33.52N	147°35.00W	44	No	No
09/21	ROVP021B	Northwestern Bay	60°33.52N	147°35.00W	44	No	Yes
09/21	ROVP022A	Northwestern Bay	60°33.90N	147°34.35W	18	No	No
09/21	ROVP022B	Northwestern Bay	60°33.90N	147°34.35W	18	No	No
09/21	ROVP023A	Northwestern Bay	60°33.94N	147°34.61W	40	No	No
09/21	ROVP023B	Northwestern Bay	60°33.94N	147°34.61W	40	No	No
09/21	ROVP024A	East Twin Bay	60°43.50N	147°55.88W	31	No	No
09/21	ROVP024B	East Twin Bay	60°43.50N	147°55.88W	31	No	No
09/21	ROVP025A	East Twin Bay	60°43.29N	147°56.45W	46	No	No

Table 3: List of bottom trawls conducted in Kachemak Bay before VCR filming via Remotely Operated Vehicle (ROV) by location and date, 1989.[a]

Date	Trawl No.	Location Name	Latitude	Longitude	Depth (m)	Oil Observed via: ROV	Sample
10/04	ROVK01	KACHEMAK BAY	59°36.72N	151°42.50W	33	No	No
09/04	ROVK02	KACHEMAK BAY	59°40.38N	151°12.49W	46	No	No
09/05	ROVK03	KACHEMAK BAY	59°33.60N	151° 29.79W	168	No	No
09/05	ROVK04	KACHEMAK BAY	59°33.34N	151°40.51W	68	No	No
09/05	ROVK05	KACHEMAK BAY	59°26.20N	151°22.02W	77	No	No
09/06	ROVK06	KACHEMAK BAY	59°26.48N	151°22.19W	93	No	No
09/06	ROVK07	KACHEMAK BAY	59°27.66N	151°24.30W	148	No	No
09/06	ROVK08	KACHEMAK BAY	59°35.92N	151°28.11W	26	No	No

[a] A 12 m (40 ft) bottom trawl was dragged for 1.6 km (1 mi) to test for physical presence or absence of petroleum hydrocarbons.

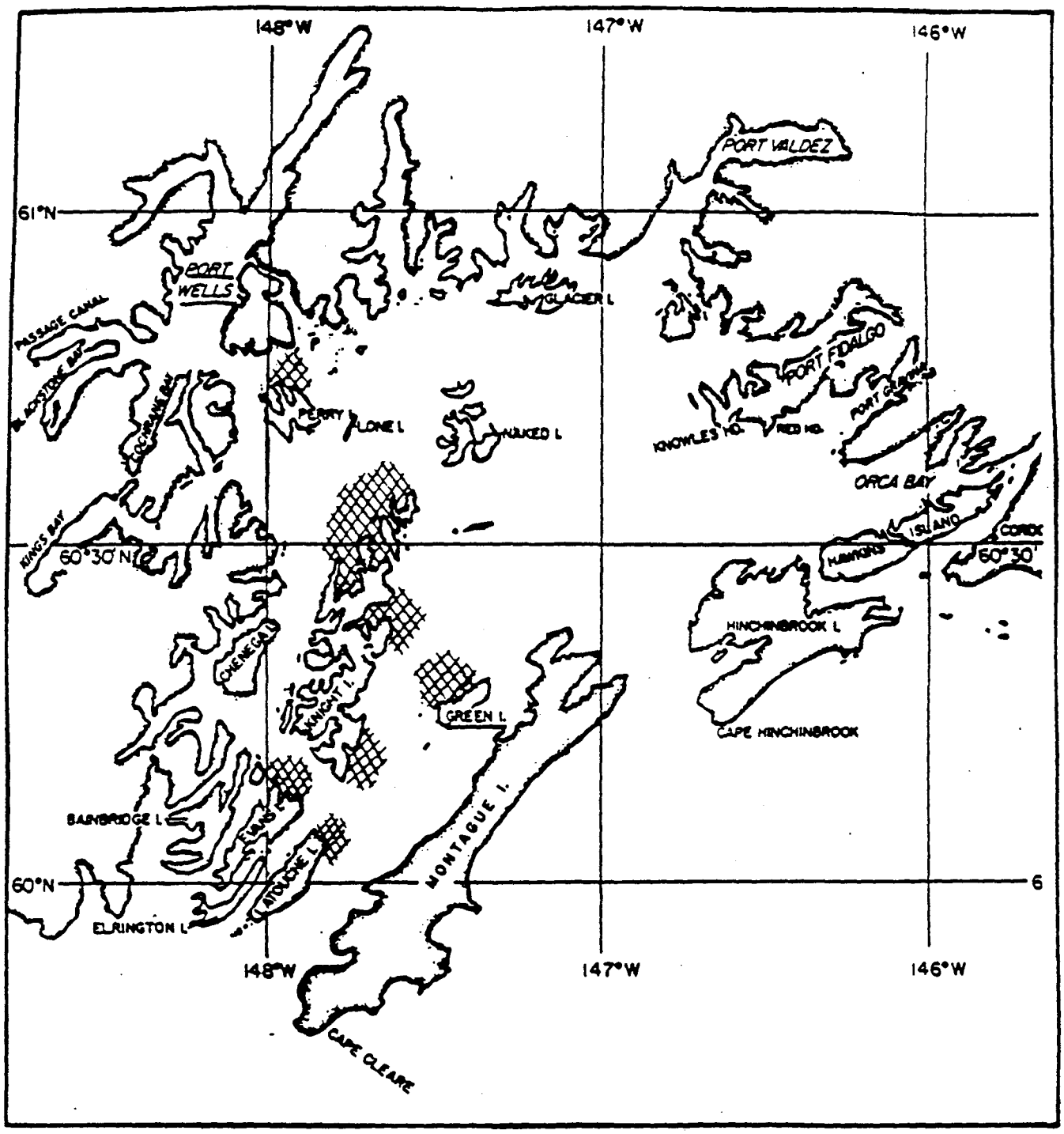


Figure 1. General areas of proposed sampling for benthic oiling via Remotely Operated Vehicle (ROV) in Prince William Sound, Alaska, 1989.

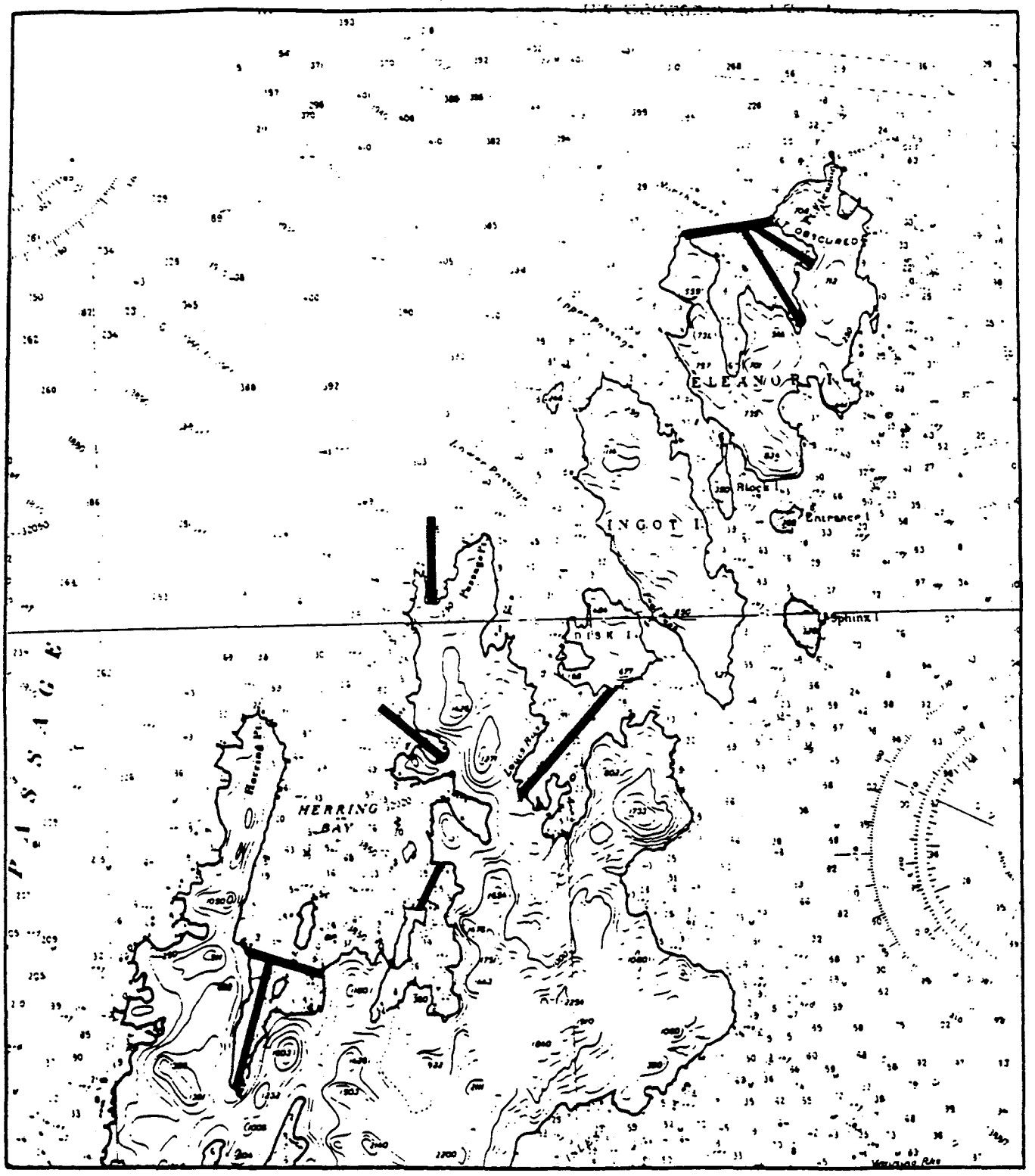


Figure 2. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons in the Upper Knight Island group, Prince William Sound, Alaska, 1989.

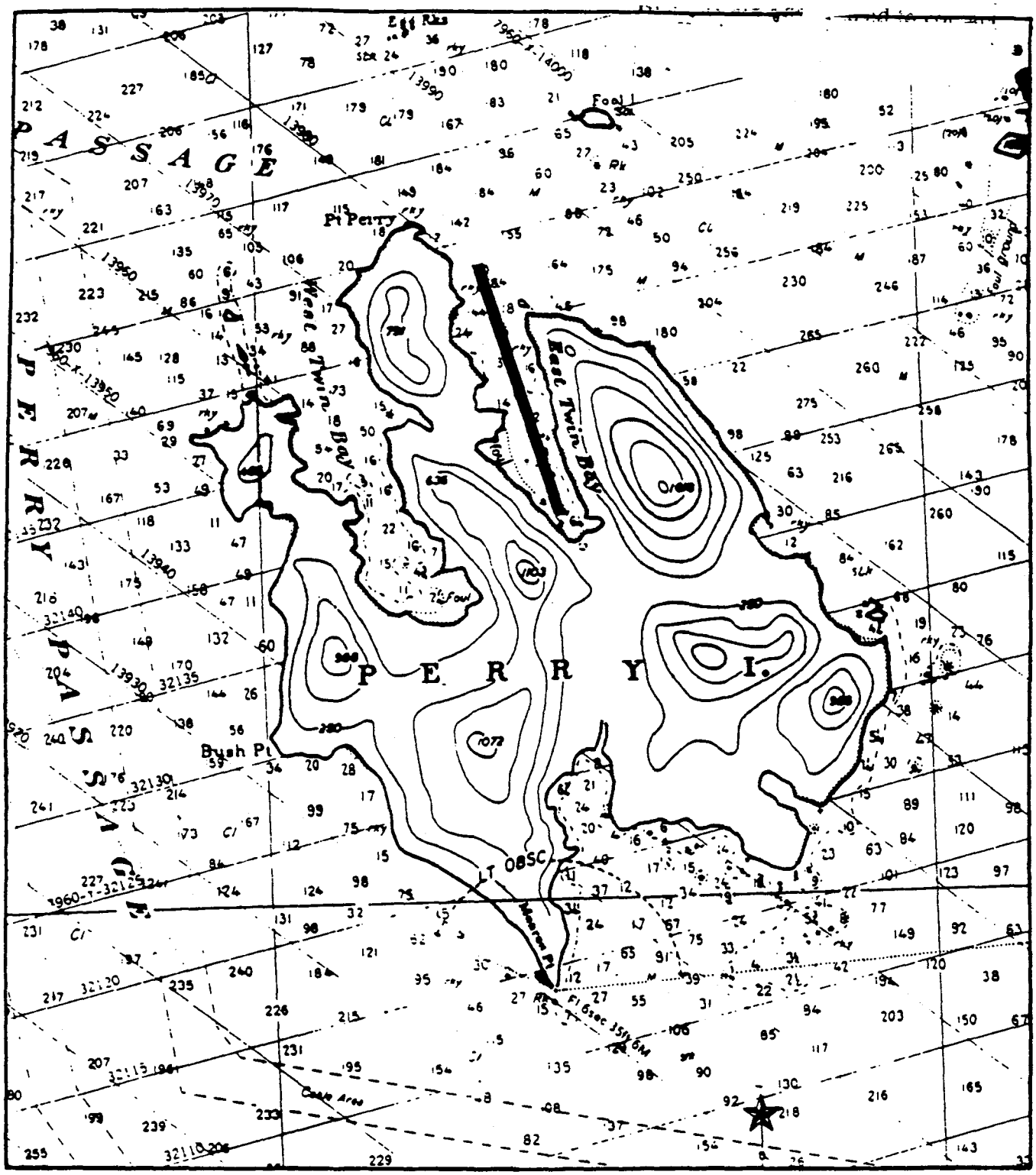


Figure 3. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons near Perry Island, Prince William Sound, Alaska, 1989.

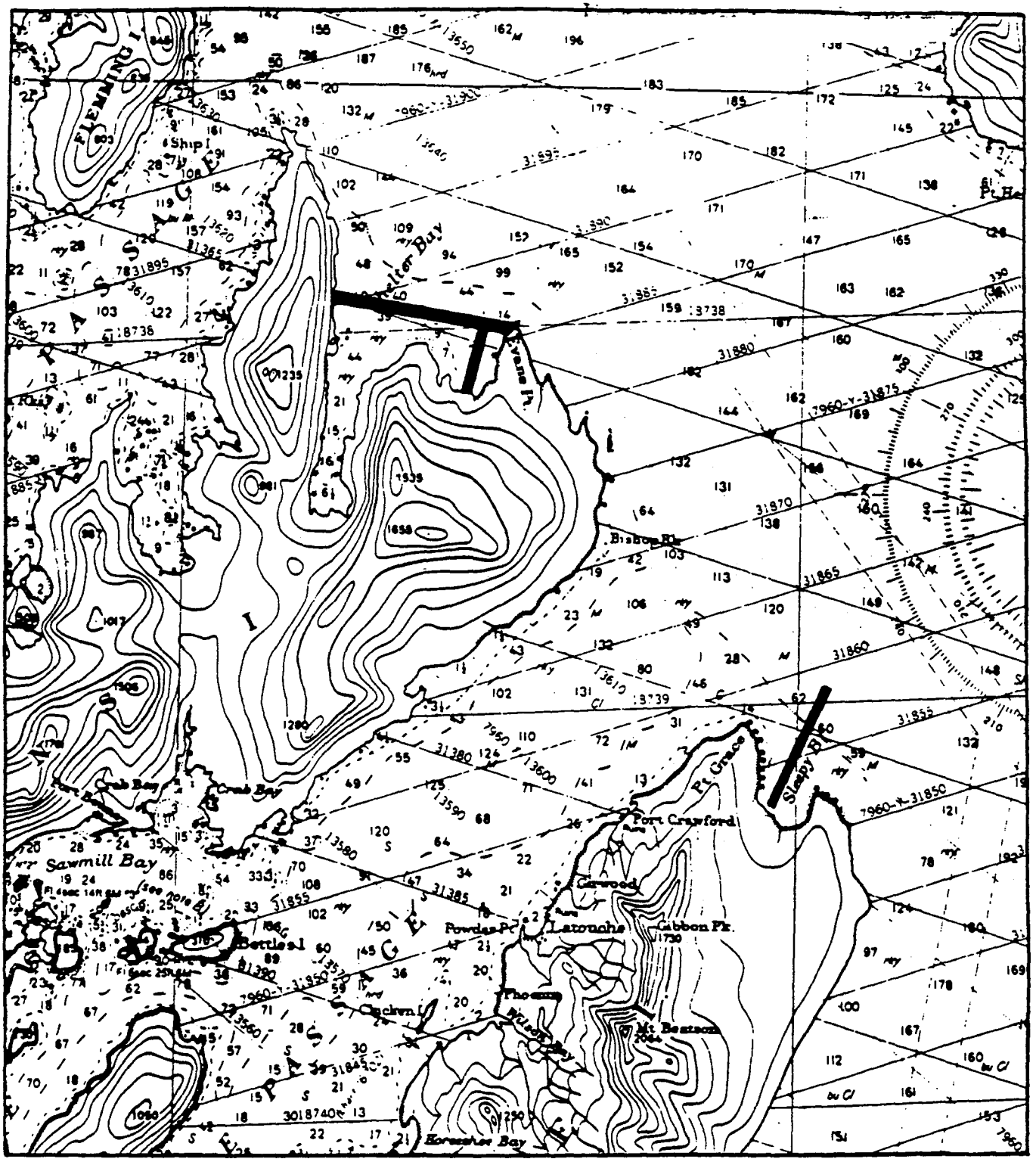


Figure 4. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons near Evans and Latouche Islands, Prince William Sound, Alaska, 1989.

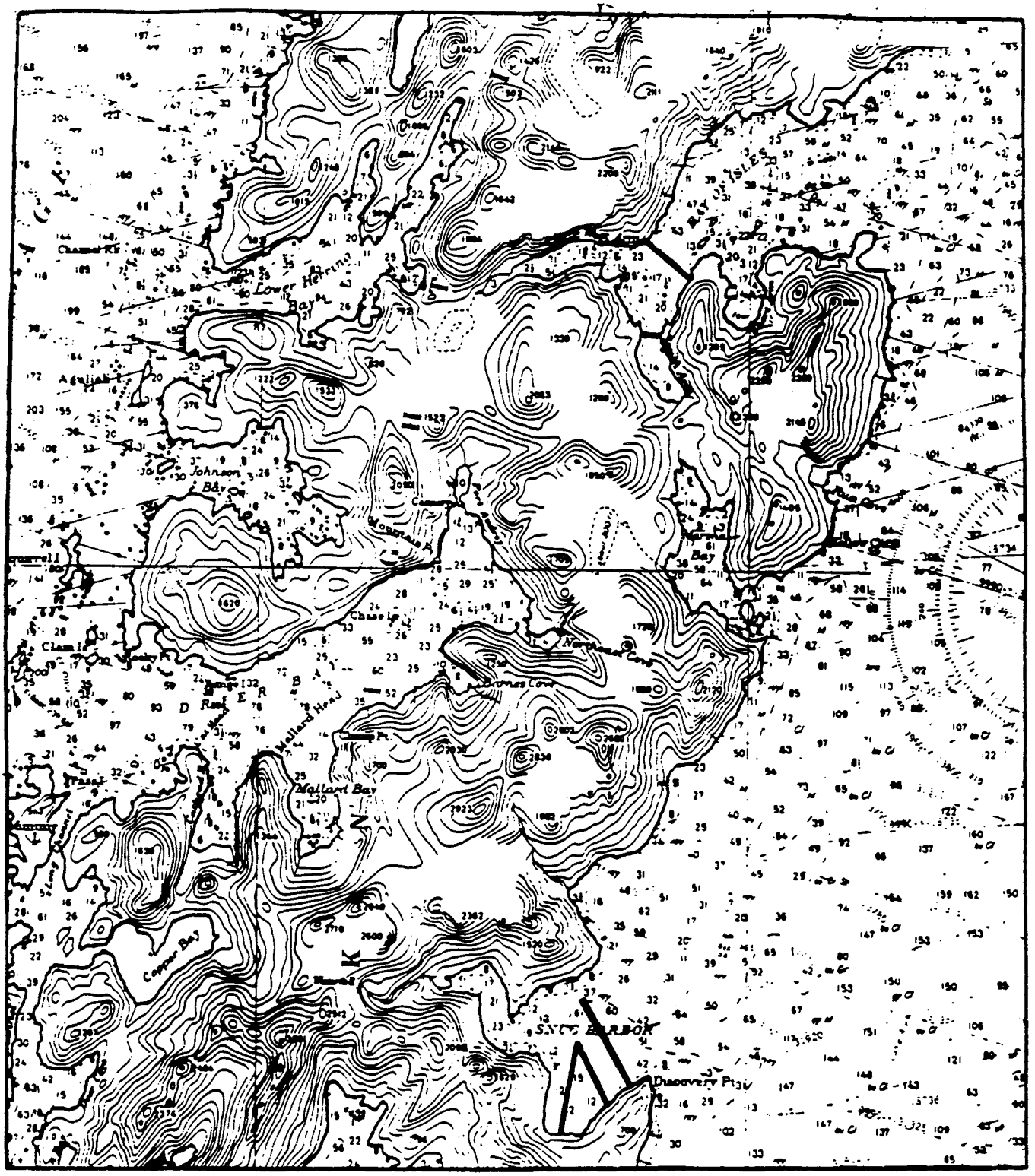


Figure 5. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons along lower Knight Island, Prince William Sound, Alaska, 1989.

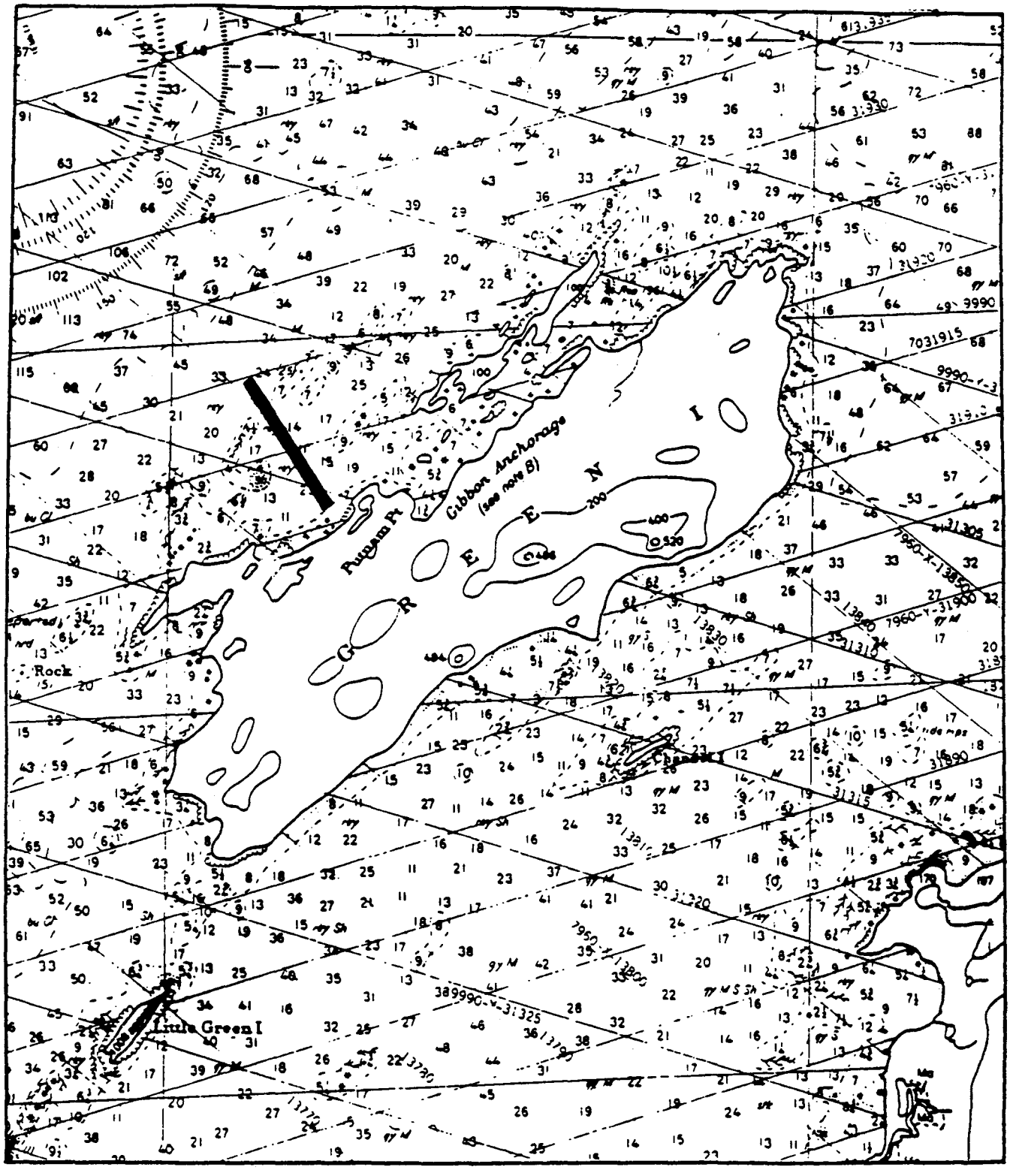
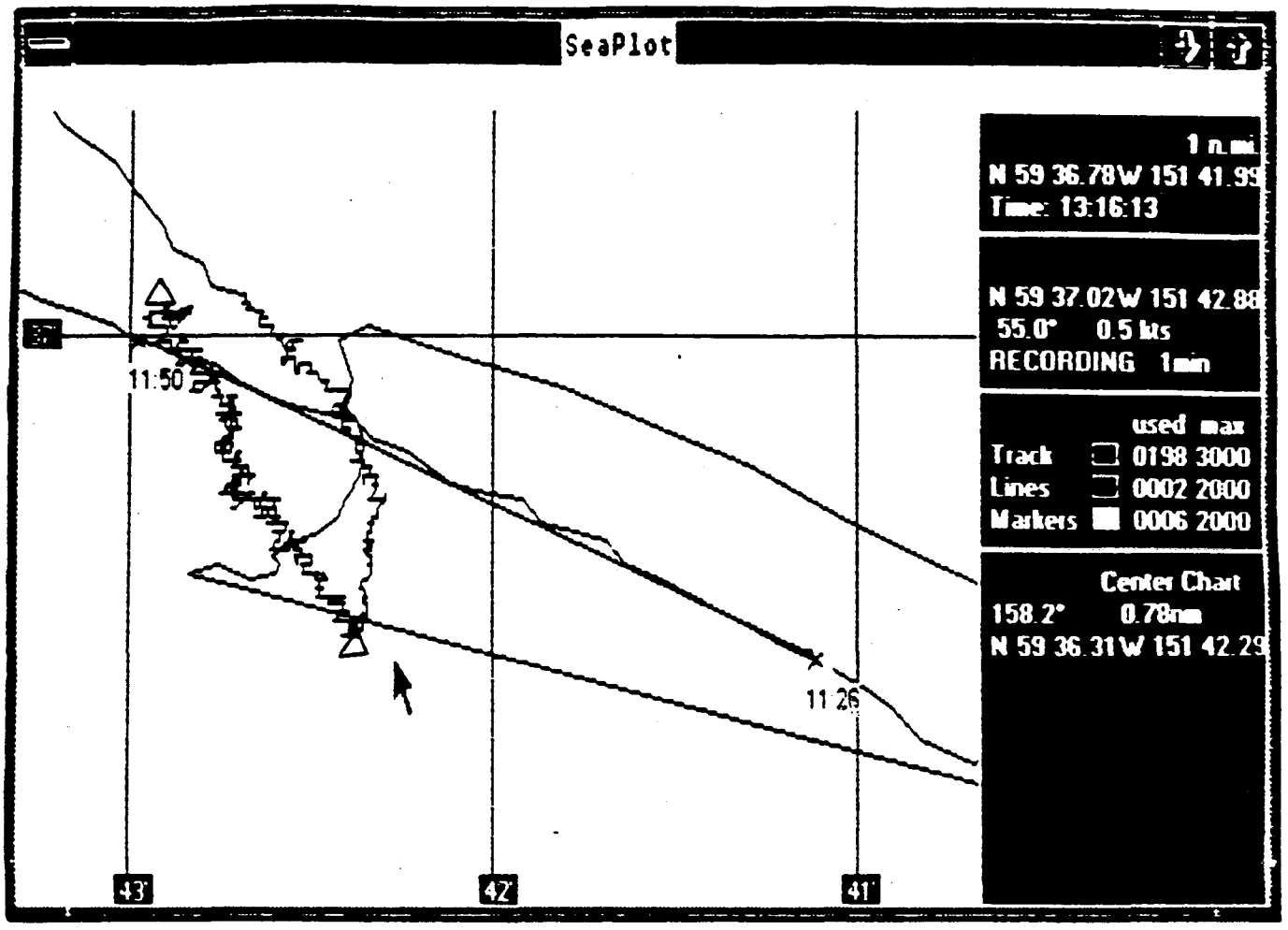


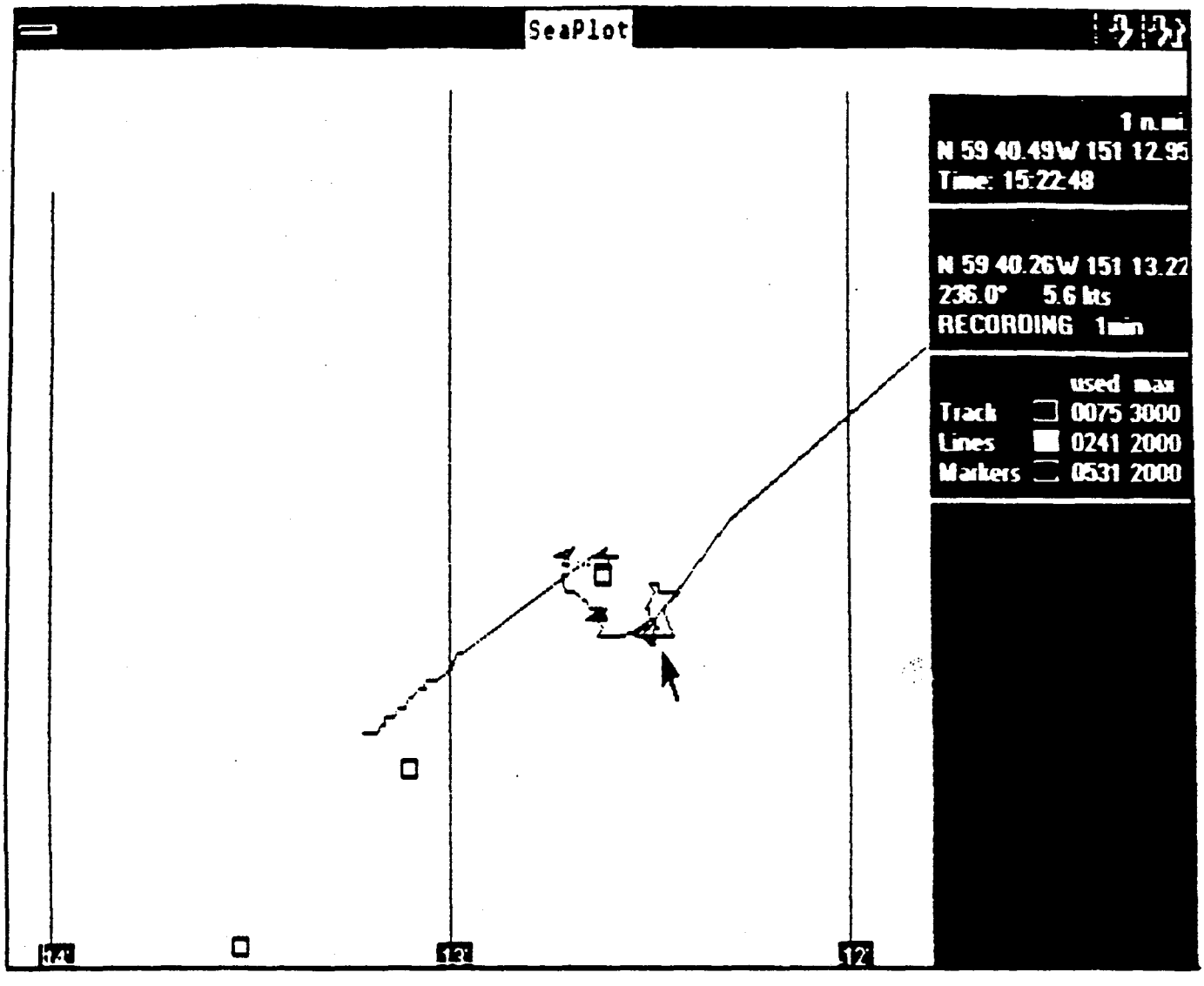
Figure 6. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons along Green Island, Prince William Sound, Alaska, 1989.

Figure 7. Proposed ROV sampling transects for visual presence of submerged petroleum hydrocarbons in Kachemak Bay, Alaska, 1989.

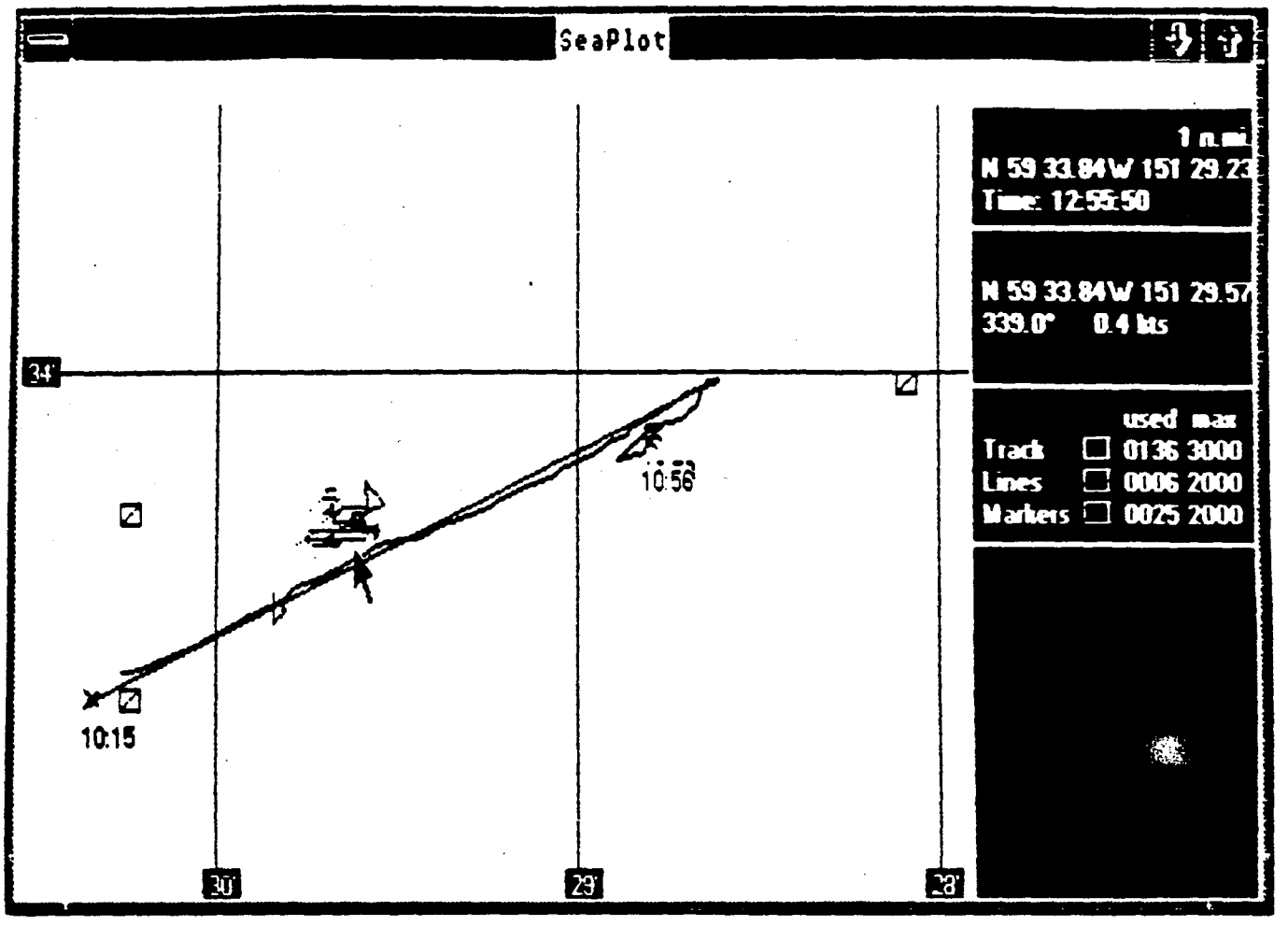
APPENDICES



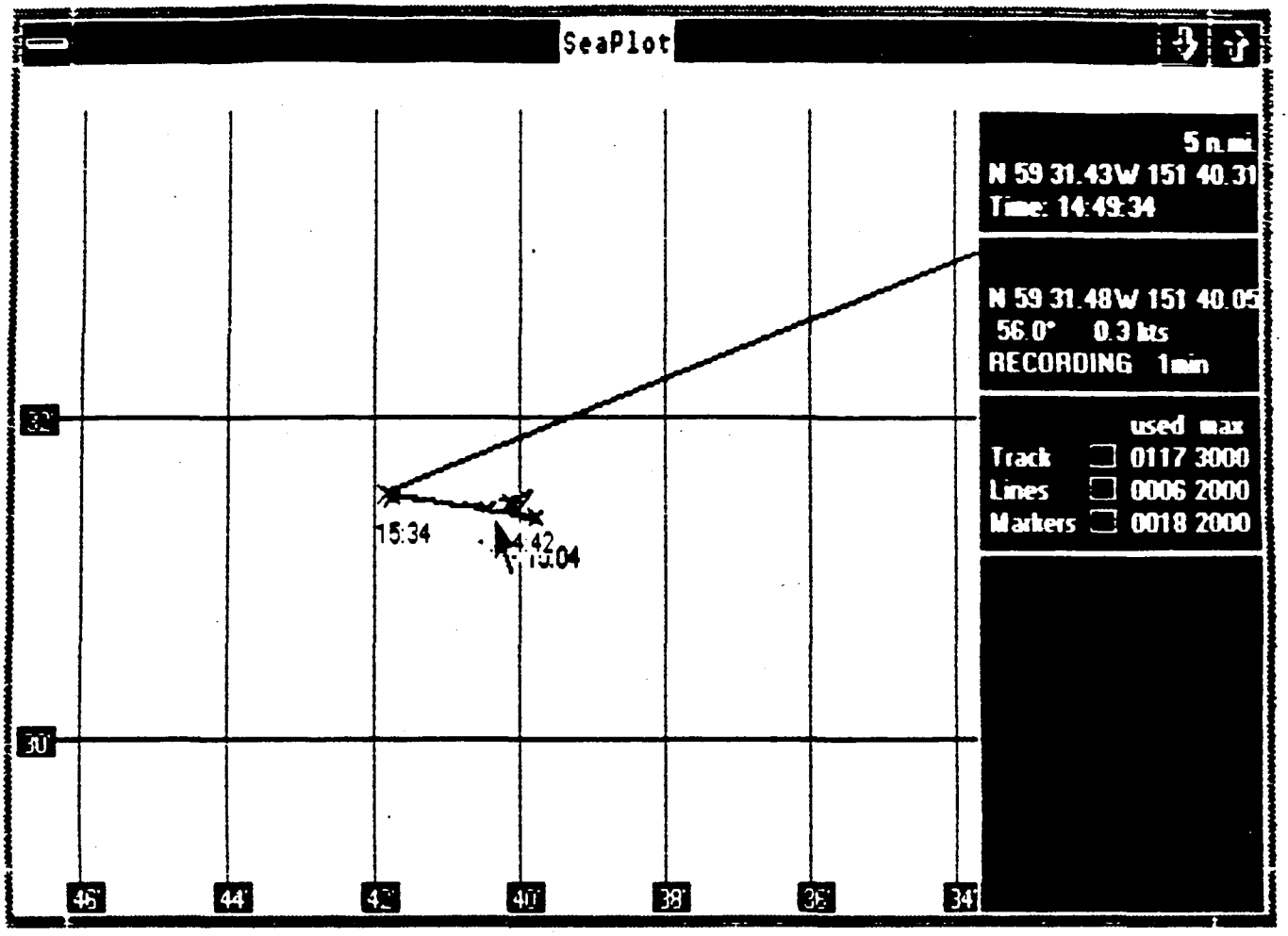
Appendix A.1. Exact ROV track during dive ROVK01 in Kachemak Bay, Alaska on 3 October 1989.



Appendix A.2. Exact ROV track during dive ROVKQ2 in Kachemak Bay, Alaska on 4 October 1989.



Appendix A.3. Exact ROV track during dive ROVK03 in Kachemak Bay, Alaska on 5 October 1989.



Appendix A.4. Exact ROV track during dive ROVK04 in Kachemak Bay, Alaska on 5 October 1989.