OCS Study
MMS 2000-025

Environmental Studies Program

Mapping Cook Inlet Rip Tides Using Local Knowledge and Remote Sensing

Prepared for Minerals Management Service

Contract No. 01-98-CT-30906

Prepared by

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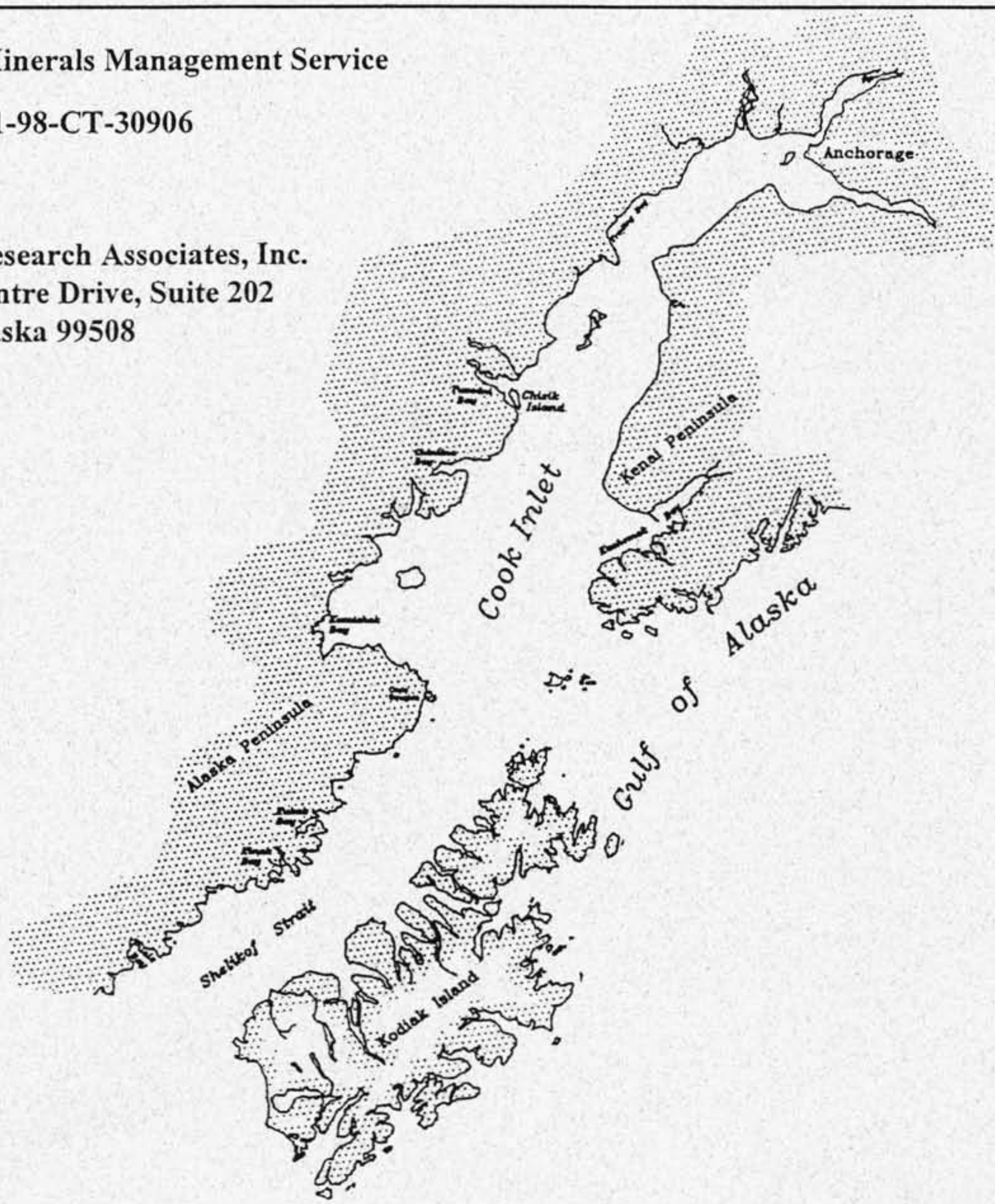

MMS
U.S. Department of the Interior
Minerals Management Service
Alaska OCS Region

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ABSTRACT

Rip tides are strong tidal currents that occur where marine water masses converge or diverge. Commercial drift gillnet salmon fishermen in Cook Inlet, Alaska, often focus their fishing effort on rip tides, because salmon are known to concentrate in these areas. Offshore oil development in Cook Inlet poses potential conflicts with the salmon driftnet fishery because drilling rigs could create obstacles and spilled contaminants may converge and submerge along rip tides. Because of this, Cook Inlet fishing groups have asked the Minerals Management Service (MMS) to exclude Cook Inlet rip tide areas from upcoming oil and gas leases.

The objectives of this study were to map rip tides in Cook Inlet, provide statistics on the consistency of rip tide locations, and develop an information base on fishermen's use of rip tides that could help the MMS avoid conflicts between local fishermen and future offshore oil industry activities. Local knowledge was obtained from fishermen on the location and use of rip tides within Cook Inlet. The locations of rip tides also were interpreted and mapped using satellite-borne Synthetic Aperture Radar (SAR) imagery. During the summer of 1999, the Canadian Space Agency's RADARSAT 1 satellite was programmed to image the study area during commercial gillnet openers in Cook Inlet. These image data were simultaneously ground-truthed with the help of local fishermen and aerial surveys to document both the fishermen's use of rip tides and the ability of satellite radar imagers to map rip tide locations. Historic radar imagery collected by the European Radar Satellites (ERS-1 and ERS-2) between 1992 and 1999 were also examined to determine the consistency of Cook Inlet rip tide locations at different tide stages among years.

The results of this work were entered into a database, interpreted, summarized, and presented to scientific and local stakeholder audiences. Several rip tides consistently appear along the longitudinal axis of lower Cook Inlet. A west rip tide and a combined middle and east rip tide were noticeable on the SAR images analyzed. Fishermen verified the persistent presence of these rip tides, and reported that they often fish along rip tides where salmon may concentrate. Thus, any future offshore oil and gas development in Cook Inlet should consider these rip tide locations and their use by fishermen.

1.0 INTRODUCTION

Cook Inlet, Alaska is an approximately 340-kilometer (km) extension of the Gulf of Alaska that contains an important commercial driftnet salmon fishing industry (Figure 1). Because of Cook Inlet's importance to the Alaska economy, the U.S. Department of Interior, Minerals Management Service (MMS) contracted with LGL Alaska Research Associates, Inc. to map the location and variability of rip tides in Cook Inlet, Alaska (Figure 2). The particular emphasis of the study was to use both local knowledge and remote sensing to examine rip tides in the portion of Cook Inlet used by the driftnet salmon fishery.

Rip tides are strong tidal currents that occur where water masses converge or diverge. Cook Inlet is characterized by extreme tidal fluctuations of up to 12.2 meters (m) (National Oceanic and Atmospheric Administration—NOAA 1999) that produce strong currents in excess of 8 knots (Tarbox and Thorne 1996). The convergence and divergence of different water masses (generally, southward-flowing low-salinity water and westward-intruding sea water) create robust rip tides in Cook Inlet. A map of approximate locations of Cook Inlet rip tides was generated in 1977 based on interviews with local fishermen, pilots, and other people with experience in the Inlet (Burbank 1977). This map was produced before geographical information systems (GIS) or global positioning systems (GPS) were available (Figure 2). This map was part of the historic database available prior to initiating the present study.

The Cook Inlet salmon driftnet fishery is of great importance to the local and state economy. The annual catch of salmon by the driftnet fleet between 1990 and 1997 averaged $23.3 million (Commercial Fisheries Entry Commission web site), and deliveries during the 1998 and 1999 seasons were estimated to be worth $5.3 and $13.2 million, respectively (Jeff Fox, Alaska Department of Fish and Game, Cook Inlet Commercial Fishery Management Biologist, pers. comm., 13 January 2000). Cook Inlet drift gillnet fishermen often focus their effort at rip tides because salmon are known to concentrate in these areas.

The three nautical-mile boundary that separates state from federal waters delineates the areas of State of Alaska jurisdiction (within three nautical miles of shore) from MMS jurisdiction (three or more nautical miles offshore) (Figure 1). The MMS is responsible for permitting oil and gas exploration and development beyond the three nautical-mile boundary.

The possibility of offshore oil and gas industry development in Cook Inlet poses potential conflicts with the salmon driftnet fishery. Construction of stationary drilling rigs could create obstacles where fishermen typically fish. Oil and gas exploration and development and production facilities would add possible sources of contaminants to existing sources, i.e., commercial vessels and other boats. There is a possibility that spilled contaminants may concentrate along rip tides. Because some Cook Inlet fishermen fish predominantly along rip tides, they have requested that the MMS consider excluding rip tide locations from future lease sales to avoid interference with the fishery.

1.1 Objectives

The objectives of this study were to: (1) quantify the spatial and temporal variability of rip tide locations; (2) determine the locations of rip tides used by the fishing fleet; and (3) collate information on fishery use of rip tides and identify potential conflicts between fishermen and the oil and gas industry.

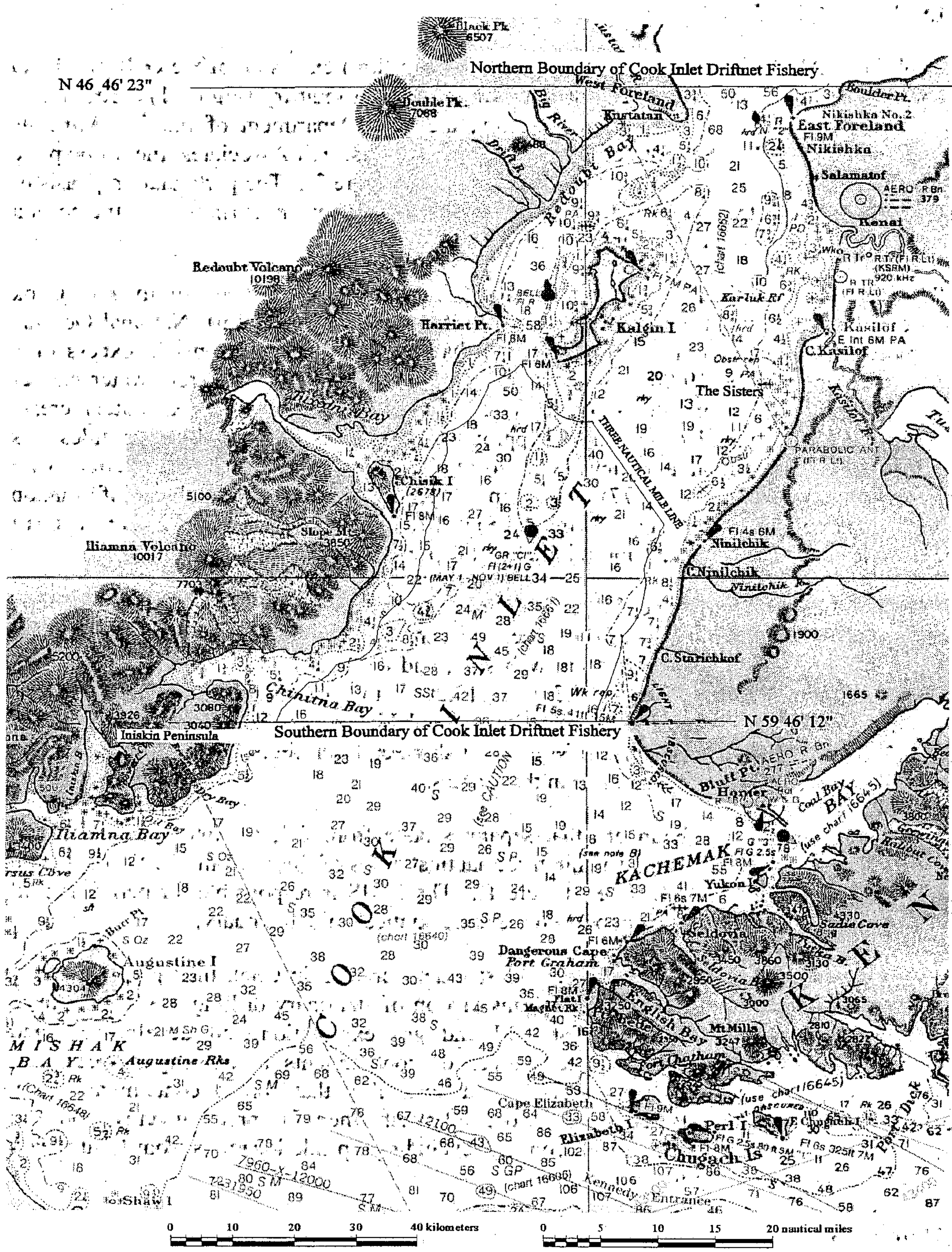


Figure 1. NOAA Chart #16013 driftnet fishery boundaries (water depths in fathoms) in Cook Inlet, Alaska. One fathom equals 1.8 meters. The three nautical-mile boundary within the commercial salmon fishery zone indicating the separation of State and Federal waters is shown. Note: the boundary of the Territorial Sea extends near Ninilchik through southern Kalgin Island to Harriet Point.

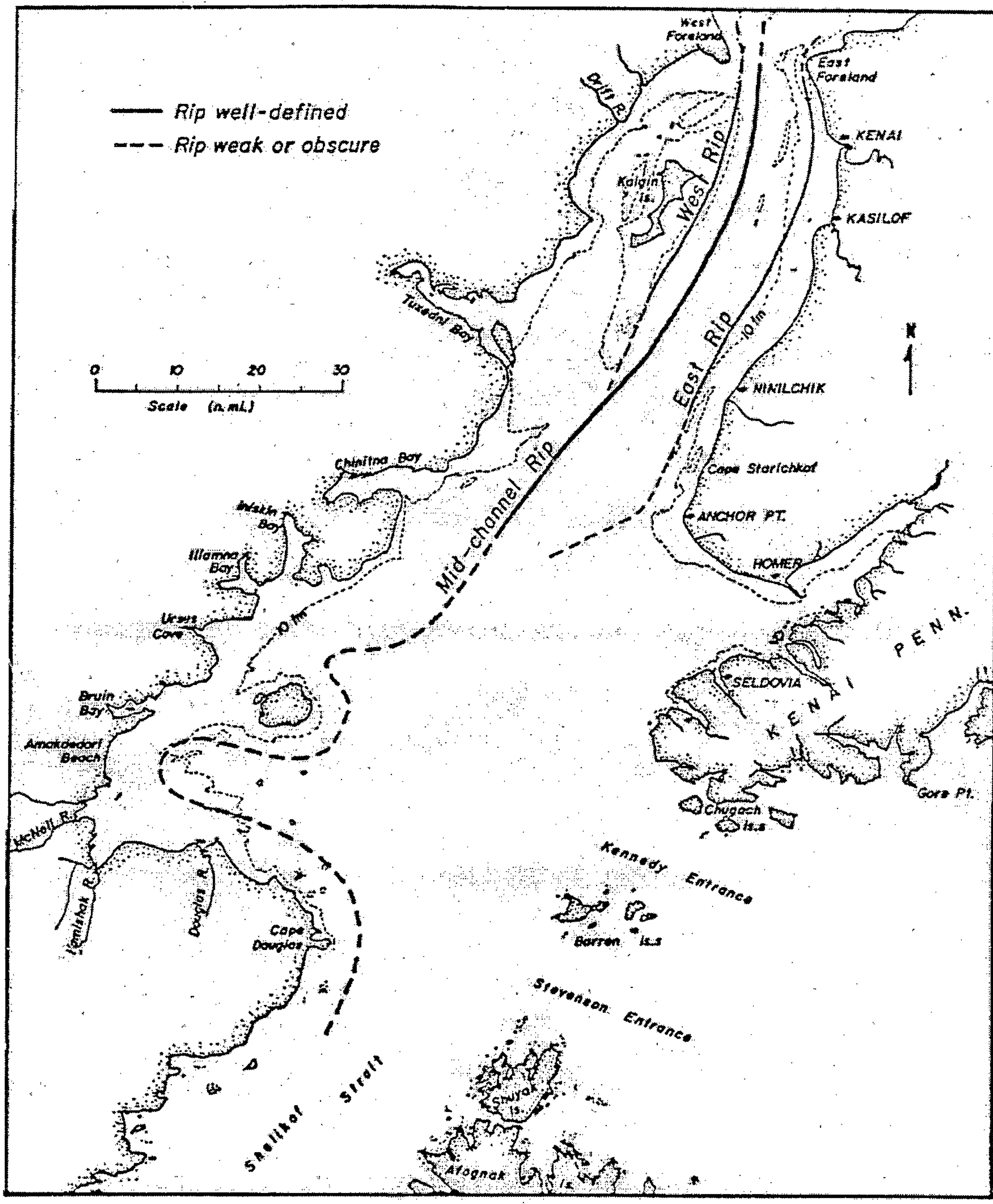


Figure 2. Historic map of major rip tides (frontal zones) in lower Cook Inlet, Alaska (Burbank 1977). The dashed lines indicate where the rips are weak or obscure. The bathymetry shows only the 10-fathom (20 m) contour. One fathom equals 1.8 meters.

2.0 BACKGROUND: OCEANOGRAPHY OF COOK INLET RIPTIDES

According to drift gillnet fishermen, rip tides are bands of strong currents delineated by chaotic surface roughness, 'slicks', or lines of flotsam. Three oceanographic processes are probably associated with the presence and behavior of rip tides, or currents, in Cook Inlet. These include tides, wind-induced surface motion, and variations in seawater density. Any or all of these processes may influence generation of the rip tides and their surface signatures.

2.1 Cook Inlet Water Depth

All three oceanographic processes are affected by average water depth, which generally increases from north to south in Cook Inlet (Figure 3). Upper Cook Inlet, between Fire Island and the Forelands, has an average depth of approximately 18.3 m. Central Cook Inlet, from the Forelands to Kachemak Bay, has an average depth of about 27.4 m. The average depth from Kachemak Bay to the Barren Islands (inlet mouth) is approximately 36.6 m. Also notable are the constrictions caused by islands and prominences at the Barren Islands, Augustine Island, Homer Spit (mouth Kachemak Bay), Kalgin Island, the East and West Forelands, Middle Ground Shoal (just north of the Forelands), and Fire Island at the confluence of Knik and Turnagain Arms.

2.2 Cook Inlet Circulation

The general circulation pattern of lower and middle Cook Inlet is that denser, saltier water flows northward along the east shore and fresher, silty outflowing water flows southward along the west shore (Burbank 1977; Wapora Inc. 1979; Figure 4). The lower Inlet, including outer Kachemak Bay, has a "salt wedge" system characterized by incoming salty Gulf of Alaska water that lies below buoyant outgoing water freshened by runoff from tributaries. These patterns overlay tidal currents that reverse in the upper Inlet and become increasingly elliptical (rotating in direction) in the middle and lower Inlet. The average location of the east, west, and middle rip tides are noted in Figure 4.

2.3 Cook Inlet Tides

Cook Inlet rip tides are primarily driven by tides, since they follow the reverse direction pattern of rising and falling water levels. The speed with which rip tides move along the surface is proportional to the range of tide heights. Daily changes in tidal ranges, termed *diurnal inequality*, are due to the moon's declination from the plane of the equator during its orbit around the earth. Complex interactions between the earth-moon and sun-earth astronomical systems are magnified in Cook Inlet, making it extremely difficult to predict tide levels.

Tides wash in and out of the Cook Inlet basin like a very long wave. Fluid motion on this large scale is affected by the rotation of the earth, causing incoming currents in Cook Inlet to veer toward the east coast and outgoing currents to veer to the west coast. Because incoming currents have more energy, tidal ranges on the east shore are generally larger than those on the opposite shore. In the deeper, broader areas of the lower Inlet, the tidal current changes directions in an elliptical pattern, known as *rotary tides*.

Cotidal lines are lines along which the phase of the tide is equal (i.e., high tide occurs at the same time). Cook Inlet cotidal lines from concurrent coastal water level measurements, generally run east-west directly across the waterway (Figure 5). Cook Inlet fishermen commented in meetings for this project that they observed differences in tide phase between the

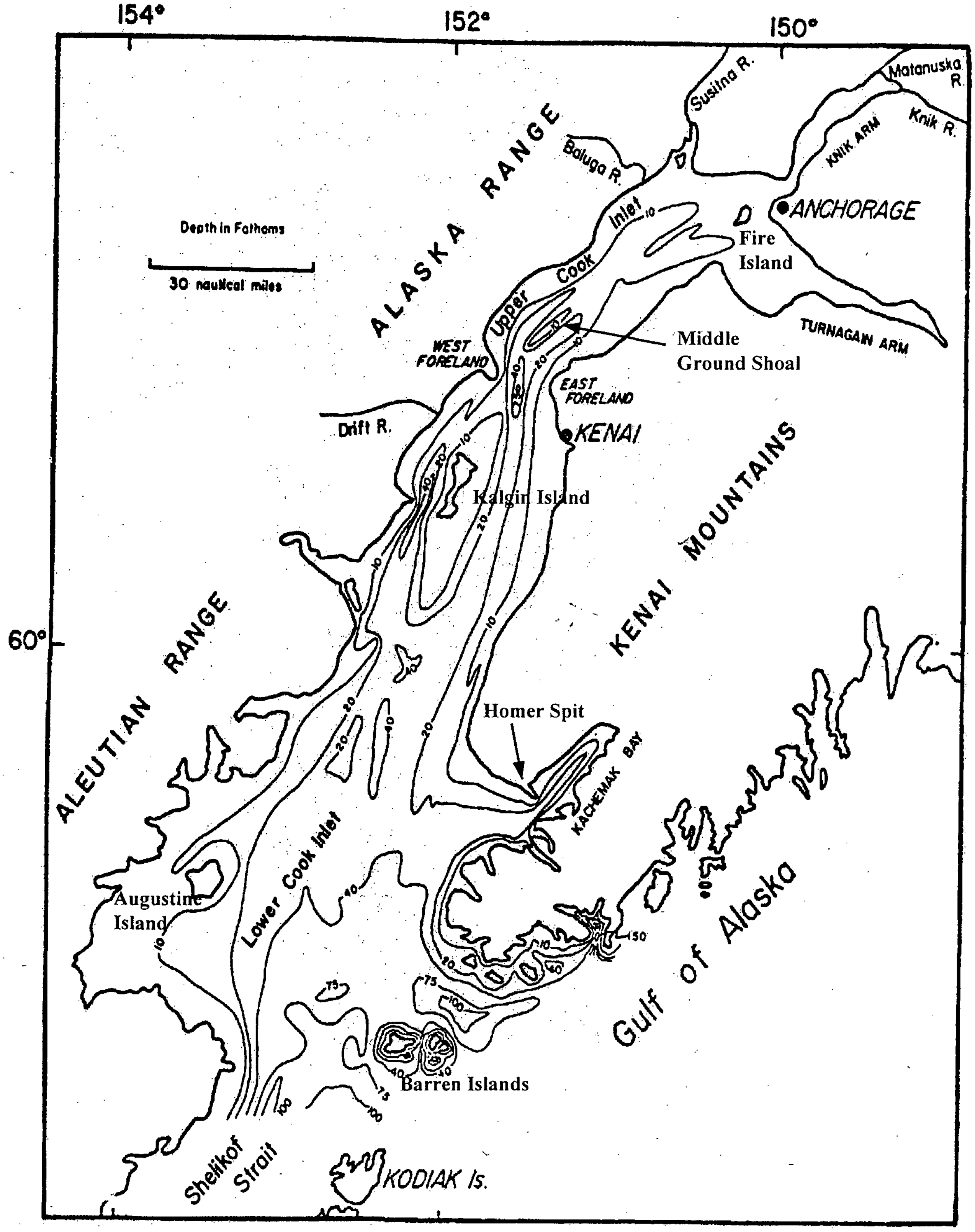


Figure 3. Water depths in fathoms in Cook Inlet, Alaska (Sharma and Burrell 1970). One fathom equals 1.8 meters.

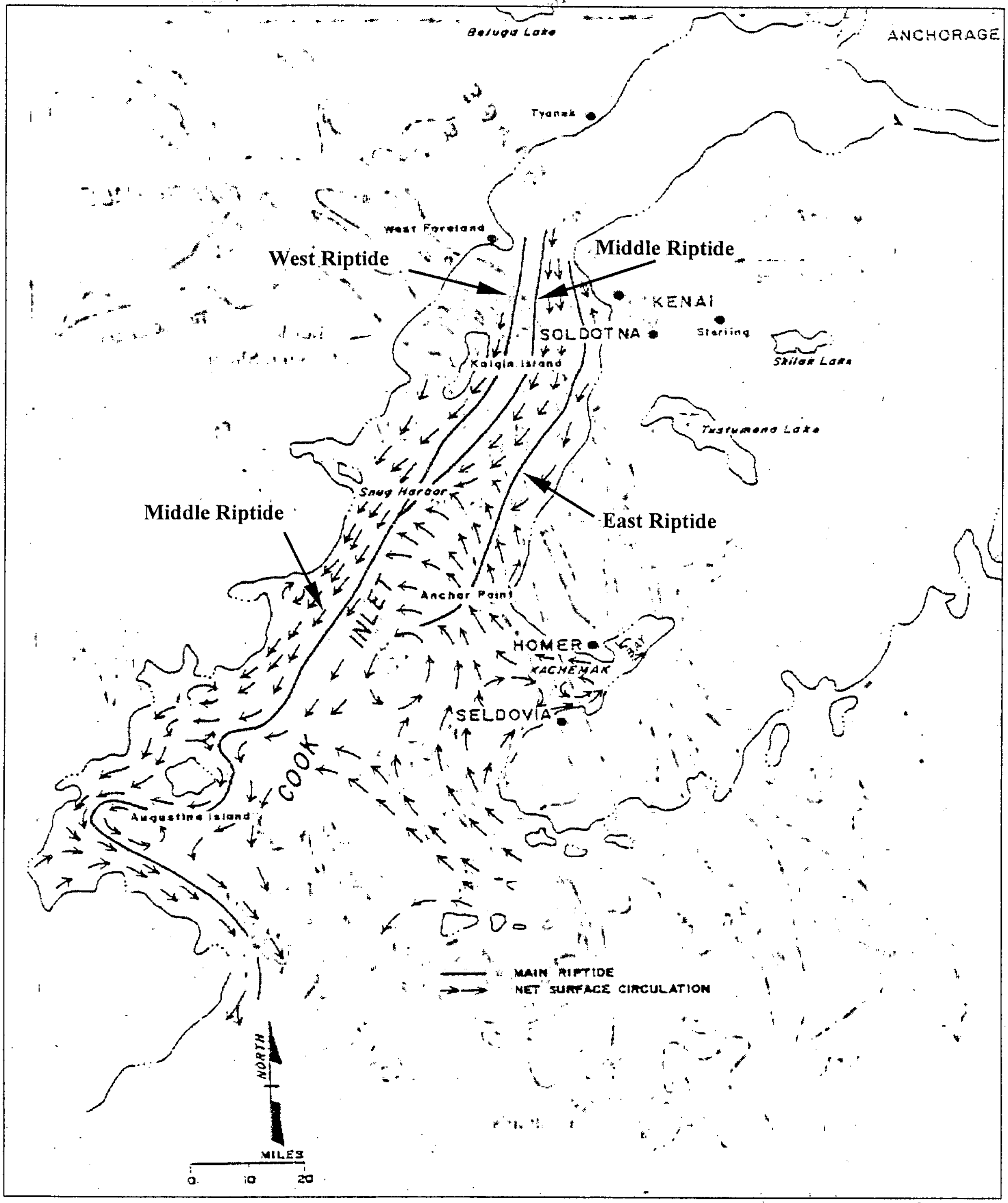


Figure 4. Water circulation patterns in Cook Inlet, Alaska (Wapora Inc. 1979).

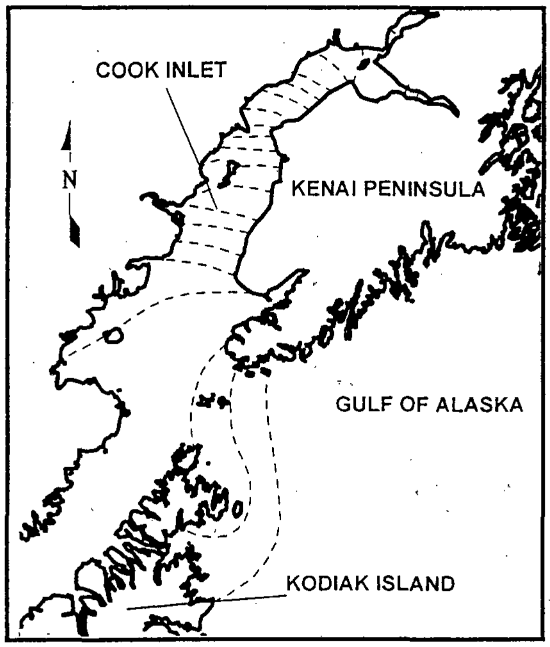


Figure 5. Cotidal lines for Cook Inlet, Alaska (graphics provided by Center For Operational Oceanographic Products and Services [CO-OPS]/NOAA).

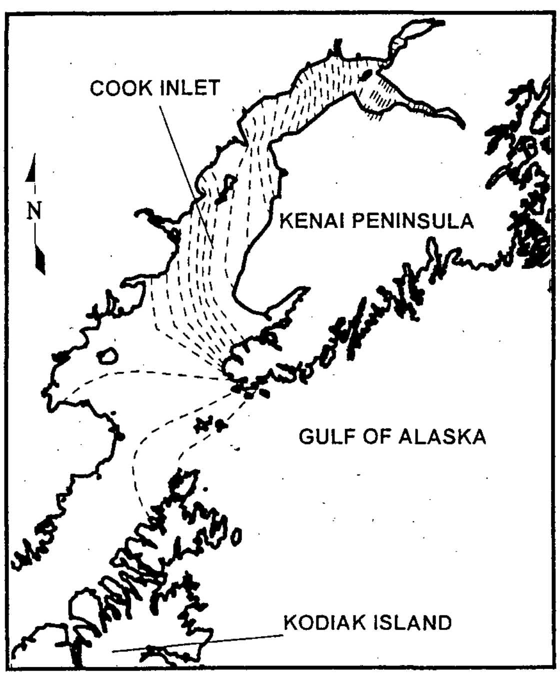


Figure 6. Corange lines for Cook Inlet, Alaska (graphics provided by CO-OPS/NOAA).

center of the Inlet and the opposite eastern shore. These observations are as yet unverified by measurements.

Corange lines, along which the tidal range is equal, are not parallel to cotidal lines in Cook Inlet. Ranges on the east shore are considerably higher than those on the opposite west shore (Figure 6). Ranges on both sides of the Inlet increase northward, reaching a 9.1-m daily range at Anchorage with recorded spring tide extremes in excess of 12.2 m (NOAA 1999). In summary, tides in Cook Inlet are extraordinarily complex and energetic, dominating all other hydrodynamic forces in the waterway. Though other forces, such as wind, waves and ice, may affect the detection of rip tides, tidal forces drive rip tides.

2.4 Bottom Friction Effects On Cook Inlet Currents

Measurements of currents in upper Cook Inlet have revealed that bottom friction influences the speed and alters the direction of tidal currents (USACE 1993, 1996). Currents are slowed and veered several meters above the bottom. In this way, friction created by sloping inlet banks and shoals steer tidal currents. These trends are particularly notable when an acoustic Doppler current profiler measures continuous profiles of currents. A bottom boundary layer several meters thick tends to reverse direction before surface tidal currents. High sediment concentrations near the bottom may also affect the balance of friction forces. Recent multi-beam hydrographic surveys of central Cook Inlet reveal large sand dunes on the bottom with heights on the order of 2 m (unpublished charts by Terra Surveys, Ltd. and Racal Pelagos, Inc. under contract to NOAA). These bed forms appear in constricted areas and in the vicinity of rip tides. Their presence is indirect evidence of vertical shear extended several meters above the bottom.

2.5 Cook Inlet Roll Cells

Observations from fishermen, scientists, and satellite imagery interpretation suggests that horizontal current speeds in Cook Inlet have large and frequent fluctuations, routinely near banks and shoals. These fluctuations create zones of divergence marked by upwelling that appears to boil on the water surface. Upwelling currents on one side of a rip tide exaggerate the upward motion of wind-generated surface waves, creating a steep random chop at the water surface. The choppiness on the small scale of capillary waves appears bright on a SAR satellite image. Parallel zones of downwelling occur on the opposite side of a rip tide, causing surface slicks (smooth water surface) and lines of flotsam. Slicks appear dark on SAR images. Both the choppy and slick types of surface signatures are associated with rip tides in Cook Inlet, indicating vertical circulation in the form of spiraling roll cells. Water spirals across the strong surface current from upwelling to downwelling zones. The spiral is completed beneath the surface from downwelling to upwelling zones. Figure 7 is a visualization of this concept of circulation associated with rip tides in Cook Inlet. This explains patterns observed at the surface.

A phenomenon with similar behavior, known as Langmuir circulation, can be induced by steady wind friction on the water surface. Parallel lines of foam and floating debris, known as "windrows," are common sights on a windy water surface from an airplane. These lines of flotsam are oriented along the direction of the wind and maintain themselves because buoyant matter is drawn together at zones of convergent downwelling.

Linear slicks are also associated with downwelling induced by internal waves propagating along a density layer beneath the surface. The upper layer of water is forced to converge ahead of

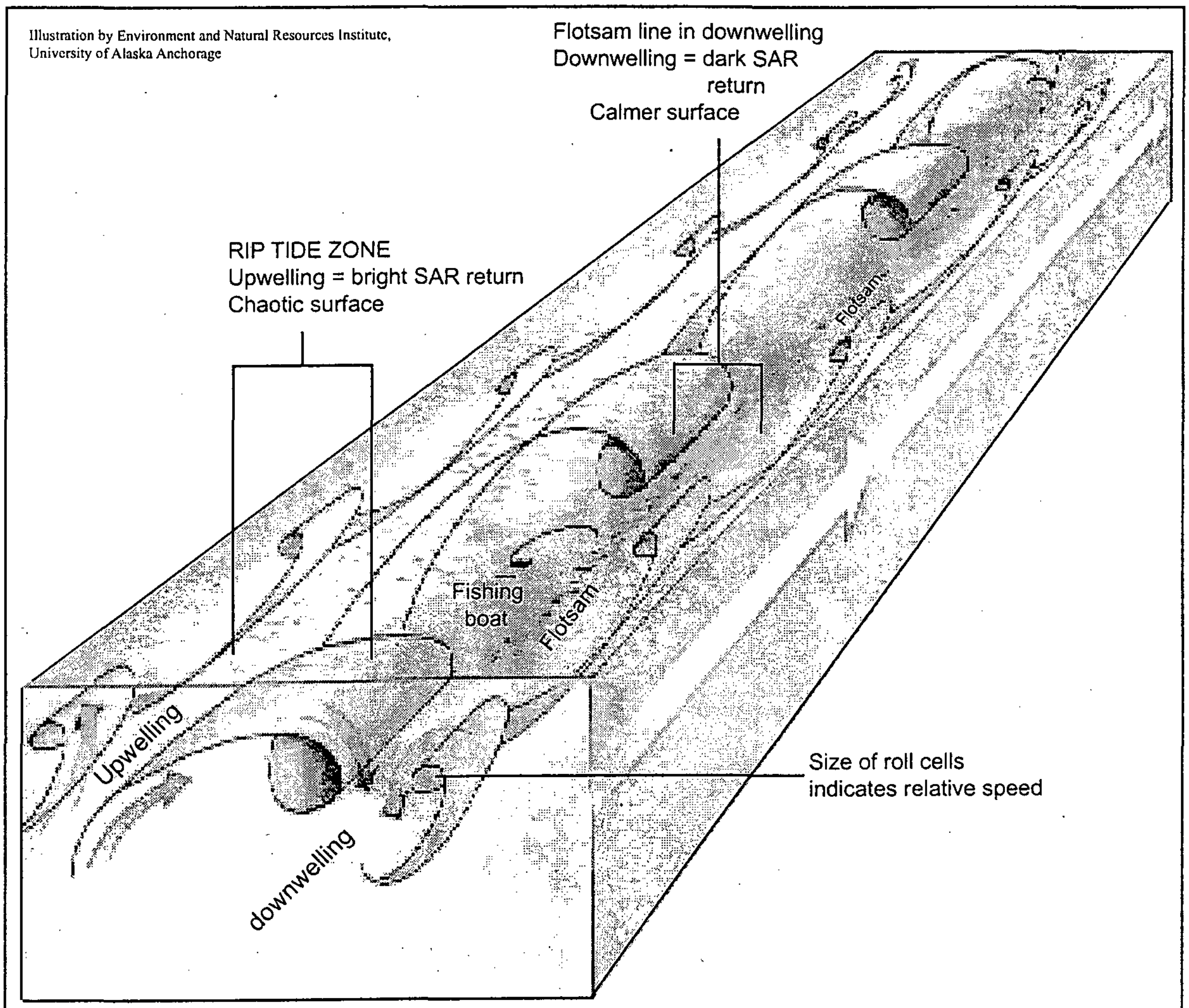


Figure 7. Graphic depiction of the properties of a possible "rip tide" in Cook Inlet.

the crest of the undulating density interface below. Slow moving surface slicks are observed to move parallel to wave crests of internal waves as they slowly advance along a thermocline (temperature layer) or halocline (salinity layer) beneath the surface.

These two more commonly observed ocean phenomena have similar surface signatures due to vertical circulation. Future studies of Cook Inlet rip tides would be more revealing if they involve measurements of both vertical and horizontal currents. Shipboard acoustic Doppler current profiler (ADCP) measurements could accomplish this.

3.0 METHODS

The following methods were used to map rip tides in Cook Inlet: (1) gathering "local knowledge" from Cook Inlet drift gillnet salmon fishery stakeholders; (2) ground–truthing contemporary satellite images to develop an accurate method of identifying rip tides and examining remote sensing images of the Inlet for rip tides; (3) obtaining information from the Alaska Department of Fish and Game's (ADF&G) test fishery regarding the occurrence of rip tides in Cook Inlet throughout July 1999; (4) conducting aerial surveys of Cook Inlet to locate potential rip tides and reviewing historical ADF&G surveys of the salmon fishery; and (5) conducting a literature search for Cook Inlet rip tide information. Also, public testimony regarding possible offshore development in Cook Inlet was reviewed for fishermen's concerns.

3.1 Local Knowledge

Communications with Cook Inlet stakeholders provided critical information (i.e., local knowledge) on the location of rip tides and on identifying the surface signatures of rip tides. In addition, local fishermen collected GPS locations of rip tides that allowed satellite imagery to be correlated to surface information (ground-truthed). Data concerning the rip tides were collected by means of interview sessions, mass-mailings, a public outreach initiative, and a workshop with driftnet fishermen.

3.1.1 Interviews

Twenty-seven phone interviews with Cook Inlet driftnet fishery shareholders were conducted from late April through June 1999 (Appendix A). Personal interviews were conducted with 13 of the stakeholders on the Kenai Peninsula. During interviews, the following four topics were discussed: (1) Cook Inlet rip tide dynamics; (2) fishermen's use of rip tides and their adjoining waters; (3) potential conflicts between Cook Inlet fishermen and future offshore oil and gas industry activity; and (4) opportunities for fishermen to contribute to ground-truthing satellite data. This information was used to develop our field sampling approach and interpretation.

Cook Inlet driftnetters indicated that they typically use nets that are three shackles (274.3 m) long. Fishermen suggested that they could be "working" a rip tide anywhere within a distance of 926 m (0.5 nautical miles—or 3.4 net lengths) from a rip tide. That standard was employed when analyzing fishing proximity to rip tide data. The 926-m (0.5 nm) distance was broken down into three categories: (1) in the rip tide, (2) less than or up to 463 m (0.25 nm) from the rip tide, and (3) between 463 m and 926 m from a rip tide.

3.1.2 Mailings

In addition to direct communication with driftnet fishery stakeholders, brochures describing the rip tide project and its purpose were mailed to all (575) active Cook Inlet driftnet salmon fishery permit holders. The mailings appealed to fishermen to contribute to the project.

3.1.3 Meetings and Publicity

Study personnel attended the United Cook Inlet Drifter's Association (UCIDA) annual meeting in June 1999 to present the rip tide project to Cook Inlet fishermen and request their help with the project. Public Service Announcements were printed in the Kenai Peninsula newspapers, the *Peninsula Clarion* and the *Homer News*, regarding the project and the project team's attendance at the UCIDA meeting (Appendix B1, B2).

3.1.4 Workshops

A workshop was conducted with Cook Inlet driftnet salmon fishery stakeholders to present preliminary findings on 8 November 1999. The purpose of the workshop was to review and add to the local knowledge the study team had gathered from fishermen during the 1999 fishing season. A total of 37 people participated, including fishermen, municipal, borough and industry representatives, and scientists. A final workshop was held 6 March 2000 during which we reviewed our findings with nine attendees.

3.2 Satellite Imagery

Satellite-borne SAR technology was used to provide remote sensing imagery of Cook Inlet. This method had the following advantages: (1) a large area could be surveyed, (2) data were available for several years, and could be collected at different tidal stages, (3) acquisition of data was not affected by weather conditions, and (4) the imagery from this technology was relatively inexpensive.

Radar imagery can be collected day and night and in all weather conditions and there is an archive of images for the Cook Inlet area dating back to 1992. Two types of SAR satellite images were examined, those from the European Radar Satellites ERS-1 and ERS-2 and those collected by the Canadian Space Agency RADARSAT 1 satellite. Both ERS and RADARSAT measure radar returns in the C-band (5.6 cm wavelengths), but they differ in polarization and incidence angle (Table 1). The steep viewing angle and vertical polarization of ERS radar is sensitive to surface roughness and was designed to gather information about ocean water conditions, including subtle surface water features. RADARSAT imagery is more efficient at detecting point sources, such as fishing vessels, due to horizontal polarization and shallower viewing angles. Consequently, rip tides are more likely to be detected using ERS images, whereas RADARSAT is better suited to vessel detection. Depending on the operating mode, RADARSAT images may also show pronounced rip tides and thus document both the rip tide and any vessels in its vicinity.

Table 1. Operating parameters, RADARSAT and ERS.

Parameter	RADARSAT	ERS
Altitude (km)	793–821 km	780–785 km
Period (min)	101 minutes	100 minutes
Orbits/day	~ 14	~ 14
Revisit cycle (days)	24 days	35 days
Wave length	C Band, 5.66 cm	C Band, 5.66 cm
Polarization	HH	VV
Incidence Angle	20–60 degrees	20–26 degrees
Swath	50–500 km	100 km
Range resolution	~ 10-100 m	~ 30 m

3.2.1 RADARSAT Data Collection

One objective of the project was to confirm that rip tides interpreted from satellite radar were in fact rip tides as classified by Cook Inlet fishers, or to "ground-truth" the satellite imagery. Because the RADARSAT satellite may be programmed to operate in multiple beam modes and at different viewing angles, the same region of Cook Inlet could be repeatedly surveyed at frequent intervals. These capabilities allowed us to ensure fishermen were on the water when the RADARSAT satellite was collecting images overhead.

The Canadian Space Agency (CSA), owner of the RADARSAT 1 satellite, programmed the satellite to image Cook Inlet during the 1999 driftnet fishery openers (Table 2). To obtain appropriate coverages, beam mode and viewing angle were adjusted differently for each fishery opener. Also, RADARSAT had not previously been used for the detection of rip tides, or small (10 to 15 m) fishing boats, so no prior information was available with which to establish appropriate settings.

The ground-truth program in this study was designed to collect as much locational data as possible at or near the time of the scheduled RADARSAT overpasses. Members of the Cook Inlet driftnet fishery were asked to log their locations during five of the seven scheduled passes over Cook Inlet (Table 2). Data sheets, in the form of self-addressed, stamped post cards, were mailed along with brochures in the mass mailing to Cook Inlet fishermen for this purpose (Appendix C). We asked fishermen to record their GPS positions, their proximity to any rip tide, and weather conditions during the time of the five satellite overpasses. Nine fishermen offered to assist the project beyond recording data once per opener. The study team asked those fishermen to provide the same information at hourly intervals throughout six, 12-hour openers (the 22 July opener was added), between 7:00 a.m. and 7:00 p.m.

In addition, LGL personnel were on board a commercial fishing boat and a private vessel during the first two openers (28 June and 1 July 1999) to record coordinates of rip tide locations. These data were added to the rip tide location information from fishermen. GPS locations of rip tides recorded by fishermen and study team personnel were entered into a database for comparison with the satellite imagery.

3.2.2 Analysis of Historical Satellite SAR Images of Cook Inlet

ERS satellite images of North America are archived at the Alaska SAR Facility (ASF) at the University of Alaska Fairbanks. A visit to the ASF was made to select appropriate ERS imagery archived since the satellite was launched in 1992. Photographic imagery for ERS-1 was available for the years 1992–1995.

ERS digital data are available as either "Full-Resolution" or "Low-Resolution" data. The "Full-Resolution" data are processed by ASF to 8-bit data (256 grey levels) at 12.5-m cell size. The standard scene is 100 km by 100 km, and the digital scene is 64 megabytes (mb) in size. The "Low-Resolution" data have a pixel spacing of 100 m, and are about 1 mb each in size.

We examined 247 separate images of lower Cook Inlet acquired on 69 separate dates between 14 May 1992 and September 1995. For each date, there was a minimum of one and a maximum of three consecutive images that imaged part of the study area. We identified 26 dates in the 1992–1995 period during which linear features (possibly rip tides) were evident in the

Table 2. RADARSAT acquisitions from satellite overflights of Cook Inlet, Alaska, Summer 1999. Beam modes include N2 (ScanSAR mode), XH (extended high beam mode), W (wide beam mode), S (standard beam mode), and F (fine beam mode). Incidence angle ranges within a beam mode are shown as -2,-3,-4.

Date	Fishery	RADARSAT Local Acquisition Time	Beam	Mode	Incidence Angle (mid)	Ascending or Descending Orbit	Range Resolution (m)	Azimuth Resolution (m)	No. Scenes	Aerial Survey	Comments
*990628	District wide	7:07	XH	EH-3	53.1	D	25	28	2	Yes	Good coverage West and Mid Rip areas.
*990701	District wide	7:19	N2	W-2	38.5	D	100	100	2	No	Overview - water is uniformly black.
*990705	District wide	7:03	XH	EH-3	53.1	D	25	28	2	Yes	Good coverage East and Middle Rip areas.
*990708	District wide	18:44	SB	S-4	36.5	A	25	28	2	Yes	Good coverage of both coastlines.
990712	Western, S. of Redoubt Pt.	6:59	XH	EH-4	55.5	D	25	28	3	No	Good coverage, Excessive range ambiguities
990712	Western, S. of Redoubt Pt.	6:59	FB	F-4	44.7	A	9	9	3	No	Mostly Land on Kenai Peninsula.
*990715	District wide	18:39	WB	W-2	35.1	A	27	28	2	Attempted	Good coverage East and Middle Rip areas.
990722	Inside 3 miles only	7:07	XH	EH-3	53.1	D	25	28	3	No	Good coverage West and Mid Rip areas.
990722	Inside 3 miles only	18:35	SB	S-2	27.7	A	25	28	1	No	Restricted coverage Kalgin Island and north.
990726	no fishery	7:07	XH	EH-6	58.1	D	25	28	3	No	Mostly over Kenai Peninsula.

* Indicates dates of commercial fishery openers during which Cook Inlet driftnet fishermen were asked to record location, proximity to rip tide, and weather conditions during the RADARSAT overpass.

ASF images. The images were ranked both by extent of coverage of the study area, as well as the definition of linear features in the surface waters of the Inlet. We subsequently acquired low-resolution digital images for each of those dates.

Thirteen of the 26 dates evidenced both good coverage of the study area and good definition of linear hydrological features. Full-resolution images of these dates were also acquired and processed for extraction of rip tide information.

Photographic Quick-Looks or preview images were not produced for ERS acquisitions after 1995. We therefore checked ERS scene coverage over Cook Inlet for every orbit collected June through September for the years 1996 through 1999. Low-resolution images were ordered for those orbits on which Kalgin Island was imaged.

Table 3 lists the 61 dates for which ERS imagery was acquired over Cook Inlet.

3.2.2.1 Digital Processing of Full-Resolution Data

Fifteen full-resolution ERS scenes collected on 13 dates in the period 1992–1995 were processed to aid in the extraction of information about rip tide dynamics in Cook Inlet. The following processing steps were applied to each scene:

1. Data rotation/mirroring to correct scene orientation.
2. Geometric rectification and projection to Universal Transverse Mercator grid using U.S. Geological Survey digital raster graphics or Ground Control Points acquired from previously-rectified SAR images.
3. Spatial filtering for reduction of SAR noise.
4. Custom Look-Up Table for enhancement of surface water features.

The rectified and enhanced images were investigated for the presence or absence of a rip tide. This information was compared with the tidal stage at the time of the image acquisition.

3.2.2.2 Digital Processing of Low-Resolution Data

During analysis of the 1992–1995 imagery at both full (12.5 m) and low (100 m) resolutions, we determined that the lower resolution data were equally useful for delineating and mapping rip tides. For reasons of efficiency we therefore decided to utilize only the low-resolution data in future work:

1. The low-resolution images were much cheaper, allowing the acquisition of additional images from the ASF archive.
2. Digital processing times would be reduced from about 8 hours per scene for full-resolution data to about 2 hours per scene for the low-resolution imagery.
3. The cost and time savings would increase the number of images analyzed, improving the ability to statistically evaluate different factors that might affect rip tide locations.

Forty-eight low-resolution ERS images were subsequently digitally processed (Table 3). Each image was rotated, rectified, and contrast enhanced. It was not necessary to filter the images for noise due to the averaging effect of reduced resolution. Image features that were interpreted as possible rip tides were extracted by tracing the cursor over the feature of interest and saving the traced linework as polylines. This method is commonly known as "Heads Up

Table 3. ERS scenes and tide conditions. ADT = Alaska Daylight Time.

Scene ID	Image	Full (F) or Low (L) Resolution	(A)scend or (D)esc	ERS Acquistn ADT	High Tide ADT	Low Tide ADT	High Tide ADT	ERS Tide Height at Ninilchik FT	Time from start of Flood Tide	Time from start of Ebb Tide
1	920514	L	D	13.22		8.68	14.70	5.62	4.53	
2	920602	L	D	13.27		11.17	17.35	(4.49)	2.10	
3	920618	L	D	13.22		12.32	18.53	0.04	0.90	
4	920621	F	D	13.32	7.50	14.12		7.61		5.82
5	920703	L	A	0.02	(6.20)	(0.05)		1.85		6.22
6	920723	F	D	13.22	9.75	15.63		11.99		3.47
7	920726	F	D	13.32		7.47	13.73	10.14	5.85	
8	920827	L	D	13.23		9.55	15.55	1.21	3.68	
9	920830	F	D	13.32		11.60	17.47	(2.44)	1.72	
10	920915	F	D	13.28		11.87	17.57	2.82	1.42	
11	930502	L	D	13.32		7.10	12.93	14.01	6.22	
12	930518	F	D	13.27		8.52	14.43	7.51	4.75	
13	930606	L	D	13.32		11.57	17.75	(3.73)	1.75	
14	930622	F	D	13.27		11.93	17.42	(2.95)	1.33	
15	930727	L	D	13.27	10.82	16.75		14.46		2.45
16	930815	F	D	13.32		8.53	14.67	6.90	4.78	
17	930916	L	D	13.22		10.12	15.97	(0.16)	3.10	
18	940526	L	D	13.28		11.13	17.28	(5.74)	2.15	
19	940702	F	D	13.30	11.18	17.18		12.86		2.12
20	940722	F	D	13.25		9.97	16.10	(1.43)	3.28	
21	950527	L	D	13.22		9.30	15.32	3.22	3.92	
22	950615	L	D	13.27		11.93	18.10	(4.71)	1.33	
23	950720	F	D	13.27	10.35	16.43		13.30		2.92
24	950808	L	D	13.32		8.32	14.48	7.37	5.00	
25	950824	F	D	13.27		9.38	15.38	4.14	3.88	
26	950912	L	D	13.32		12.07	17.88	1.46	1.25	
27	950924	F	A	0.02		(2.32)	3.47	3.09	2.33	
28	960615	L	A	0.07		(2.55)	3.13	6.17	2.62	
29	960619	L	D	13.32		12.38	18.52	0.45	0.93	
30	960705	L	D	13.28	6.82	13.48		3.59		6.47
31	960720	L	A	0.07	(5.43)	0.85		6.39		5.50
32	960721	L	D	13.23	7.15	13.67		6.62		6.08
33	960724	L	D	13.33	10.12	16.22		12.91		3.22
34	960824	L	A	0.07		(5.57)	0.13	17.20	5.63	
35	960825	L	D	13.23		7.33	13.50	11.95	5.90	
36	960828	L	D	13.32		9.82	15.83	(0.28)	3.50	
37	960913	L	D	13.28		10.50	16.35	0.82	2.78	
38	970604	L	D	13.32		9.72	15.77	(0.32)	3.60	
39	970706	L	D	13.22		11.08	17.18	(2.53)	2.13	

continued

Table 3 (continued). ERS scenes and tide conditions. ADT = Alaska Daylight Time.

Scene ID	Image	Full (F) or Low (L) Resolution	(A)scend or (D)esc	ERS Acquistn ADT	High Tide ADT	Low Tide ADT	High Tide ADT	ERS Tide Height at Ninilchik FT	Time from start of Flood Tide	Time from start of Ebb Tide
40	970718	L	A	0.00		(3.67)	1.97	11.43	3.67	
41	970720	L	A	0.02		(2.08)	3.56	3.92	2.10	
42	970806	L	A	0.00	(6.45)	(0.18)		2.81		6.45
43	970810	L	D	13.23	8.17	14.43		10.00		5.07
44	970813	L	D	13.32	11.95	17.80		13.27		1.37
45	970914	L	D	13.22		8.25	14.33	9.10	4.97	
46	980726	L	D	13.22		12.15	18.20	(0.95)	1.07	
47	980729	L	D	13.32	7.47	13.95		7.92		5.85
48	980830	L	D	13.30	9.68	15.63		12.47		3.62
49	980922	L	D	13.32		11.15	16.93	0.38	2.17	
50	990602	L	A	0.00	(6.15)	(0.15)		4.60		6.15
51	990606	L	D	13.22	8.42	15.25		10.32		4.80
52	990609	L	D	13.32	12.17	18.52		14.47		1.15
53	990620	L	A	0.02	(1.97)	4.42		14.60		1.99
54	990621	L	A	0.02	(2.05)	4.60		16.16		2.07
55	990710	L	A	0.07		(4.93)	0.88	15.88	5.00	
56	990711	L	D	13.22		8.88	15.00	3.74	4.33	
57	990714	L	D	13.32		11.23	17.35	4.26	2.08	
58	990811	L	A	0.00		(2.30)	3.43	4.09	2.30	
59	990815	L	D	13.22	6.32	13.47		2.72		6.90
60	990818	L	D	13.32	8.65	14.87		11.44		4.67
61	990830	L	A	0.02	(6.27)	0.18		1.77		6.28

Dates for which high resolution images acquired and processed	*13*
Dates for which low resolution images acquired and processed	*48*

Digitizing." Automatic feature extraction, using an edge-filter and raster-to-vector process, generated either too many lines and artifacts or insufficient detail to be useful for our purpose. We found manual digitizing to be more accurate and much faster.

Interpretation Keys

During the preliminary work, a set of Interpretation Keys was developed to help identify rip tides. Many of the SAR images show water surface features in lower Cook Inlet that may be caused by factors other than rip tides including water depth, currents, salinity changes, or local weather conditions—particularly near-surface winds.

The following four Interpretation Keys were initially used: (1)location—between the Forelands and Iniskin Peninsula (Figure 1) to cover the driftnet fishing grounds; (2) linearity—longitudinal, parallel to the coastline in NNE-SSW direction; (3) length—several tens of miles in extent; and (4) persistence—feature should be present in other images.

These criteria were later modified after the 8 November 1999 workshop, when Cook Inlet fishermen stated that

1. rip tides can appear anywhere in lower Cook Inlet,
2. rip tides can be less than a mile long, and
3. rip tide orientation is generally NNE-SSW, but small rip tides can also appear running E-W across the Inlet.

Consequently, interpretation of rip tides was expanded to include linear features as little as a mile in length, and those of any orientation. Also the "persistence" interpretation key was discarded.

3.3 Test Fishery

Information on rip tide locations was collected from ADF&G during their July 1999 test fishery (a contracted fishing vessel fishes short time periods in specific locations to "test" the strength of the salmon run entering Cook Inlet). The vessel captain conducting the test fishery collected data on rip tide location, time, and weather conditions on a daily basis during July 1999. These data were checked for temporal coincidence with 1999 fishing season RADARSAT images and then examined for locational coincidence with rip tides evident in historical SAR satellite images.

3.4 Aerial Surveys

Aerial surveys were flown during three driftnet fishery openings in Cook Inlet (28 June, and 5 and 8 July 1999), concurrent with the satellite overpasses, to provide an additional opportunity to photograph and document rip tide locations. Aerial surveys were flown in a Piper Navajo twin engine aircraft over the fishing grounds (between the 60°46.38' and 59°46.2' parallels) in areas where fishing vessels were present. In addition, historical aerial survey data were incorporated into this project. Ken Tarbox of ADF&G in Soldotna, Alaska allowed the project team to review aerial survey charts of fishery openers dating back to 1978. These charts indicated the locations of fishing vessels and occasionally included the location of rip tides. The charts were also examined for the co-occurrence of fishing boats and rip tide zones.

3.5 Literature

A literature search for Cook Inlet rip tides was conducted through the Alaska Resources Library and Information Services (ARLIS) and the Internet.

4.0 RESULTS AND DISCUSSION

Both quantitative and qualitative information was gathered to map Cook Inlet rip tides. Quantitative information included fishermen logs, test fishery observations, satellite data, and tide data; qualitative information included interviews, workshop input, and historical aerial survey charts. The two types of information were examined, compared, and synthesized to create the most accurate charts of Cook Inlet rip tides possible.

4.1 Location and Dynamics of Rip Tides

4.1.1 Qualitative Local Knowledge About Cook Inlet Rip Tide Location and Dynamics

Conversations with 27 Cook Inlet driftnet fishery stakeholders in 1999 indicated that rip tides in the Inlet vary in form, force and location (Appendix D). Burbank (1977) reported a similar finding: "The various persons consulted have indicated somewhat differing configurations and locations for some of the rip tides, and the actual locations of the rip tides apparently can vary significantly at times."

During the 8 November 1999 workshop with Cook Inlet driftnet fishery stakeholders, fishermen reviewed definitions of rip tides and clarified the difference between "rip tides" and "riplines (or zones)." They indicated rip lines are distinct features along the edge of a rip tide, whereas a rip tide can be miles wide. However, obvious rip lines do not necessarily materialize along the side of a rip tide.

From interviews and on-the-water experience, the project team learned that fishermen use five indicators to locate a rip tide: (1) large waves or "boiling" water—surface roughness, (2) change in water color, (3) lines of debris or flotsam, (4) concentrations of birds on the water surface, and (5) temperature change.

4.1.1.1 General Locations of Cook Inlet Rip Tides

Fishermen, in general, reported three re-occurring main rip tides in Cook Inlet: the west, middle (or main), and east rip tides (see Figure 2 for historic locations). The middle rip tide is the largest and deepest of the Cook Inlet rip tides, extending along a 40+ fathom (73 m) channel through the center of the Inlet. Initially, the middle rip tide was believed to be as wide as 1.9 to 2.8 kilometers (1 to 1.5 nautical miles). However, fishermen at the November 1999 workshop reported that the middle rip tide can be 1.9 km wide during a flood, but that it might be as wide as 7.4 to 11.1 km (4 to 6 nm). The middle rip tide generally occurs between 13 and 22.2 km (7 and 12 nm) off the east coast of the Inlet and sometimes joins with the east rip tide in the lower portion of the Inlet. A flood tide can push the middle rip tide as far as 3.7 km (2 nm) to the west. The middle rip tide typically divides the clear, relatively warmer incoming Gulf of Alaska water to the east and silty, fresh outflowing water to the west.

Some fishermen occasionally use the term "violent" to characterize the surface appearance and water mass movement in Cook Inlet rip tides. Fishermen have indicated that the east rip tide is not as violent as the middle rip tide, and some fishermen fish across the east rip tide. The east rip tide tends to align with a 10-fathom (18 meters) contour along the east shore of the Inlet. It can be as far offshore as 7.4 km and as close as 3.7 km off Cape Kasilof during a flood tide (refer to Figure 1 for geographic locations).

Burbank's (1977) findings reflected the fishermen's knowledge at that time. He reported that ocean water flowing up the east side of Cook Inlet during a flood tide wedged between the east and middle rip tides. The flood tide forced the middle rip tide 3.7 km (2 nm) to the west and the east rip tide 3.7 km (2 nm) to the east, west of Kasilof, separating the two from a "typical" distance of 9.3 km (5 nm) during an ebb to an approximate 16.7 km (9 nm) distance during the flood (Burbank 1977).

The west rip tide forms approximately 3.7 km east of Kalgin Island and follows the shelf of the island's east shoal along a 10-fathom (18 m) contour (Figure 8). The west rip tide can bend to the west across the shoal south of Kalgin Island.

4.1.1.2 Cook Inlet Rip Tide Dynamics

Aside from the three main rip tides, fishermen also reported that rip tides can materialize at almost any location in central Cook Inlet, although they tend to run along deep channels and follow bathymetric contours. This study focused on central Cook Inlet where the salmon driftnet fishery occurs. Occasionally, several rip tides have been seen over the Kalgin Island shoals. These rip tides join together south of the shoals and the associated navigational buoy or can (USCGS light list #26270). A small rip tide has also been observed north of the can to the east of the middle rip tide, but generally lasts for only 1 to 1.5 hours. Another rip tide has been seen along a 50-fathom (91 m) contour finger, or "hole," near the 152°20′W parallel between the latitudes of 59°52′N and 60°00′N (Figure 8).

Fishermen have reported that rip tide current velocity in the Inlet can range between four and six knots, and can be as swift as eight knots near the Forelands (Figure 1). Fishermen also acknowledged that water speed can vary significantly across a rip tide. On three separate occasions during July, the ADF&G test fishery captain recorded a noticeable difference in velocity between one side of a rip tide and the other (Table 4). All rip tides dissipate during slack tide for approximately 1.5 hours.

Table 4. Test fishery observations of velocity difference within Cook Inlet rip tides.

Day	Time	Latitude	Longitude	Wind Speed	Wind Direction	Comments
11-Jul	11:15	59°49.99'	152°15.42'	0		E side moving N much faster than W side of rip, strong rip during flood
12-Jul	11:25	59°49.19'	152°14.76'	20	SE	E side calmer that W side of rip, large rip, 5- to 6-ft seas, 0.25 mile wide
19-Jul	12:45	59°49.48'	152°15'	10	SE	W side moving much faster to south than E side, 2-ft seas, distinct 2 colors of water, ebb tide

Fishermen reinforced the fact that the rip tides are relatively predictable. They emphasized that tide stage, wind and weather can influence rip tide manifestation and location, and that the development and location of lesser rip tides are not as predictable.

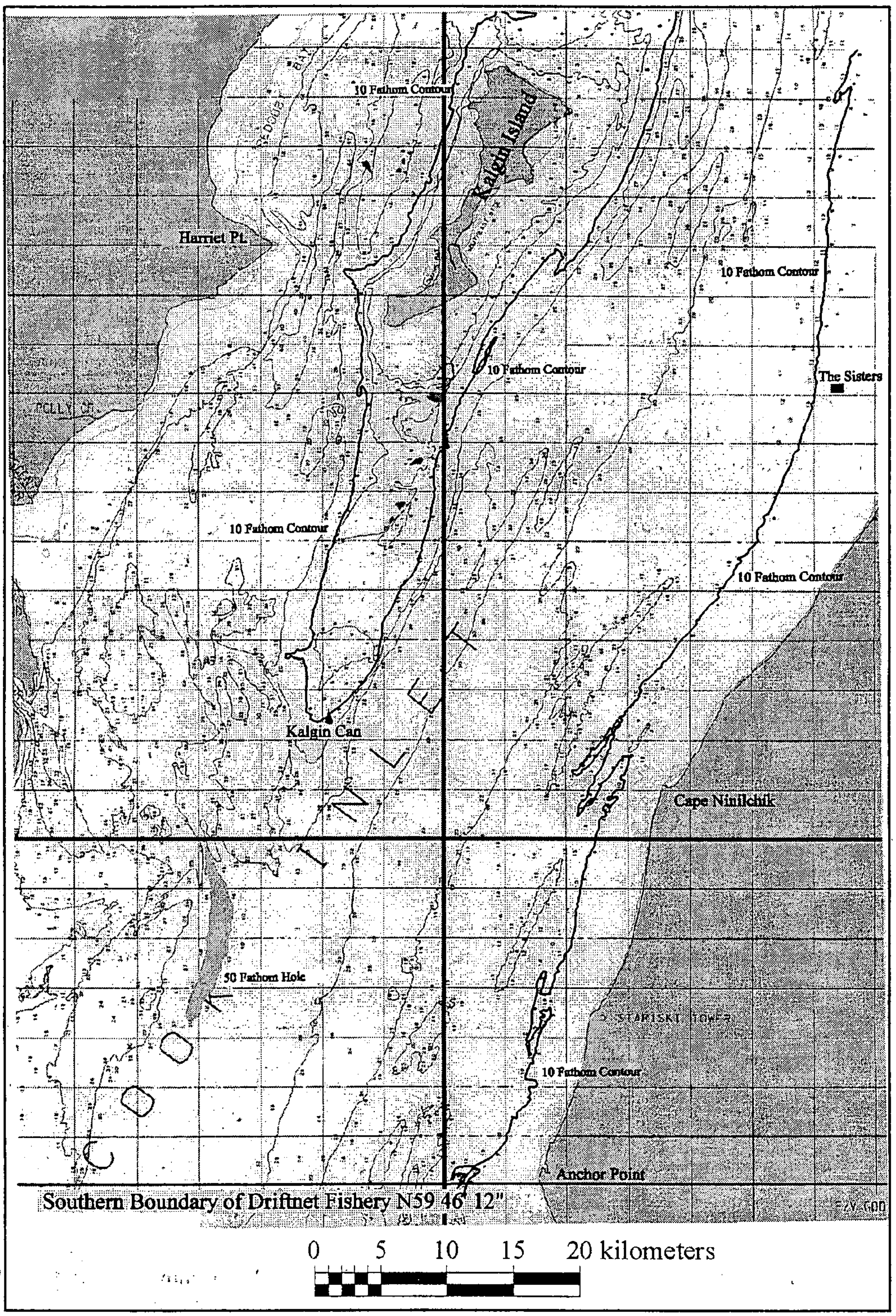


Figure 8. Driftnet fishery area with highlighted 10-fathom contours and 50-fathom hole in Cook Inlet, Alaska. One fathom equals 1.8 meters.

4.1.2 Quantitative Information About Cook Inlet Rip Tide Location and Dynamics

4.1.2.1 Fishermen Surveys

Twelve percent (68 of 575) of all active Cook Inlet driftnet permit holders responded to mailed brochures and recorded data during five fishery openers. On average, 10% of the fishermen participating in each of the five fishery openers collected GPS locations of rip tides during the satellite overpass (Table 5).

Table 5. Percent of fishermen recording observations of Cook Inlet rip tides per total fish delivery during satellite overpasses. Overall percent of recordings per fish deliveries during satellite overpasses = 10%.

Date	Total Fish Deliveries	Total Observations	Fishery Participants Recording Data
28-Jun	224	28	13%
1-Jul	372	37	11%
5-Jul	430	45	10%
8-Jul	402	34	8%
15-Jul	477	36	8%

4.1.2.2 Remote Sensing

Our interpretation of SAR images of central Cook Inlet is consistent with the hypothesis that rip tide currents are bounded at the surface by lines of upwelling, where the surface appears to boil, and downwelling, where a surface slick occurs on the opposite side of the rip tide. Zones of upwelling have a chaotic surface texture that causes a bright return to the SAR. Zones of downwelling tend to calm the sea and have a low (dark) return to the SAR.

Figure 9 shows an ERS image of Kalgin Island in central Cook Inlet, taken at mid-flood tide on 22 July 1994. The northward flowing, west rip tide is usually found by fishermen along the 10-fathom (18 m) contour offshore of Kalgin Island. The image shows a bright line near the eastern shore of the island, just inshore of the 10-fathom (18 m) contour on nautical charts. A distinct parallel dark line occurs beyond the 10-fathom (18 m) contour east of Kalgin Island. The bright line probably indicates a zone of upwelling and the dark line indicates a surface slick associated with downwelling. The strongest currents of the west rip tide probably occurred between these lines. A spiraling roll cell along this current would have a secondary west-east current component across the rip tide at the surface and a secondary east-west current component some distance beneath the surface.

Figure 10 shows another ERS SAR image collected 30 August 1998 at mid ebb tide. A rip tide is interpreted between Kalgin Island and the Kenai Peninsula running approximately parallel to the coastline. In this image the rip tide is 11 km (6 nm) offshore at Humpy Point (near the top center of the image), and is more than 1.9 km (1 nm) wide. The location of this rip tide is in the undefined area between the east and middle rip tides defined by fishermen at the November 1999 workshop (Section 4.1.1.1). Rip Tides were identified in most of the ERS images, but rarely were they as clear and well defined as in Figure 10.

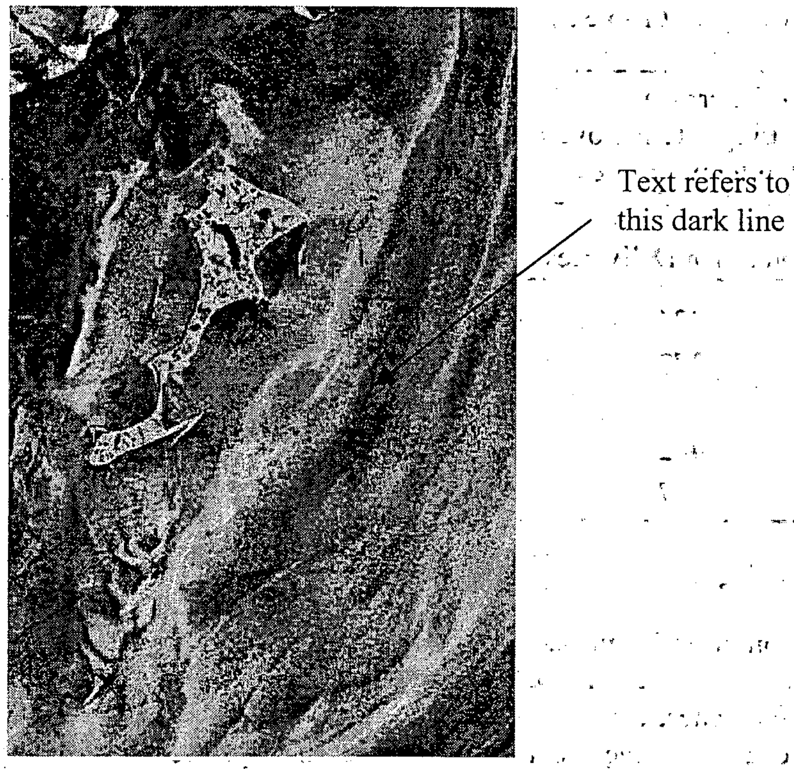
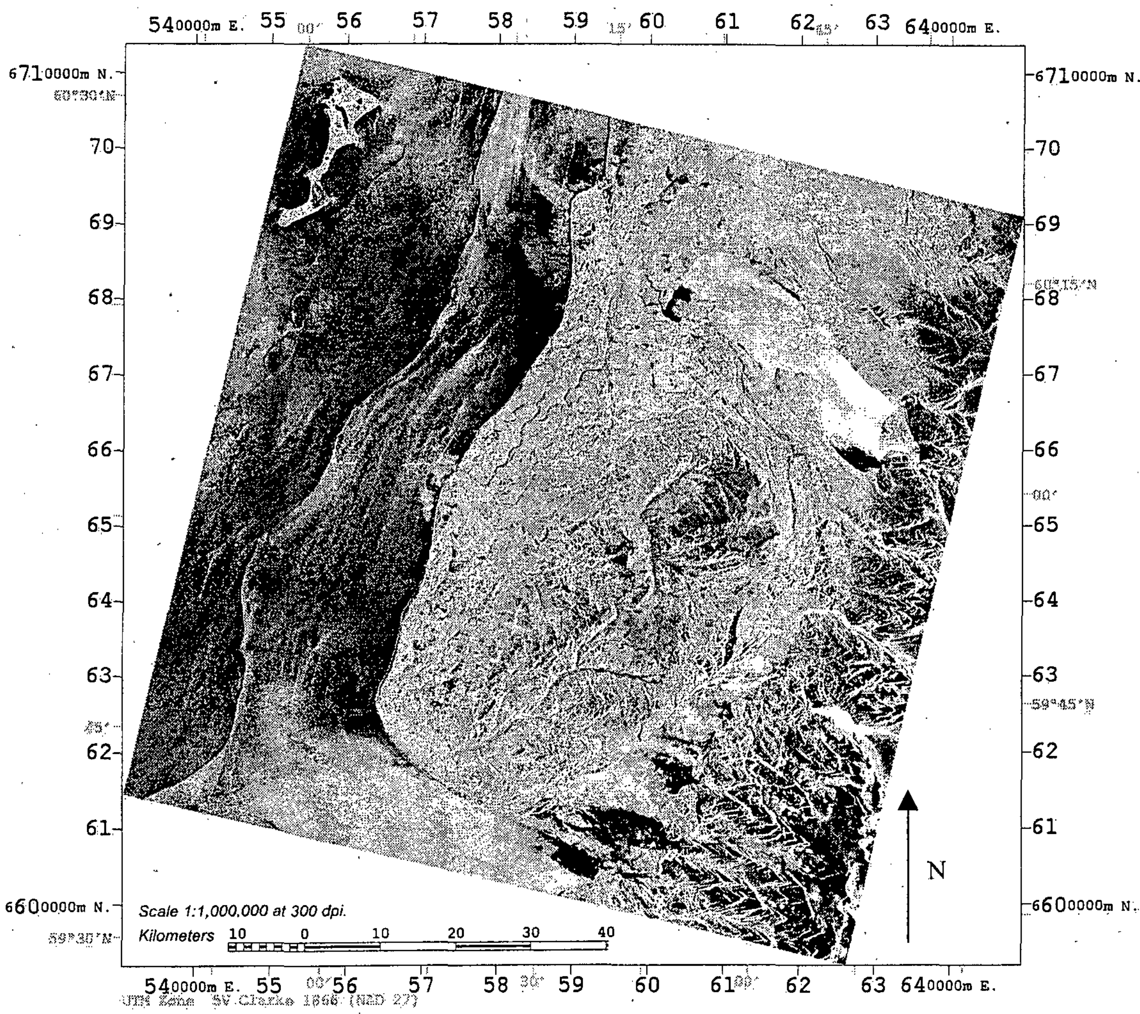


Figure 9. Synthetic aperture radar (ERS–1) image of Kalgin Island in central Cook Inlet, Alaska on 22 July 1994. Image provided by Pacific Geomatics Ltd., Surrey, B.C. Clearly visible are a dark line and a white line/band east of Kalgin Island which are interpreted to be zones of downwelling and upwelling in a rip tide.



ERS Acquisition date: 98-08-30

Figure 10. Synthetic aperture radar (ERS-2) image of Kalgin Island in Cook Inlet, Alaska, 30 August 1998. Imagery collected during ebbing tide, 3.62 hours after a high tide of 3.8 meters at Ninilchik. Copyright 1992–2000 European Space Agency, prepared by LGL Alaska Research Associates, Inc. and Pacific Geomatics Ltd., February 2000.

During our search of ERS images we were able to identify the presence of rip tide features in the 1992–1995 period using the ASF photographic images (Section 3.2.2). This process ensured that the full-resolution images later purchased from ASF would be useful for mapping Cook Inlet rip tides. We attempted to correlate the presence or absence of rip tides in the 1992–1995 imagery with stage of tide in order to guide purchase of 1996–1999 imagery, for which no previews were available. No simple correlation was found. We then decided to acquire low-resolution digital data for every pass of the ERS satellite having good coverage of lower Cook Inlet during summer months (June through September) in the 1996–1999 period.

4.1.2.3 Aerial Surveys

Aerial surveys of the Cook Inlet salmon driftnet grounds were conducted on 28 June, 5 July and 8 July 1999, coinciding with RADARSAT coverage. Distinct rip tides were visible from the air on the fishing grounds (between the 60°46.38'N and 59°46.2' parallels) during the 28 June aerial survey of Cook Inlet. On both 28 June and 5 July prominent rip tides were evident from the air north of the fishing grounds. On 5 July, a rip tide was apparent, running for approximately 5.6 km (3 nm) southwest from the south side of Fire Island. Consistent, rigorous winds churned Cook Inlet's water surface during the satellite's overflight on 8 July and may have made it difficult to observe any rip tides that day, whereas previous aerial flights occurred on better weather days (Table 6).

Table 6. Weather conditions reported by fishermen on the grounds during aerial surveys, Cook Inlet, Alaska.

Date	Wind Speed	Cloud Cover
28 June	8–15 knots	Clear—broken clouds
5 July	0–10 knots	Clear—overcast
8 July	15–35 knots	clear

4.1.2.4 Literature

The most comprehensive report that expressly addresses Cook Inlet rip tides is Burbank (1977). Burbank (1977) described rip tides in Cook Inlet based on information provided by local fishermen, pilots and others with experience in the Inlet. This anecdotal information was incorporated in Burbank's map of the three main rip tides in Cook Inlet (Figure 2). No quantitative, inlet-wide description of Cook Inlet rip tides is currently published.

4.2 Fishermen's Use Of Cook Inlet Rip Tides

4.2.1 Qualitative Information About Fishermen's Use of Cook Inlet Rip Tides

4.2.1.1 Local Knowledge

The use of rip tides by fishermen varies widely, apparently in response to the dangers associated with fishing such areas. Although most fishermen indicated they fish the rip tides in Cook Inlet at least some of the time, individual use ranged from always to never.

Many fishermen are wary of setting nets on rip tides because of the danger involved. Rip tides can (1) accumulate debris that can clog fishing nets, (2) turn a net very dramatically, and (3) even submerge a net along or down into itself. In addition, there can be a large shear in current velocities immediately at or adjacent to a rip tide. Some fishermen avoid rip tides completely, while others set their nets beside them. Fishermen have indicated that the east rip tide is not as violent as the middle rip tide, and some even fish across it. Although rip tides can be a dangerous location to fish, fishing along rip tides can also be very productive.

Biological, physical, practical and personal factors influence whether fishermen fish rip tides. For example, salmon behavior has varied over the years, and fishing tactics have followed this pattern. During some years, fish have migrated along the east side of a rip tide, while during other years fish migrated along the west side of a rip tide. During years when a particularly large jellyfish bloom occurs, a heavy concentration of jellyfish floats along the rip tides. Consequently, fishing success along the rip tides was reduced, causing fishermen to avoid the rip tides with large jellyfish concentrations.

Two Cook Inlet salmon fishermen allowed the project team to peruse their charts marked with fishing locations and catch. Each fisherman stated a preference to fish the rip tides, and each pointed out fishing locations along a rip tide that had been very productive. However, each fisherman also pointed out fishing locations, miles away from present rip tides, that were also very productive. Both fishermen use rip tides as markers where fish are likely to be, but they may fish anywhere in the Inlet—sometimes based on intuition. Both charts were spattered with seemingly random, "good" fishing locations. Each fisherman has studied the high-catch positions on his chart in conjunction with logs of weather, tide stage and other variables. Neither was able to find any predictable pattern. Other fishermen claimed to have attempted the same.

4.2.1.2 Historical Aerial Survey

ADF&G's historical aerial survey charts of the Cook Inlet salmon fishery provided a very general view of fishing locations. The charts were reviewed for apparent fishing trends along acknowledged rip tide zones; the boats seemed to fish in the general area of rip tides (Appendix E).

4.2.2 Quantification of Fishermen's Use of Cook Inlet Rip Tides

During 1999, sixty-eight fishermen collected GPS positions of their fishing locations once as the satellite passed overhead during five fishery openers; nine of these provided the same information throughout six 12-hour openers at, roughly, hourly intervals. These data offered an indication of "how" fishermen used the rip tides. The once-an-opener records provided a snapshot of participants' locations during an opener, and the hourly observations presented a profile of how some fishermen change their fishing locations throughout the duration of an opener.

4.2.2.1 Distance Fishing to Rip Tide

The snapshots (once-an-opener records) of fishermen's locations during openers as the satellite collected data indicated that between 35% and 68% of fishermen participating in this project set nets within 926 m (0.5 nm) of a rip tide (Table 7). The average percent of participating fishermen fishing within 926 m of a rip tide for all five openers was 51% ± 12.4 (mean ± SD; 91 of 180 fishermen). Across all five openers, the average of these fishermen fishing in the rip tide was 19% ± 10.5, the average of these fishermen within 463 m of a rip tide was 58% ± 7.1, and the average of these fishermen between 463 m and 926 m of a rip tide was 23% ± 7.2.

Table 7. On-ground observations of Cook Inlet rip tides from data forms on 28 June 1999 during the commercial fishery.

Date	In Rip	Distance From Rip Tide < 463 m	426 m–926 m	> 926 m	No Rip in Sight	Total Observations	% Total Participating Fishermen Fishing within 926 m of Rip
28-Jun	1	10	6	3	10	30	57%
1-Jul	6	8	3	4	17	38	45%
5-Jul	5	14	5	11	12	47	51%
8-Jul	2	8	2	7	15	34	35%
15-Jul	4	12	5	1	9	31	68%
Overall	18 (10%)	52 (29%)	21 (12%)	26 (14%)	63 (35%)	180	51%

4.2.2.2 Profiles of Fishermen's Use of Rip Tides

The periodic data (profiles) of locations and proximity to rip tides collected by nine fishermen during the six, 12-hour openers indicated that they positioned themselves at various proximities to rip tides while fishing (Table 8). On average, the largest percentage of fishermen fished out of sight of a rip tide. This was followed by those fishing within 463 m of a rip tide, those fishing in a rip tide, those fishing greater than 926 m from a rip tide, and finally those fishing between 426 m and 926 m of a rip tide. The largest variation in fishing use occurred within the rip tide, with between 1% and 55% of the observations recorded in this area. The second greatest variance occurred in the "no rip tide in sight" category, ranging from 17% to 61%. The least variance appears in the 426-m to 926-m category where the least percentage of recordings was taken (4% to 8%). Overall, the data indicate that the fishermen recording data for the project were within 926 m (i.e., the rip tide working area) 51% of the time they recorded their positions.

Table 8. Percent of time fishermen spent fishing in or adjacent to rip tides in Cook Inlet, Alaska during six, 12-hour fishery openers in June and July 1999. Each value represents the percentage of observations recorded by all fishermen combined on that day. The Cook Inlet salmon fishery on 22 July was limited to a three-mile open corridor along the east shore, reducing the opportunity to fish a rip tide.

Date	In Rip	≤463 m	426 m – 926 m	> 926 m	No Rip in Sight	# of Fishermen
28-Jun	15%	22%	5%	10%	48%	5
1-Jul	55%	14%	5%	8%	18%	3
5-Jul	22%	42%	4%	14%	17%	7
8-Jul	9%	16%	8%	6%	61%	4
15-Jul	23%	44%	4%	1%	28%	7
22-Jul	1%	25%	4%	20%	50%	5
Grand Mean ± SD	21% ± 18.7	27% ± 12.9	5% ± 1.5	10% ± 6.6	37% ± 18.5	9

4.3 Remote Sensing

4.3.1 RADARSAT Imagery

A total 23 RADARSAT images of lower Cook Inlet were collected on 10 orbits between 28 June 1999 and 26 July 1999 (Table 9). Figure 11 shows examples of these images.

The Scan SAR image acquired 1 July 1999 provided a good overview of Cook Inlet with its 300-km swath, but the 100-m resolution and 8-bit quantization provided little information about water surface features. The water surface was uniformly black. A series of three fine-beam images (50-km footprint, 8-9 m resolution) was collected on 12 July. Unfortunately, the coverage was mostly land on the Kenai Peninsula.

The remaining RADARSAT images were all at approximately 25 m resolution at incidence angles ranging from 27 to 58 degrees. In Figure 11, water appears uniformly dark in the high incidence angle Extended High Beam 3 (EH-3) image acquired 28 June 1999. This appearance is misleading as image processing of the 28 June image showed there was valuable information in the image.

Conversely, images generated at lower incidence angles (16 July, 23 July, and 9 July) appear to show more features in surface water (Figure 11). Again, this initial observation should be treated with caution as certain "surface features" are in fact artifacts caused by topographic "ghosting." This effect is most evident in the EH-3 images of 12 July 1999 and 26 July 1999. It was also observed in the EH-3 image of 28 June 1999.

4.3.1.1 EH-3 RADARSAT Image, 28 June 1999

We were able to examine in detail only one of the RADARSAT images due to time and budget constraints. On 28 June 1999, an EH-3 RADARSAT image was collected within one hour of the start of a driftnet fishery. Coverage of the image included Kalgin Island and more than 100 km to the south and west (Figure 12). This image was selected for detailed processing.

The north and south scenes were geometrically rectified and mosaicked together. All processing was performed at 16-bit radiometric resolution. Figure 13 shows the 28 June image after processing. The white lines represent rip lines and the white dots are fishing vessels.

As explained in Section 3.2, RADARSAT is less useful than ERS for detection of sea surface conditions due to the horizontal polarization of the radar signal and shallower viewing angle. In Figure 12, which shows the area between Chisik Island (NE) and Anchor Point (SW) during a driftnet fishery, the water surface shows very little current or tide information compared to ERS images. Linear features that appear to be rip lines are evident in the image in mid-channel south of the Kalgin Island shoal. Fishing boats of the Cook Inlet driftnet fleet are also detected by the RADARSAT satellite.

The *"topography"* that appears in the RADARSAT image is an artifact of the imaging geometry and local environment. Images from SAR are comprised of multiple signal returns that are integrated over time. At low viewing angles, bright returns from high elevation features in the background can contaminate foreground features. In this case, signal returns from the west coast mountains show in the dark waters of Cook Inlet.

Table 9. ERS images used to map rip lines.

West Rip (Date of ERS image)	Middle/East Rip (Date of ERS image)	Other Rip Lines (Date of ERS image)
920622	920723	920726
920723	940722	940702
920830	950824	940722b
930518	970706	950720
930622	970810	950924
930815	970813	960615
940722	970914	960619
950824a	980830	960705
950824b	990606	960720
960705	990621	960721
960721	990711	960724
960824	990811	960825
960828		980729
960913		980922
970604		990620
970706		990815
970720		990818
970806		
970914		
980726		
980830		
990606		
990609		
990621		
990710		
990711		
990714		
990811		
990815		
990830		

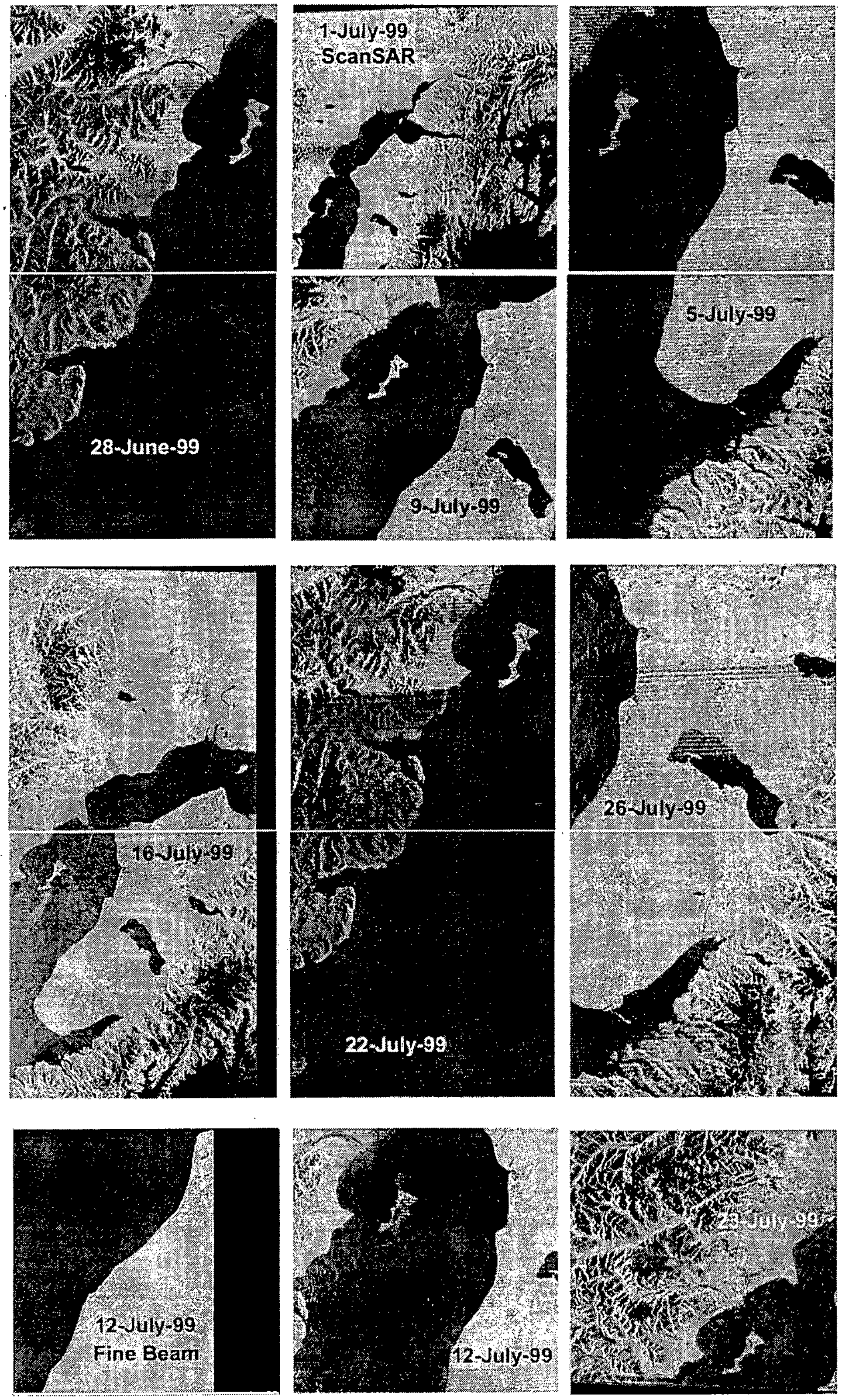


Figure 11. RADARSAT images of lower Cook Inlet collected between 28 June and 26 July 1999.

Figure 12. Synthetic aperture radar (RADARSAT EH-3) image of central Cook Inlet, Alaska between Chisik Island and Anchor Point, 28 June 1999. The white lines represent rip tides and the white dots are fishing boats.

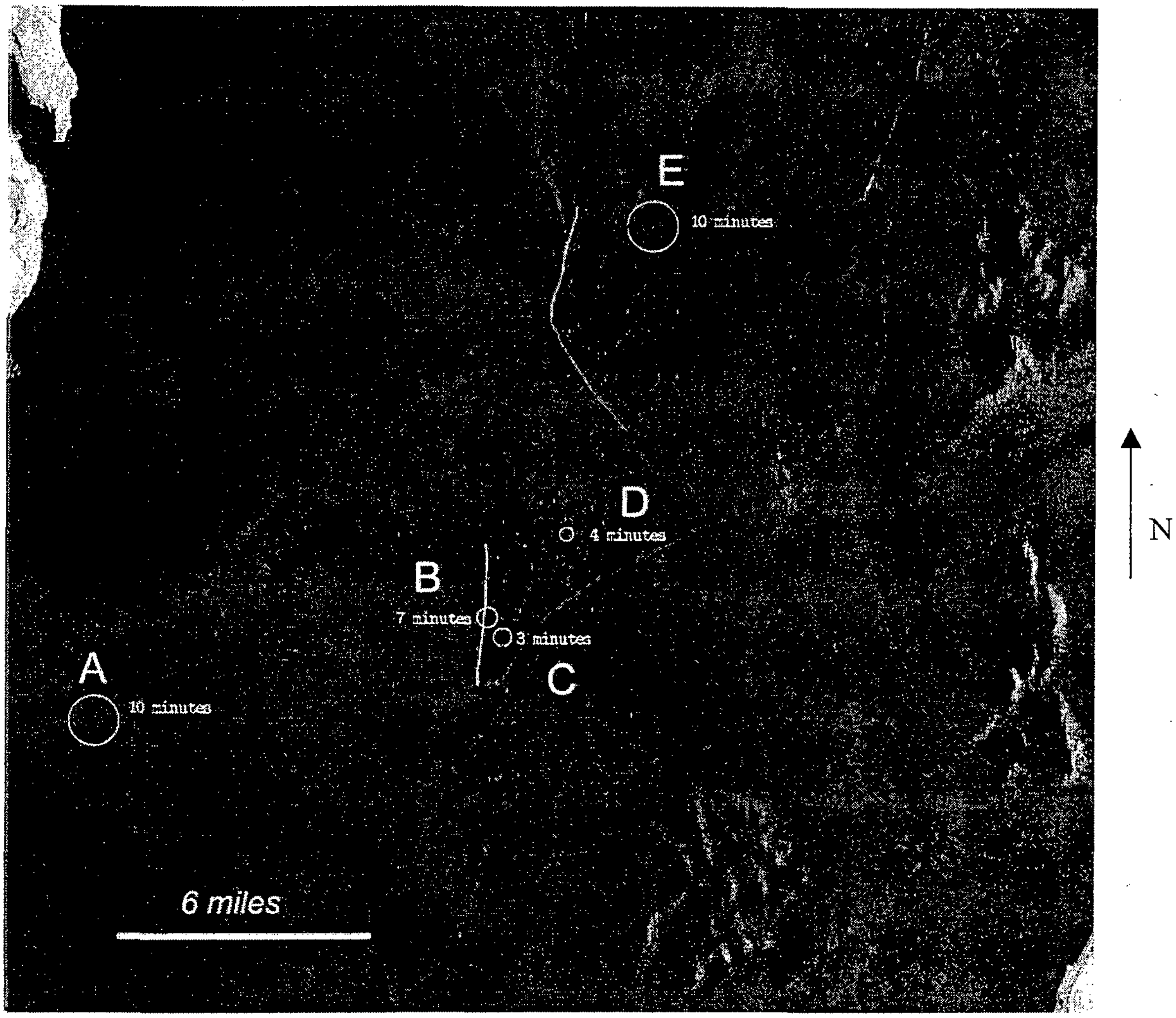


Figure 13. Boat positions and RADARSAT imagery of 28 June 1999 fishery opener, Cook Inlet, Alaska. Rip lines have been enhanced, and are plotted with logged fishing boat positions at the time of imaging. Circle radius is distance to nearest boat from logged position. Also shown is the time difference between logged position and imaging time. Ghosting is evident in this image as apparent "mountains" in the water (see text).

Because Daylight Savings Time was not incorporated into our ground-truthing design, Cook Inlet fishermen recorded their positions one hour before the RADARSAT satellite imaged the study area. Consequently, we have near-synchronous positions (+/- 10 minutes) for only five boats that logged their positions at hourly intervals throughout that day.

A fishing vessel appears in the RADARSAT image as a small bright dot, one or two pixels in size. It is not possible to differentiate between boats, only to determine whether a vessel is detectable in the image at a particular location. We were able to identify the presence of the five logged vessels within a one-mile radius of reported position (Figure 13). Two of the vessel captains reported being in the rip tide at that time (vessels B, C), a third was 500 yards away (vessel D), and two were in open water (vessels A, E). Rip Tides or rip lines can also be seen in the RADARSAT image (Figure 12). The fishing fleet is aligned along these lines. Even though individual vessels cannot be identified, the following conclusion is reached by comparing the imagery with the fishing location logs: Although our sample size is small, the imagery represented in Figure 13, together with the information in the fishermen's logs, provide evidence that rip tides are correctly identified in the RADARSAT imagery.

Information collected by the RADARSAT satellite on 28 June 1999 was incorporated with a 1995 ERS image of Cook Inlet. This compilation of radar satellite image data was printed as posters for presentation at the second workshop (Appendix G). The base of the map is the ERS satellite image acquired during a flood tide 24 August 1995. Surface water features, interpreted to be the middle rip tide, are highlighted in light blue. Overlaid on the ERS image is information collected by the RADARSAT satellite during an ebb tide 28 June 1999. Fine white lines on the image are interpreted rip tides from the 1999 RADARSAT image, and white dots are positions of boats participating in the Cook Inlet driftnet fishery at the time of the satellite overpass. The compilation of satellite images on the poster supports Burbank's (1977) findings and fishermen's reports that the middle rip tide can move as much as 3.6 km to the west during a flood tide [Section 4.1.1.1].

4.3.2. Historic ERS Imagery

We examined 61 ERS images of lower Cook Inlet (Table 3), and almost all displayed evidence of rip tides. We followed the description provided by fishermen at the November 1999 workshop as well as our own experience of interpreting the ERS SAR imagery. "Rip lines are distinct features along the edge of a rip tide, whereas a rip tide can be miles wide. However, obvious rip lines do not necessarily materialize along the side of a rip tide" [Section 4.1.1]. "Rip tides can materialize at almost any location in central Cook Inlet" [Section 4.1.1.2].

Figure 14 compares two ERS images acquired two years apart, both at mid-flood tide. The west rip tide is seen offshore of Kalgin Island in the same position in both images. This rip tide remains quite constant in its location off Kalgin Island, but appears to be further south in the 1999 image. It is more difficult to identify the limits of the middle and east rip tides in Figure 14, although the east rip tide appears much closer in-shore off Cape Ninilchik in the July 1997 image.

This image pair reflects the project team's experience analyzing the other 59 ERS images. From the Forelands to southern Kalgin Island, the west rip tide boundaries are very well defined and consistent, but they start to widen south of Kalgin Island. The middle and east rip tides seem to move laterally across the inlet much more, and the project team was unable to distinguish between them.

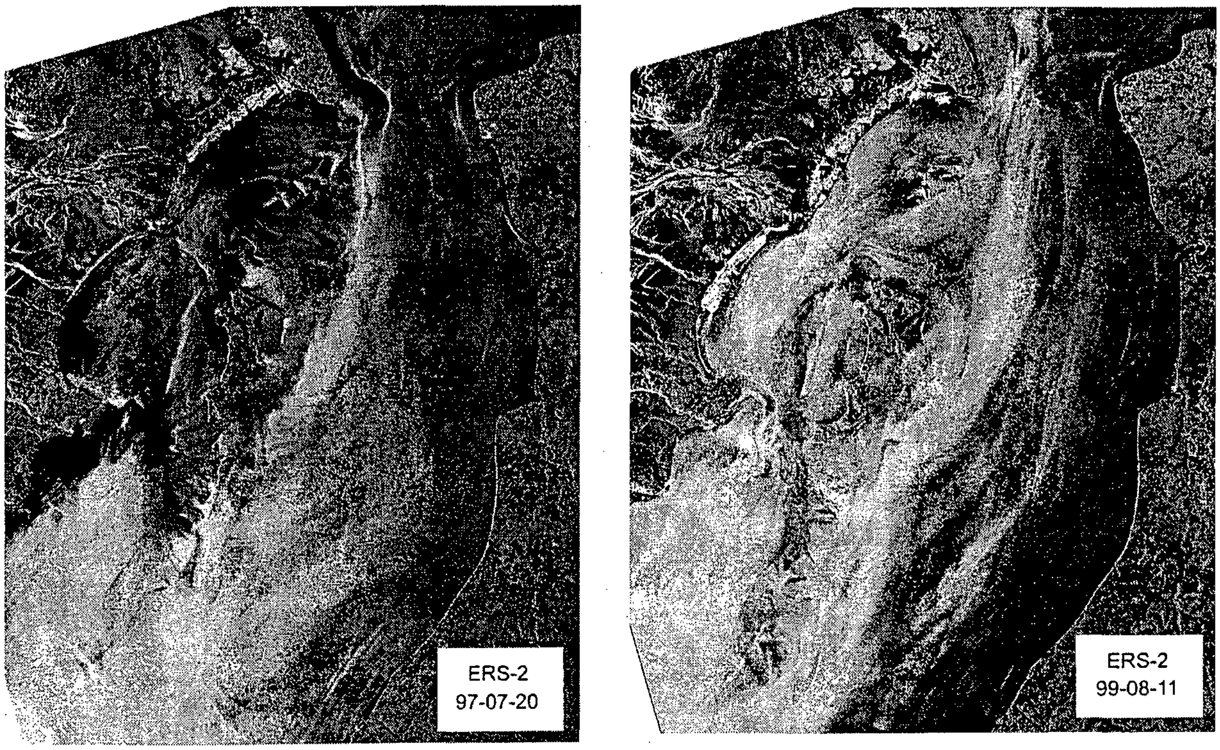


Figure 14. The west rip tide line during mid-flood tide off Kalgin Island, Cook Inlet, Alaska in July 1997 and August 1999.

4.3.2.1 West Rip Tide Location

The interpreted rip lines were sequentially overlaid on a background ERS image of Cook Inlet, and the linework for each date was visually examined for presence of lines in the general area of the west rip tide. Where such lines were present, they were copied to a new file and assembled with similarly classified linework from the other dates.

The west rip linework was taken from 30 images acquired at all tide stages in the period 1992–1999, and this linework was edited to remove lines outside the general area of the west rip tide. Figure 15 shows the maximum east and west boundaries of the interpreted west rip lines. Between the Forelands and southern Kalgin Island, the west rip tide is very stable. The east-west bounds rarely vary by more than 3.7 km (2 nm), and are often less than 1.9 km (1 nm) apart. The eastern boundary closely follows the 20-fathom (37 m) contour in this area, and the western boundary appears at about 5 fathoms (9 m). South of Kalgin Island the west rip tide bounds widen to as much as 18.5 km (10 nm) and may join with the middle rip tide. Table 9 lists the ERS images used to map west rip linework.

4.3.2.2 Middle and East Rip Tide Locations

The middle and east rip linework was classified in the same manner as for the west rip linework (Table 9). Rip lines in the central channel and east side of the Inlet were mapped from twelve ERS images. These lines were assembled and edited. Figure 16 shows the maximum east and west boundaries from this work.

We were unable to differentiate between the middle and east rip tides. Rip lines were found at all areas between the classical locations of the east and middle rip tides. The eastern boundary closely follows the 10-fathom (18 m) contour 3–5 miles off the Kenai Peninsula. The western boundary is in the central Inlet at 30–40 fathoms (55–73 m) depth.

4.3.2.3 Other Rip Tide Lines

Figure 17 shows rip lines interpreted from the ERS images that occurred in other parts of the Inlet (Table 9). At the 8 November 1999 workshop, fishermen reported seeing rip tides over the Kalgin Island shoals and south of the navigation buoy (USGGS light list #26270). Figure 17 shows that many ERS images had rip lines in this area.

Two other areas of rip tide activity are indicated in Figure 17. Interpretation of the ERS imagery suggests rip tides can develop along a 40-fathom (73 m) trench that occurs in the narrows between Harriet Point and the southern tip of Kalgin Island. The second area where rip tides occur frequently is along the 10-fathom (18 m) contour on the west side of the Inlet.

4.4 Potential Conflicts Between Fishermen And Offshore Industry Development

4.4.1 Obstacles

The establishment of fixed drilling platforms or other industry equipment may pose a hazard to fishermen. Numerous fishermen recounted problems with nets getting caught on the stationary navigational buoy south of Kalgin Island and on the Sisters, south of the Kasilof River (Figure 8).

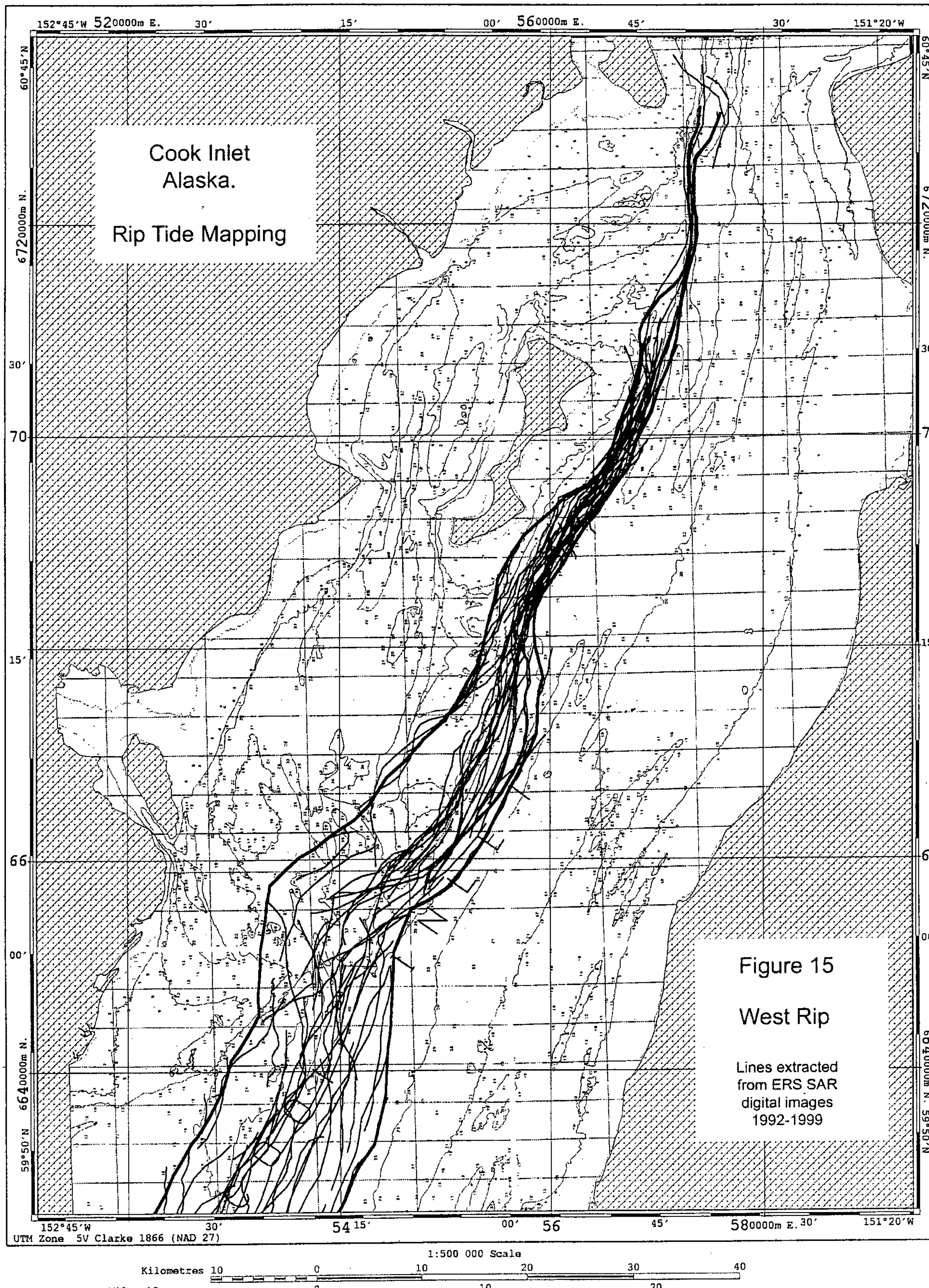


Figure 15. Maximum east and west boundaries of interpreted west rip lines at all tide stages from ERS synthetic aperture radar images of Cook Inlet, Alaska from 1992–1999.

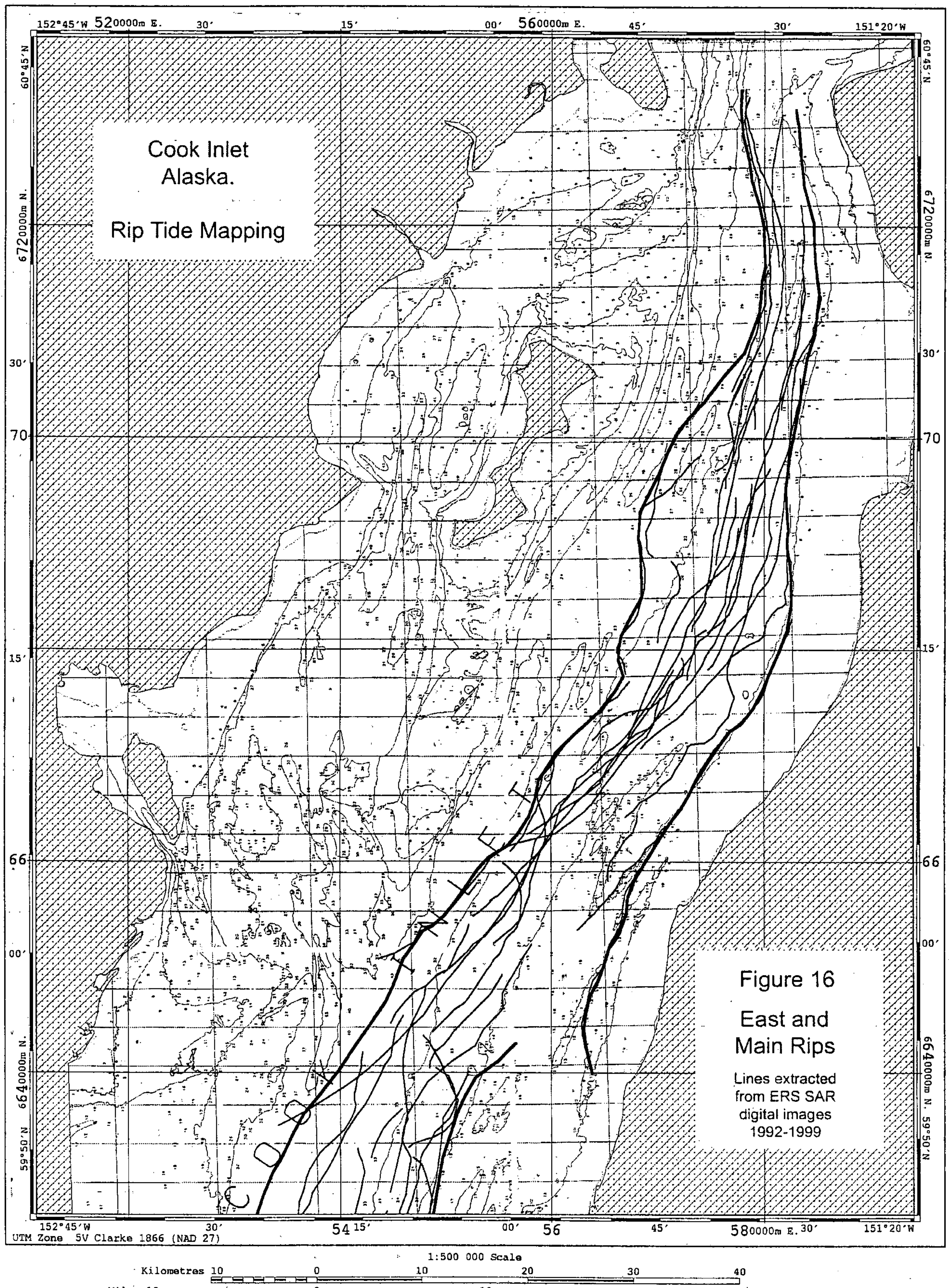


Figure 16. Maximum east and west boundaries of interpreted middle and east rip lines at all tide stages from ERS synthetic aperture radar images of Cook Inlet, Alaska, 1992–1999.

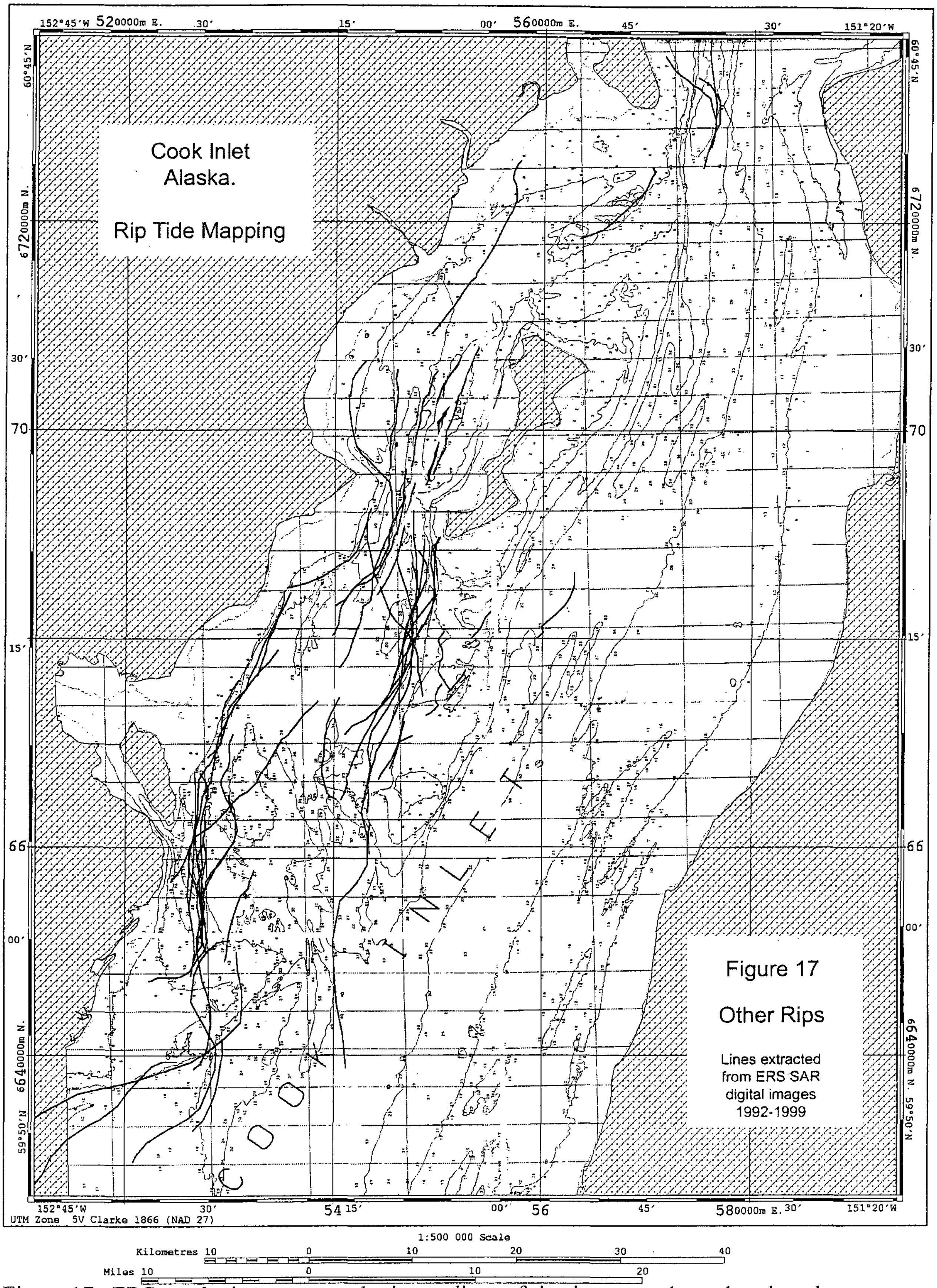


Figure 17. ERS synthetic aperture radar image lines of rips interpreted as other than the west, middle, or east rips in Cook Inlet, Alaska from 1992–1999.

Avoiding fixed objects while drifting with a 274.3-m long net is difficult given the distance a boat may float while hauling up a net. For example, fishermen reported taking 15 minutes to pull in an empty net, if nothing goes wrong. During this time, a boat and gear might travel 1 nm, given a conservative current of 4 knots. Consequently, avoiding stationary objects in Cook Inlet is difficult during an active fishing operation. New stationary objects, such as surface oil and gas platforms, might require fishermen to allow 1.9 to 3.7 km (1 to 2 nm) buffer zones to avoid entangling nets.

To eliminate a fishing gear conflict, the use of "non-surface" oil and gas production methods, such as directional drilling, was suggested by fishermen. The operation of mobile exploration platforms during the off-season was also proposed. One stakeholder suggested development be limited to less-fished areas of the Kalgin Shoals, north of the navigational buoy and to the west of Kalgin Island.

4.4.2 Discharges/Spills

Further concerns were expressed regarding the potential discharge or spills of drilling fluids, other substances, and oil. Rip tides may concentrate oil within or along their edges. In July 1987, spilled crude oil from the *M/V Glacier Bay* concentrated and persisted in rip tides (U.S. Coast Guard 1988). Some of the oil was difficult to collect as it submerged after being boomed (Whitney 1994). In addition, the spiraling circulation of a rip tide current provides a powerful dispersion mechanism for contaminants. Understanding the short- and long-term ramifications of oil spills is difficult given that the transport of such materials by tides and currents in Cook Inlet is unpredictable.

5.0 COMMENT

In this study we examined 61 Synthetic Aperture Radar (SAR) images acquired by the ERS-1 and ERS-2 satellites, and one SAR image collected by the RADARSAT satellite. RADARSAT images from another nine dates in summer 1999 were inspected but not analyzed. ERS radar images can provide valuable information concerning surface feature information in ocean waters. RADARSAT images are most useful for detection of point-source reflectors, such as fishing boats or other vessels on the ocean surface.

Time and budget constraints did not allow a comprehensive analysis of the SAR imagery with state of tide. Our preliminary work found no obvious correlation between tide state and rip tide location. ERS coverage of Cook Inlet is predictable. It is recommended that any planned oceanographic work in the Inlet consider the possibility of synchronizing on-water studies with a scheduled ERS image acquisition program. A fisherman reported that salmon cannery operators customarily conduct fish spotting flights along rip tide lines the night before salmon openings. These aerial surveys could provide opportunities to coordinate with satellite overpasses and further ground-truth rip tide interpretations of satellite images.

6.0 SUMMARY

6.1 Rip Tide Location

Cook Inlet rip tides vary in form, force and location, but there are certain areas of the Inlet where rip tides persist. The major rip tides in the Inlet tend to run along deep channels and follow bathymetric contours. Satellite mapping of Cook Inlet rip tides supports the generalized chart of Cook Inlet rip tides produced by Burbank (1977; Figure 2). The satellite mapping further supports the fishermen's reports that rip tides can appear almost anywhere in the Inlet, that they occur over Kalgin Island shoals, and that they are found south of the navigation buoy (USCGS light list #26270).

Thirty satellite images acquired at different tide stages over eight years showed the west rip tide consistently in one location, whereas the middle and east rip tides in the central channel occur over a wider area of the Inlet. The satellite mapping was unable to differentiate clearly between the middle and east rip tides.

In addition to the rip tides discussed above, the satellite mapping has repeatedly identified other areas where rip tides have been reported by Cook Inlet fishermen. These include the Kalgin Island shoals and south of the navigation buoy, in a 40-fathom (73 m) trench between Harriet Point and the southern tip of Kalgin Island, and following the 10-fathom (18 m) contour along the west coastline of Cook Inlet.

6.2 Fishermen's Use of Rip Tides

Cook Inlet fishermen indicated that they fish rip tides inconsistently. Some prefer to work rip tides, but do not limit their fishing to the rip tides. Both the fishery "snapshot" and fishing "profile" data suggest there is a wide range of fishing methods fishermen use to factor rip tide locations into their fishing practices.

A RADARSAT image of the 28 June 1999 fishery opener was able to document the position of the driftnet fleet 67 minutes after the opening. Most fishing boats were aligned along rip tides, which is an indicator of the importance of the rip tides to the Cook Inlet driftnet fishery.

6.3 Potential Conflicts with Oil and Gas Industry Development

Cook Inlet driftnet fishery stakeholders indicated the addition of surface obstacles and potential for pollution associated with oil and gas development could pose problems for their fishery. Planning for discharges or spills is further compounded by the fact that the transport of such materials by tides and currents in Cook Inlet is unpredictable. Understanding and predicting circulation associated with rip tide currents would allow prediction of pollutant dispersion patterns so that a rational response plan could be formulated.

7.0 ACKNOWLEDEMENTS

The U.S. Department of Interior, Minerals Management Service (MMS) sponsored this work. We are grateful for the assistance provided by Dr. Richard Prentki, the MMS Contracting Officer's Technical Representative, who helped plan logistics and reviewed work products and reports. We thank Ms. Valerie Elliott of the MMS who provided logistical help regarding the use of the Service's vessel, *Launch 1273,* during two fishery openers. The Contracting Officer for the program, Wallace Adcox, cheerfully helped the study team navigate the government procedures necessary to complete this project.

This study was supported in part by the Canadian Centre for Remote Sensing (CCRS). The CCRS subsidized an expansion of the project to examine the utility of using its satellite, RADARSAT 1, to identify, characterize and enumerate the various types of fishing vessels in Cook Inlet. The CCRS paid for the printing and mailing of the post card questionnaires in support of their part of the project.

Drs. Mark Johnson and Steve Okkonen of the University of Alaska showed interest in this project, provided comment on the approach, and invited us to a Cook Inlet oceanography workshop to present this work. Wanda Seamster of the University of Alaska prepared the artist's illustration of a Cook Inlet rip tide.

We thank all fishermen who participated in the project, and especially those 13 who spent the extra time with us during interviews (Appendix A). Special thanks is extended to Darwin and Alison Waldsmith who operated the MMS *Launch 1273* and shared their experiences of fishing Cook Inlet, and to Ridgely Stier who allowed personnel onboard his boat, *F/V Blueback.* Marc Zimmerman shared his fishing charts and logs, and Bruce Gabrys shared his historic fishing locations with our study team. We thank the Cook Inlet Aquaculture Association for hosting stakeholder workshops, and the United Cook Inlet Drifters Association who let us participate in their annual meeting.

Finally, we thank the staffs of LGL Alaska Research Associates, Inc. and Pacific Geomatics, Ltd. for their technical support and assistance throughout this study, especially Peggy Kircher, Jessy Coltrane, Matt Nemeth, and Drs. Rick Lanctot and Dale Funk.

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LIST OF APPENDICES

APPENDIX A. Cook Inlet driftnet stakeholders interviewed April through June, 1999.

Name	Occupation	Date	Interview
Roy Self	ADF&G test fisher	19 April	phone
Paul Dale	seafood processor	19 April	phone
Susan Saupe	RCAC scientist	19 April	phone
Ken Tarbox	ADF&G biologist	3 May	personal
Jeff Fox	ADF&G biologist	3 May	personal
Drew Sparlin	fisherman	4 May	personal
Bill Sullivan	fisherman	4 May	personal
Dan Mahan	retired fisherman	4 May	personal
George Jackinsky	retired fisherman	5 May	personal
Bill Holt	fisherman	5 May	personal
Phil Squires	UCIDA/fisherman	5 May	personal
Loren Flagg	retired fisherman/guide	6 May	personal
Chris Kempf	fisherman	6 May	personal
Theo Matthews	UCIDA/retired fisherman	6 May	personal
Marc Zimmerman	fisherman	7 May	personal
Ridgely Stier	fisherman	8 May	personal
Emmet Heidemann	fisherman	12 May	phone
Karl Kirscher	fisherman	17 May	phone
Marvin Peters	fisherman	7 June	phone
Mike Wade	fisherman	7 June	phone
M.L. "Moon" Mullin	fisherman	7 June	phone
Jim Williamson	fisherman	7 June	phone
Mark Mahan	fisherman	9 June	phone
John Lindeman	fisherman	10 June	phone
Darwin Waldsmith	retired fisherman	14 June	phone
Alexander Stuart	fisherman	17 June	phone
Grace Kendall	fisherman	7 July	phone

APPENDIX B1. Sunday, 20 June 1999 *Peninsula Clarion* article discussing the Mapping Cook Inlet Using Local Knowledge and Remote Sensing Project. Reproduced with permission of the *Peninsula Clarion*.

Ocean scientists 'rip' into Cook Inlet study

By SHANA LOSHBAUGH
Peninsula Clarion

Fishers know Cook Inlet tide rips for their hot fishing and crazy currents. Now scientists want to go a step further and find out how the rips work.

Using eyes in the skies and underwater sensors, two studies this month are scrutinizing the inlet's dynamics. Concerns about oil development in sensitive marine environments underlie both projects.

A team from the University of Alaska Fairbanks, the Cook Inlet Regional Citizens Advisory Council and Cook Inlet Spill Prevention and Response Inc. is measuring water movements in and under the rips, which occur when opposing tides or currents meet. Their work is a pilot project to refine computer models of the inlet's physical oceanography.

LGL Alaska Research Associates, an Anchorage consulting firm, is working with the federal Minerals Management Service to compare boat-based observations with simultaneous views from satellites. To get the best results, they are enlisting the help of the drift fleet.

"They are separate projects," said Bill Wilson, a fisheries biologist who manages LGL's operations in Alaska. "But we are coordinating."

Mark Johnson, an oceanographer from UAF, said, "All of us working together are going to have a good data set to deal with future oil spills."

He described his project as generating a "curtain" of underwater data across the inlet, while the satellite images study the inlet's "skin." The resulting complementary information will give computer modelers challenging new tools, he predicted.

Models of the inlet currents, which the university and CIRCAC are refining and testing, are used to plan for oil spill prevention and response.

Their oceanography project group, led by Johnson, Steve Sweet and Steve Okkonen of the UAF Institute for Marine Science and CIRCAC Science Director Susan Saupe, spent three days offshore last week.

CISPRI provided the vessel Heritage Service. CIRCAC provided the initial funding, and the university team provided an in-kind match of staff time.

Saupe, speaking about the partnership, said, "This is a classic example of what we are aiming for — collaboration."

CIRCAC also is working with university and National Oceanic and Atmospheric Administration scientists this summer in Kachemak Bay studying the long-term effects of beach cleanup.

"It is really neat all these collaborative things are happening," Saupe said. "It is a real coup for CIRCAC."

Researchers use a tool called an acoustic Doppler current profiler to measure how water moves at every depth from the surface to the ocean floor. Results should show how the rips churn the surface down into the water column — a factor that could be important for pollutants at sea.

Measurements will give clues to the three-dimensional structure of the rips. Understanding the structure will allow scientists to analyze other factors such as the winds and tide.

Johnson said the tool is new and worked even better than he had hoped.

The ultimate goal is to improve computer forecasts to accurately predict the path of any oil spill.

In contrast, the LGL and Minerals Management Service study will refine satellite maps of the inlet.

"That information will be useful to the MMS in their oil lease decisions," Wilson said.

"Fishermen commonly fish these rips. They would like to see these areas considered for deletion from lease sales."

Resource managers have been collecting satellite images of Cook Inlet since 1992. They map the locations and movements of rips, but they need to check what the actual sea surface conditions are that go with the images so they know how to interpret them.

They call this process "ground truthing."

The researchers cannot cover the inlet with observers, so they are asking for help.

They arranged for a satellite, owned by the Canadian Space Agency, to fly over during fishery openings in Lower Cook Inlet and take pictures. The satellite uses Synthetic Aperture Radar (SAR), which produces images regardless of cloud cover or daylight.

LGL recently sent two mailings to Cook Inlet drift fishery permit holders, about 600 in all. They are asking the driftnetters to fill out postcards detailing sea conditions and rip positions at the exact times of the satellite flyovers.

They want to find about 15 boats to provide more detailed information at regular intervals throughout the openings.

Everyone who responds will get a poster of a satellite photo taken during the summer fishery.

The Minerals Management Service will have a boat on the inlet, an LGL representative on a fishing boat and another flying overhead in a chartered plane during the first opening on June 28, and personnel on the water off and on during the other openings. They will videotape and photograph tide rips to compare to what the satellite sees.

Wilson said the maps of the rips planners have now are old and possibly inaccurate. Now Alaska researchers have the tools to make modern maps — satellites, numerous observers and a plan to systematically canvas the area.

"There's kind of a triple whammy here," he said.

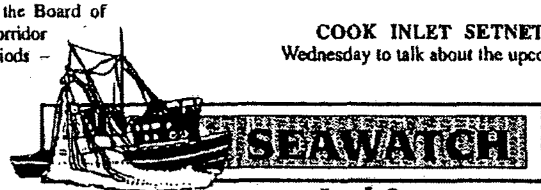
Satellite imagery specialist Geoff Tomlins and LGL representative Beth Haley will attend the June 30 meeting of the United Cook Inlet Drifters Association to explain the project. That meeting is at 1 p.m. at the Kenai Elks Club on Barnacle Way across from the post office.

The CIRCAC and university team plan to present their findings at a workshop this fall analyzing the physical oceanography of Cook Inlet.

The University of Alaska Institute of Marine Science is organizing the workshop, tentatively planned for October or November.

APPENDIX B2. Thursday, 24 June *Homer News* Public Service Announcement of the Mapping Cook Inlet Rip Tides Using Local Knowledge and Remote Sensing Project and LGL personnel presence at the annual UCIDA meeting. Reproduced with permission of the *Homer News*.

Drift fleet asked to help pinpoint tide rips



Joel Gay

THE COOK INLET DRIFT SEASON begins Monday with a 12-hour opening beginning at 7 a.m. Fishermen are hoping for more, but the Department of Fish and Game is projecting a harvest of just 2 million sockeyes, one of the lowest harvests in years. Other than fewer fish than usual, the big change this year is that fishing periods are Mondays and Thursdays, said Jeff Fox, the new Area Management Biologist in Soldotna. "Thursdays — put that in big red letters," he said. In addition to changing the traditional Friday opening, the Board of Fisheries is requiring corridor restrictions on three periods – July 12, 22 and 26. Because this year's harvest is expected to be around 2 million, the corridor is not likely to be extended to that area south of Kalgin Island, but could be in years of bigger returns.

DRIFTERS WILL MEET to talk about the upcoming season at the annual meeting of United Cook Inlet Drift Association on Wednesday at 4 p.m. at the Cook Inlet Aquaculture Association building on Kalifornsky Beach Road.

THE IMPORTANCE OF TIDE RIPS to drift fishermen is the subject of a study this summer. The Minerals Management Service is satellite mapping the location and variability of tide rips to help plan future oil lease sales and the possibility of eliminating the rips from the sale area. LGL Alaska Research Associates will be at the UCIDA meeting to explain the program, which seeks fishermen's aid in ground-truthing the satellite photographs. At the exact minute a satellite passes over during each of the first five openings, fishermen will be asked to fill out a card describing their position, distance from a tide rip, the bearing of the boat, wind speed, wave height and other information. Those who participate can then get a free satellite poster of the fishing fleet in action. For more information, contact LGL in Anchorage at 562-3339.

COOK INLET SETNETTERS also meet next Wednesday to talk about the upcoming salmon season. The annual meeting of the Kenai Peninsula Fishermen's Association begins at 7 p.m. at the CIAA building. Fishing south of the Blanchard Line begins Thursday, July 1, while setnets north of the line start Thursday, July 8. As with the drift fleet, fishing is Mondays and Thursdays, 7 a.m.-7 p.m.

ONLY A HANDFUL OF SEINERS fished Monday's opening in lower Cook Inlet, according to Wes Bucher of the Department of Fish and Game in Homer. Typically the Southern District doesn't start producing for another week or two, he said. Setnetters from Halibut Cove to Nanwalek have landed about 4,200 reds and 1,100 kings thus far. In three weeks of fishing, Resurrection Bay seiners caught about 26,000 reds bound for Bear Lake before fishing died off last week, Bucher said. That run, created through the enhancement efforts of Cook Inlet Aquaculture Association, had projected a harvest of 31,000.

ENHANCEMENT EFFORTS FIZZLED in Kachemak Bay this spring, which could have a profound effect on sockeye fishing in coming years. Cook Inlet Aquaculture Association usually stocks Hazel Lake with about 1 million sockeye fry and Leisure Lake with 2 million, yielding a combined harvest of 100,000 to 120,000 fish. But because of IHN difficulties at Trail Lakes Hatchery last fall and winter, CIAA put a total of just 750,000 in the two lakes this spring. That could reduce the harvest by three quarters when those sockeyes return in 2002 and 2003.

HERRING FINALLY REACHED Norton Sound last week, about two weeks later than usual. Some gillnet fishermen were hauling their nets through water choked with floating ice, according to the Nome Nugget. Two buyers were on the grounds when fishing began, but the Department of Fish and Game in Nome held off the closure for four hours to allow an Icicle Seafoods tender to reach Unalakleet. The quota is 8,234 tons, but Department of Fish and Game biologist Fred Bue told the Nugget that catching 4,000 tons now seems optimistic.

FIVE ALASKA TRIBES lost their bid for halibut fishing rights around their villages. Eyak, Tatitlek and Chenega in Prince William Sound, along with Port Graham and Nanwalek in Kachemak Bay, asked a federal judge to bar the Commerce Department from enacting the halibut and sablefish IFQ program, saying they had exclusive rights to their traditional fishing waters. The judge ruled against them, as did the Ninth Circuit Court of Appeals, and last week the U.S. Supreme Court refused to hear the case.

APPENDIX C. One of five data sheets mailed to all active Cook Inlet driftnet fishermen, May 1999. Each differed in date and time of satellite overpass.

Cook Inlet Fishery: July 5, 1999 Time: 0703

Please fill out <u>at the time specified above</u>, whether you are near a tide rip or not.
This will be used to "ground truth" the satellite imagery. Fill in as much as you can.

Latitude: ____________________ Longitude: ____________________

Are you near a tide rip? (circle) Yes No

What is the distance from your boat to the rip? ____________________

What is the bearing from your boat to the rip? ____________________degrees

Wind speed: ____________mi/hr. Wind direction: ____________

Wave height: ____________ft. ADF&G Vessel # **(optional)**:____________

Boat length: __________ft. Boat construction material: ____________

Address to send a free poster of satellite image and/or your **COMMENTS**:

____

____Thank you

APPENDIX D. Cook Inlet rip tide notes from interviews of driftnet fishermen.

Review Area We're Discussing

Where: Upper Cook Inlet—about 156 miles long by 40 miles long at the southern boundary fish—from can just north of Kalgin to line across from Anchor Point Light to Chinitna width and breadth of inlet—along 59 degree 46.25' (or 46'12") area of fishery over which MMS has jurisdiction from southwest of Kalgin Island to see above.

Corridor openers are 3 miles wide in "stock specific" area (including 600 feet of driftnets Fish 900 foot (3 shackle) long nets

Location And Dynamics Of Rips

- Incoming tide like hose—soars through deeper areas, showers on shallows
- Cook Inlet is home of tidal fluctuations that can be greater than 30 ft. and can produce current velocities in excess of 8 knots
- More "regular" current will run 4 to 6 knots
- Rips tend to run along area (channel) of deep water—shoulder to shoulder
- A rip acts like a vacuum and sucks debris and fish into it

Three main rips: West, Middle (or Main), East

- Mid-channel deepest rip—40 plus fathom channel
- Middle rip is dividing line between clear ocean water in east inlet and silty, fresh water to west
- Middle rip may be 1 to 1.5 miles wide
- MAIN rip 8 to 10 miles offshore, can be as far as 7 to 12 miles off east coast, main and east sometimes joins to the south

- EAST and west rips follow 10-fathom depth
- East tide can be 7 to 8 miles off east coast
- Some days east can be 8 miles offshore
- Especially on east channel—no obvious bathymetric expression

- WEST rip 2 miles east of Kalgin
- WEST may bend to west over Kalgin Island shoal south of island
- Rip on west side of middle inlet follows shelf from west forelands pretty much along 10-fathom line to east of Kalgin
- Probably preferred fishing ~ 8 miles off shore; avenue most fish take as mixed stock heads up middle along the greatest movement of water, often more clear (ocean water) on its east side
- Clear (ocean) water in the west and dirty (fresh) in the east—to main rip, agrees with circulation profile.

Relative To Tide Stage

- Rips predictable depending on tide stage
- Rips fairly steady as tide increases
- Flood pushes rips north, sometimes of Forelands
- East tides head toward the beach with the flood
- EAST rip 4 miles offshore—during flood as close as 2 miles off Humpy point (Cape Kasilof).

- Flood pushes east rip 2 nm to east and mid rip ~ 2 nm to west
- FLOOD – east rip not as violent as main – can straddle rip or fish across towing; during flood east side of rip will usually pull you into rip; Main rip is stronger on flood
- Southern extent of east/west rips dissipate
- mid channel rip dissipates during ebb, collects debris and can spread out as much as 1.5nm, during flood converges into narrow bank ~0.125 nm wide, can create swath 1.5 nm of boiling water and large waves. Noise can be heard up to 0.25 nm away

- Kalgin Island reef—ebb rip lines more obvious and violent especially near Forelands—rip follows shelf
- EBB—main (middle) and east meet below Kalgin can; tide pushes to west below Chinitna—see Keeper map
- During ebb—east and middle rip about 5nm apart; during flood ~ 9 nm

- The tide change by Kalgin can is 2.5 to 3 hours different from the east coast (Ninilchik to can approximately)
- 4-hour difference in tide between Ninilchik to can
- 1-hour difference in high tide between Ninilchik and Kenai
- Stage of tide rip fluctuates from 7 miles off east shore at low to 2 miles off east shore
- West rip follows Kalgin to shoal and then veers west south of Kalgin island on the flood
- Along line "Lower Cook Inlet" tides generally run 2 to 3 hours later than Seldovia

- All rips dissipate during slack
- SLACK: slack may last 1.5 to 2 hours when no obvious rips
- Tides (per se) not the only factor—winds have strong influence, tide pushes to the east on flood and then west on ebb

- DRIFT PATTERNS: flood—north of Ninilchik between mid and east rips strong drift to west—can float distance between east and mid channel rip
- Ebb tide drift—parallel to rips

- MANY RIPS: a small rip to east of middle lasts only 1 to 1.5 hours north of the can
- Several rips around Kalgin shoals that come together on the south side of the can
- Rips can be everywhere

- Rip along 50-fathom finger—see chart

- RIP SIDES: west side of rip you can either hold or get kicked out while you're fishing—east side will suck you in
- INDICATOR: water color, fish finder indicates turbulence
- Can have mucky water then clear patches appear, almost boiling up
- Look for color change, trash; west rip especially bad for trash

Fishermen's Use Of Rips And Adjacent Water

- Drew usually fishes east
- Some days east can be 8 miles offshore; usually fish in east rip during flood; during ebb, would rather fish in restricted east side fisheries
- Drew won't fish in them—too much stuff, some folks right in the middle
- Work two most significant rips—one on east and one on the west
- Where fish depends on weather, stage of fishery, where fish is headed—shallower tides could fish anywhere
- WIND: west wind fish to shore to NE
- FISH always at surface in heavy waves; rips can be everywhere, fish like middle of rips as two join
- What stock is coming in, may follow the west rip during shallower tides
- Fish travel back and forth across rips
- Earlier in the season the fish are loosely distributed less concentration boats scattered and concerned less with rip
- Most of fleet fishes middle rip then will travel to east
- Will fish rips about 50% low tides looks for likes rip to SW of can on ebb

Indicators

- TEMPERATURE VARIATIONS? Look for warmer incoming water
- Drew sees change in water temperature of 47 – 48degrees to 50 or 52 degrees. Some fishermen actually use thermometers to track variations
- TEMP – variations and thermocline suck fish into it
- one side is usually better than the other - Chris believes that warmer side is better for fishing
- DOESNOT use TEMP (doesn't need)
- INDICATORS: birds, debris, waves, color, surface action, fish finder
- Most active fishing during incoming tide /during FALL fish west side (different runs)
- FISH sound as tide ebbs – if fish near beach, fish in shallows
- George will set the net in muddy water with the boat "bumping" against the rip – the fish can't see the net and the muddier water more likely to be warmer water with incoming fish
- Wind helps move the fish, but tide stays the same – in a circulation report in the late 70's
- Most times fishes east side of rip, but not predictable

- Never just sits in rip to fish
- FISH enter from the SW
- Fishes rips 80% of the time
- By mid-JULY, fish are more to the east, so fishermen follow them
- Always fishes off rip

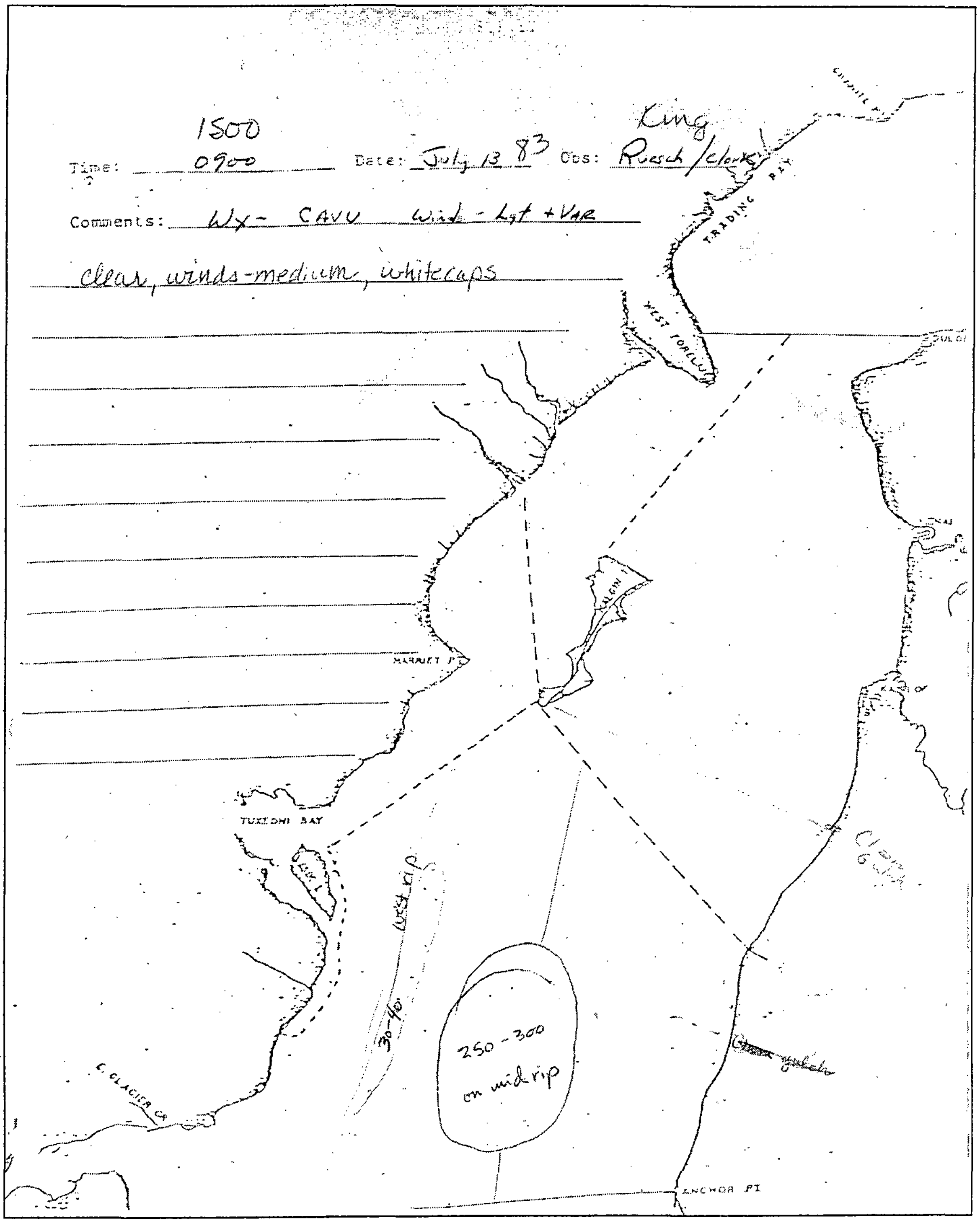
Potential Conflict With Offshore Industry

- Setnetters' corks thrown overboard with dates and locations, near east bench rip recovered west of Kalgin (NW)

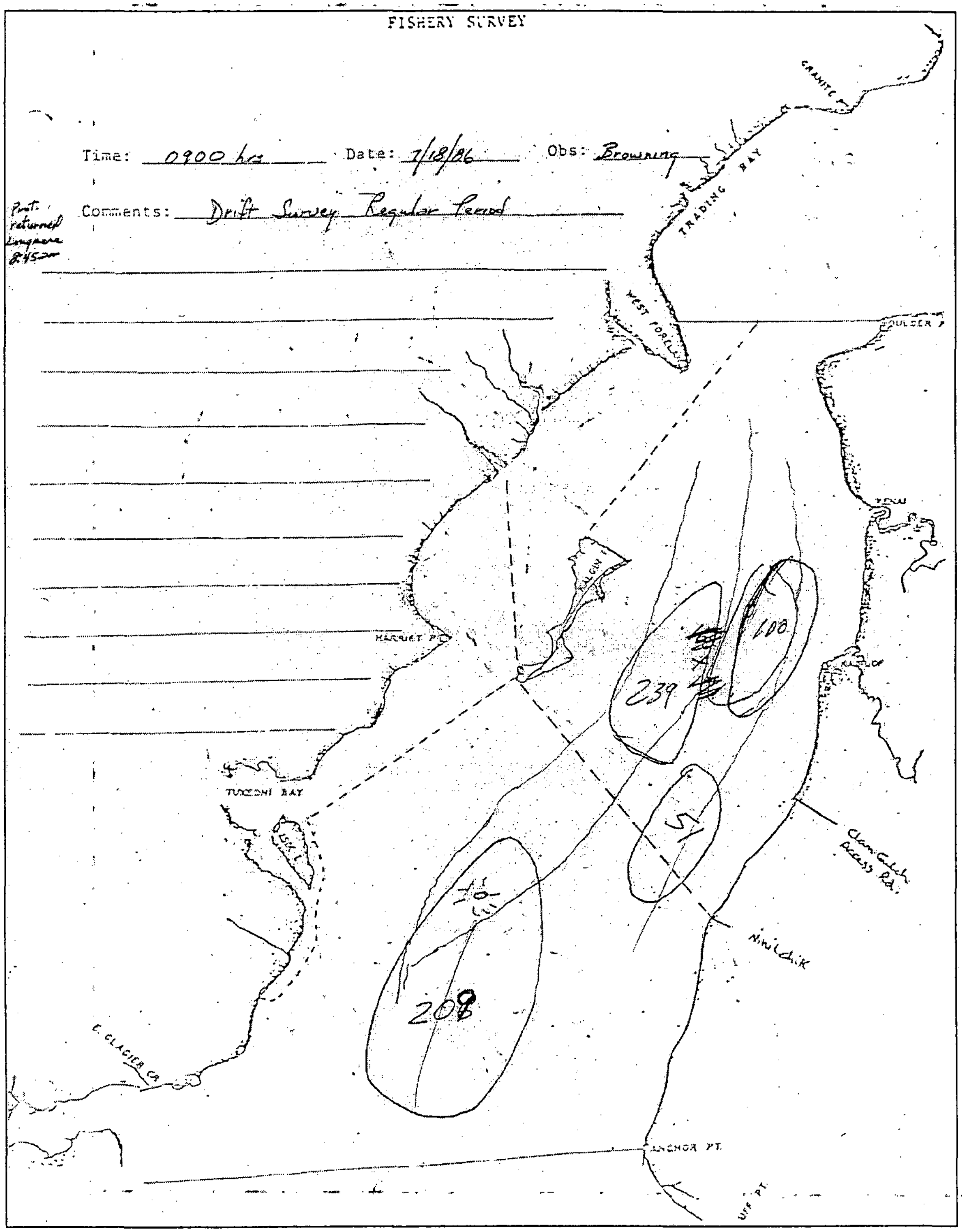
CONCERNS – obstacles!

- Platforms – rips move conservatively at 6 knots if platform in path take 15 minutes to pull in an EMPTY net – in that 15 minutes the boat would have traveled one mile
- Doesn't want oil development
- UCIDA has already suggested using bar on west side of Kalgin Island and shoal south of island for platforms
- Advises mobile exploration units – no permanent platforms, Force Energy does use mobile units
- Already countless evidence of people getting caught on the Kalgin can and the sisters (between Kasilof and Clam Gulch)
- Since oil spill, rips not very productive; can still see oil come up in rips
- After 1987 Glacier Bay oil spill on 7/2, one fishermen trashed three nets – 7/10, 7/20, and 7/22 (second opener he was fishing a rip) continued to try to avoid oil through 8/10. Did not make 8/17 opening in Chinitna but no nets available

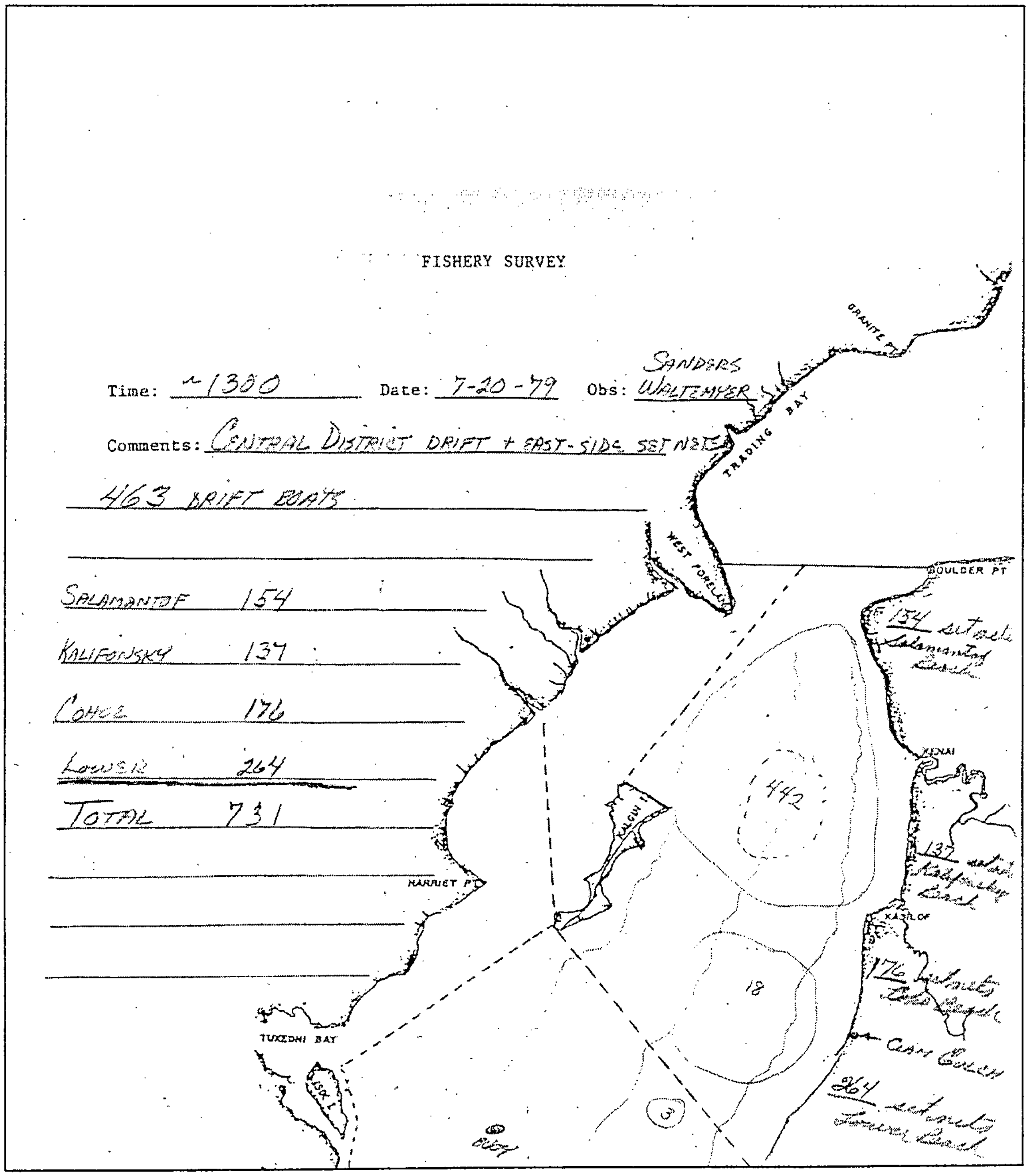
APPENDIX E1. ADF&G aerial fishery survey on 13 July 1983, Cook Inlet, Alaska. Rip tides are indicated on the chart.



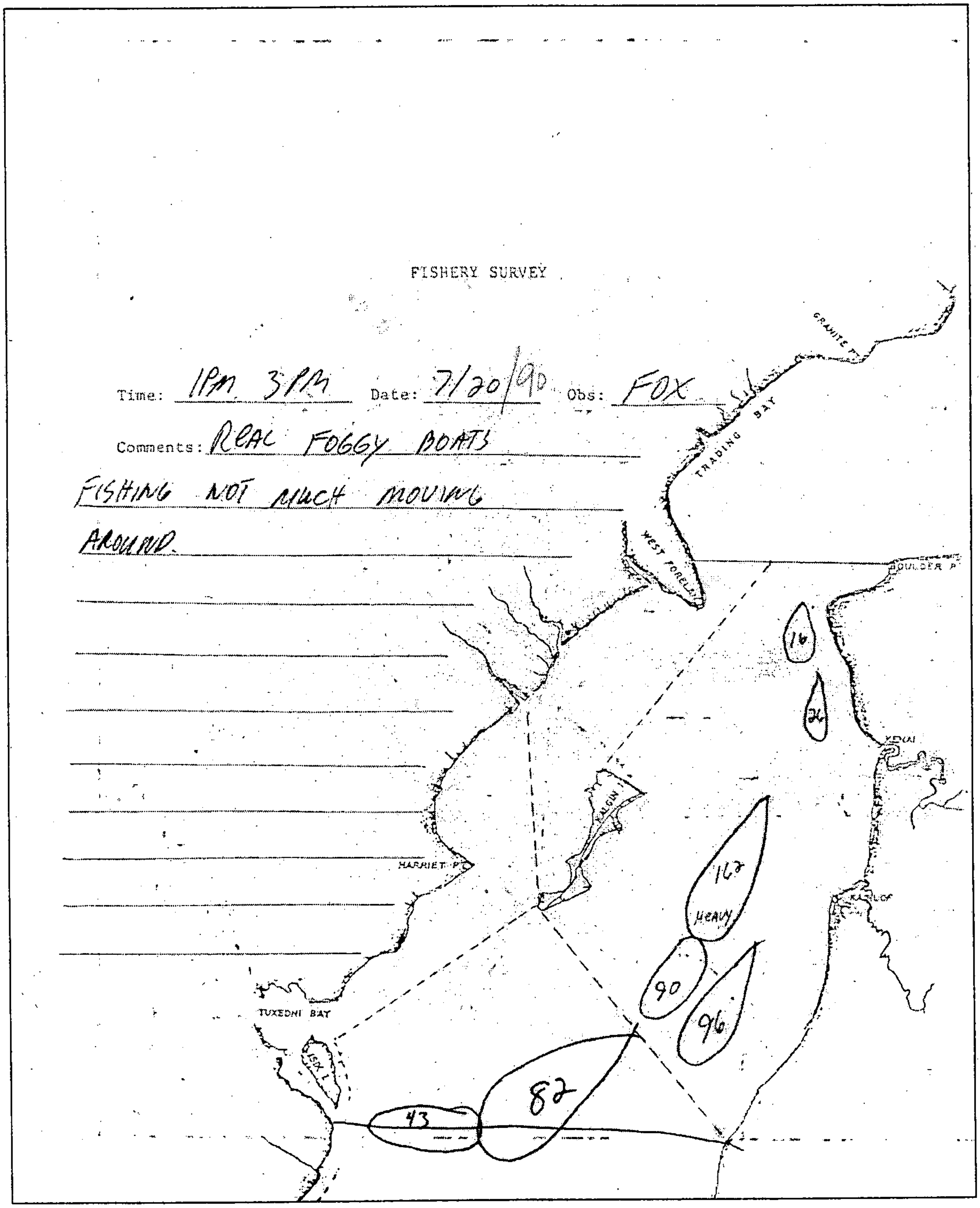
APPENDIX E2. ADF&G aerial fishery survey on 18 July 1986, Cook Inlet, Alaska. Rip tides are indicated on the chart.



APPENDIX E3. ADF&G aerial fishery survey 20 July 1979, Cook Inlet, Alaska. Rip tide are indicated on the chart.



APPENDIX E4. ADF&G aerial fishery survey 20 July 1990, Cook Inlet, Alaska.



APPENDIX F. Technical presentations resulting from this study.

Venue	Title	Date	No. of Attendees	Location
Workshop	Mapping Cook Inlet Rip Tides Using Local Knowledge and Remote Sensing	8 Nov 1999	37	Cook Inlet Aquaculture Assn. Kalifornsky Beach Road Soldotna, Alaska
Workshop	Cook Inlet Oceanography Workshop	9 Nov 1999	59	Kenai Cultural and Visitors Ctr. Kenai, Alaska
Workshop	Mapping Cook Inlet Rip Tides Using Local Knowledge and Remote Sensing	6 Mar 2000	9	Cook Inlet Aquaculture Assn. Kalifornsky Beach Road Soldotna, Alaska

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Royalty Management Program** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic