THE SELDOVIA BAY OIL SPILL

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April 1979
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In the seventy-three days from the accidental sinking of the Glacier Queen in Seldovia Bay on November 8, 1978 to its disposal in the Gulf of Alaska, 1500-3000 gallons of fuel oil and bilge residue were released into an environmentally rich area of Alaska's Kachemak Bay Critical Habitat. A salmon spawning stream at the head of the bay and a tidal lagoon near the mouth of the bay were in continual danger of contamination by floating oil. However, favorable weather conditions, season, and fast efficient response by the USCG, combined to preclude serious damage to natural resources in Seldovia Bay.

Alaska-based scientists acted quickly in response to the threat posed by the sinking. Immediate overflights by Alaska Department of Fish and Game (ADFG) and U. S. Fish and Wildlife Service (FWS) personnel were instrumental in first determining the severity of the spill and in surveying the wildlife present in Seldovia Bay. The Alaska region Scientific Support Coordinator (SSC) of the National Oceanic and Atmospheric Administration (NOAA) was notified by the U.S. Coast Guard Anchorage, Marine Safety Office in accordance with a prearranged spill response network. In the event of a spill of significance, the responsibility of the SSC as mandated in the Draft Oil and Hazardous Materials National Contingency Plan is 1) to provide assistance to the On-Scene Coordinator (OSC), 2) to assess environmental damage, and 3) to capitalize on the research opportunities afforded by a spill. To accomplish these tasks, an SSC must draw heavily upon local expertise.
In addition, an SSC must be prepared to alert scientists on-call throughout the United States. Should a spill assessment require long-term monitoring, specialists are needed to develop a multi-discipline program.

The SSC, in cooperation with other agencies, initiated a program of studies which provided advice for the OSC and became a foundation for the identification and assessment of environmental impacts. This report reviews those contributions of the science oriented governmental agencies, as represented by the Alaska region SSC, to the spill response effort lead by the U.S. Coast Guard. Following a summary of studies performed and generalized conclusions, a background section briefly depicts the setting of the City of Seldovia. A cursory scenario of events and the SSC study program are then introduced in preparation for subsequent discussions of physical processes, geomorphology and oil behavior, biological character, and socioeconomic ramifications.

SUMMARY

It is fortunate that despite the varied direct and indirect repercussions throughout human communities, the biological trophic structure was hampered little by the sinking of the Glacier Queen and on occasion suffered only mild perturbation. Therefore, while segments of society question past decisions or prepare for future threats, the response of the ecosystem may be described and examined with certain finality.

Visual daily monitoring of Seldovia Bay's marine and wildlife populations indicated that life was not noticeably impaired although
some individuals of bird and crustacean groups probably perished as a result of the pollution by oil. Eight water birds partially eaten and frozen including one spotted with oil were collected within ten days of the sinking. This correlated closely with the period of maximum oil pollution and also with the period of most thorough visual observations. In one instance, a small number of helmet crabs were stranded with oiled seaweed. These mortalities represent the only kills noted during the initial month of scrutiny by NOAA personnel.

Planktonic, benthic, and intertidal sampling programs were established as a first step towards damage assessment. Essentially no oil was encountered while sampling. In addition, life forms observed appeared unaffected by the oil pollution. Samples were secured and will be processed analytically if the need for a continued impact assessment program is declared.

At the time of the spill, the physical processes within Seldovia Bay were unknown. The dependence of boom deployment on familiarity with predominant current patterns made acquisition of this information a high priority for the SSC team. Flow predictions were initially compiled from observations of shore morphology, flotsam, and actual oil and sheen transport. Tests with plastic drift cards and subsurface current indicators supplemented this data.

As a gross generalization, surface transport of oil appeared to be controlled by the tidal currents except during periods of medium to high wind velocity. Oil and debris were thoroughly flushed into Kachemak Bay in calm weather. Wind and storm waves, however, deflected oil and debris onto the shore. Winds through Seldovia Bay were typically
northerly or southeasterly due to effects of the surrounding topography. Four oil trajectories were predictable depending on whether northerly or southeasterly winds were superimposed on an ebb or flood tidal current. Thus, for example, if a southeasterly wind occurred during an ebb tide, floating oil would ultimately contact the western shore of Seldovia Bay. Subsequent discussions on geomorphology consider shore oilings due to the four combinations of the prevalent winds and the tidal cycle.

As biological damage was slight and brief if at all, secondary impacts to marine industries are not anticipated or credible. In addition, inspection of vessels docked in the small boat basin noted no oiling of craft other than those used directly in spill response. As no complaints have been received, it is assumed that such damage to property did not occur.

Undoubtedly, the most measureable consequence of the Glacier Queen incident was the expense. Approximately 2.4 million dollars were drawn from the National Pollution Fund, a public tax-supported emergency cash fund. However, to understand the dollars-per-gallon ratio of this spill, the value of the Alaskan environment must be kept in perspective. Most of Alaska may be categorized as "pristine" and, consequently, impacts on the environment from pollutants are far more significant biologically as well as politically.

The response to the spill in Seldovia Bay consisted of two phases—an initial learning phase and a subsequent operational phase. The learning phase which lasted approximately a week was essentially a trial and error process. Many unknowns existed such as the design and cargo
of the ship as well as the tidal and current regime of Seldovia Bay. Oil on the surface occurred in variable quantities at unpredictable times and locations. In the second phase during the remaining two months, the incident resembled a salvage operation more than an oil spill.

Clean-up crews and Coast Guard personnel maintained a (holding pattern) of minor oil pick-up along with daily monitoring, supply, and reporting functions. The oil and sheen was commonly present in only trace amounts. In fact, the small boat basin used extensively by commercial fishing craft, sometimes produced more of a sheen than the Glacier Queen itself.

BACKGROUND ON SELDOVIA

Seldovia Bay is a narrow bay approximately five kilometers by one kilometer bordered by mountainous terrain on the southwest side of Kachemak Bay in lower Cook Inlet (Figure 1). The City of Seldovia, situated on the bay's northeastern shore (Figure 2), is accessible only by small aircraft and boat.

Historically, Seldovia has been a prime location for commercial fishing and trapping. Russian discovery followed by settlement in the early 1800's lead to rapid exploitation and near eradication of the local fur bearers (Becker, 1977). Fishery stocks survived and lured American fishermen to the area after Czarist Russia sold Alaska in 1867. At the time of the 1964 earthquake, Seldovia had eighteen canneries and extensive wooden boardwalks built against the sheer rock waterfront (pers. comm., local resident). Complete devastation of the town by the Good Friday earthquake necessitated construction of
Figure 1  Index map of Lower Cook Inlet from Trasky, Flagg & Burbank.
Figure 2
Index map of Seldovia Bay

LEGEND
- Glacier Queen inside containment boom
- Exclusion boom
- "Ocean" (heavy duty) boom
- Absorbent boom

SCALE

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<th>nautical miles</th>
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<td>5</td>
<td>1000</td>
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<td>3</td>
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1 kilometer = 0.55 n.miles
a new town.

Today, the tourism and timber industries are growing conspicuously but fishing and seafood processing continue to dominate the local economy. At the time of the spill in early November, tourism was essentially non-existent and the population size was approximately 900. Timber clear cuts and log rafts were situated along the bay's southeastern shore (Figure 2) and the crab fishery was preparing for the season's opening day on December 1, 1978.

INTRODUCTION

Chronology

The Glacier Queen sank on November 8, 1978 after approximately one year of derelict and often mobile moorage in Seldovia Bay. The ship was sole asset of the now bankrupt Blue Goose Corporation in Homer, Alaska. The Glacier Queen - 253' length and 36' beam - was a Navy Corvette class cruiser in the early 1940's. It was repeatedly modified by several owners to serve first as a ferry and then as a hotel-restaurant before it arrived engineless and gutted as a barge in Kachemak Bay. It sank from unpumped rain water, hull leakage, and wave slap into vandalized portholes. The sinking took place two weeks after the Coast Guard had boarded the vessel and after a compliance notice and request for action was mailed to the owner by the Alaska Department of Environmental Conservation (ADEC).

The wreck was situated roughly parallel to the shoreline in an upright position with only the rear third of the keel in contact with the bottom. At a very low tide, the bow protruded four feet out of
the water while the stern was about eight feet below sea level. The ship's bow rested in approximately thirty feet of water during the higher tides. Stability of the vessel was questionable during the first few days. While plugging holes which released upward streaming ropes of oil, USCG divers detected considerable ship movement particularly at highwater. This uncertainty called for extreme caution during operations as shifting of the vessel would threaten human safety and perhaps cause additional pollution from the unknown quantity of oil on the vessel. Eventually the ship was secured by sedimentation and by settling of the ship into the substrate.

Immediate notification by the Coast Guard in Anchorage activated many groups including their own Pacific Strike Team, a Navy salvage expert, and the NOAA SSC. Crowley Environmental Services was contracted to provide manpower and equipment. The Alaska Regional Response Team (RRT) members from State and Federal agencies communicated frequently to provide assistance and support on decisions to the USCG On-Scene Coordinator. Remoteness - not excessive by Alaskan standards - complicated logistics and elevated the cost of equipment and personnel movements. Variable weather, limited daylight, and powerful tides often disrupted the initial containment and clean-up process.

The RRT recommended complete removal of the Glacier Queen from Seldovia Bay for the following reasons. The designation of Kachemak Bay as a Critical Habitat by the Alaska State Legislature in 1973 prompted the State to buy back oil leases due to public concern about the environmental sensitivity of the area. The wreck also posed a hazard in navigable although isolated waters. Moreover, a worst-case
situation could develop if the wreck were left in Seldovia Bay. The operation of the Pacific Pearl Cannery could have been seriously affected and saleability of its products reduced.

Fred Devine Diving and Salvage Corporation was contracted to refloat the sunken hulk with the aid of the Salvage Chief from Portland, Oregon. After about five days en route, the Salvage Chief set up operations adjacent to the hulk. Hard hat divers immediately began sealing portholes, hatches, and other openings with a steel plate, nut and bolt, and Neoprene rubber gasket technique that minimized underwater welding. After seven weeks of tedious underwater operations, approximately 40% of the main deck had been patched. Calculations indicated at this time that air pumped into the sealed airspaces would refloat the vessel.

During the night of January 9, 1979, raising of the vessel was accomplished by pumping air into the various compartments. Numerous air leaks were indicative of badly deteriorated hull plating. The bow lifted first and gently pivoted on the stern. When the Glacier Queen finally surfaced, minor oil and sheen comparable to those stirred up by divers' activity were released. The area had been boomed so as to minimize the impact to the environment in the event that the raising broke the hull of the barge or released large volumes of oil. Due to the extensive booming and thorough planning, therefore, work crews were able to absorb most of the oil and only minor amounts of sheen drifted into Kachemak Bay.

Before the raising, the Coast Guard had sought permission to dispose of the Glacier Queen in the Gulf of Alaska. An ocean dumping
permit was granted by the U.S. Environmental Protection Agency (EPA) to the ADEC who requested the permit for the Coast Guard. NOAA's National Marine Fisheries Service and other RRT member agencies selected a location in the Gulf of Alaska where sinking of the barge would not threaten commercial fishery stocks of interfer with bottom fish and crab harvesting operations.

High winds and rough seas delayed removal of the Glacier Queen from Seldovia Bay. Finally on January 19, 1979, the Salvage Chief towed the barge into position over an old military dump site west of Cape St. Elias. Detonation of explosives sent the vessel to the bottom of the Gulf of Alaska in 2,000 fathoms of water.

The Scientific Support Program

The NOAA Alaska Region SSC team reported to Seldovia on the morning of November 9, 1978 with a chartered Cessna 206. The plane was retained several weeks for overflights which were initially conducted at least three times a day. A chart prepared for each flight noted slick and sheen positions, effectiveness and position of booms, and other indicators of surface currents. Each chart was used by the OSC to direct work crews to floating oil and areas of oiled shoreline. The charts were taped in sequence to a wall at the Control Center. This series provided a rough but effective documentation of the surface circulation patterns in Seldovia Bay.

In addition to overflights, daily observations of the shoreline in a Boston whaler loaned by the Alaska Department of Fish and Game efficiently monitored the location and stranding of oil, oiled debris and loose seaweed, and resource mortalities. Radio notification by
the NOAA field party from an oiled beach to USCG Spill Control allowed rapid deployment of work skiffs to the freshly oiled, high priority area. Immediate clean-up minimized beaching and subsequent spread of pollutant by the changing tide. By the third week, the daily oil emissions from the wreck caused primarily by divers had diminished to two or three gallons. The morning overflight proved to be an efficient tool for dictating which sections of bay should be inspected by the whaler.

A major portion of the SSC study and sampling program was completed within the first two weeks of the spill. Samples of fresh oil were taken from the water surface and from the ceilings of the ship's boiler and engine rooms by USCG divers. The biological survey of representative bay habitats and current studies were completed as quickly as possible while the oil pollution was at its maximum level. It became readily apparent that the most valuable information to be collected each day for all parties concerned were: 1) aerial tracking of the movement of oil on the water, 2) natural resource data, and 3) tidal and wind effects on surface circulation patterns. Tides and limited visibility due to occasional bad weather and less than seven hours of daylight greatly restricted the scheduling of all scientific activities.

Gradually, the physical and biological character of Seldovia Bay was established. Reconnaissance of the shoreline and of the bay itself revealed no apparent accumulation of oil. Attention was, therefore, concentrated on an investigation of possible subsurface oil movement. Permission was received from the Alaska Department of Fish and Game
(pers. comm., H. Keiser, ADEC) to deploy locally available dungeoness crab pots in Seldovia Bay. Samples of crab body and gill tissue were taken, but no oil in any form was observed on the surface of the crabs, the pots, or ropes.

The Seldovia Bay scientific program along with results and specific observations are reviewed in the following sections.

PHYSICAL PROCESSES

General Description of The Study Area

Seldovia Bay is small, lenticular, partially enclosed bay adjoining Kachemak Bay (Figure 1). Physical oceanographic research in Alaska is still scanning broad areas so that small secluded bays such as Seldovia are largely unstudied except for tide table information and the nautical chart series. Climate data is sparse as well. Synoptic wind data for Homer (Appendix I) serves the region although local topography will control wind conditions and often render Homer reports unrecognizable. The steep mountains that border Seldovia Bay funnel winds along the north-southeast axis of the bay and effectively block winds from other directions. On one occasion during an overflight, this author documented southeasterly winds (forming surface waves) in the valleys east of Seldovia which were transformed by the topography of the area to northerly winds in Seldovia Bay.

During the fall and winter at Homer, however, northeasterly winds prevail, although there is a strong northerly component (Figure 3). Winds are strongest during late summer to early fall. Tides for the region are semi-diurnal with a pronounced diurnal inequality (Appendix
Figure 3 Wind Frequency Distribution
from Hayes, Brown & Michel

FALL

WINTER

Wind Frequency
0% 5% 10%

<10 >10 knots
Wind Velocity
II; NOAA Coast Pilot, 1977).

Review of Previous Investigations

Several studies in Lower Cook Inlet applied current measurements, ship movements, distribution of sediment and water properties, and satellite imagery to plot surface circulation (Kinney, et. al., 1970; Wright, 1970; Burbank, 1974; and Galt, 1976). These works showed that relatively clear saline water flows from the Gulf of Alaska up the eastern side of the Lower Inlet, while relatively fresh, silt-laden water flows out of the inlet on the west side reflecting the effect of coriolis forces. Burbank (1977) also conducted drogue and drift card studies in Kachemak Bay during spring, summer and fall conditions. This work identified two large gyres in the outer bay west of Homer Spit (Figure 4). A clockwise gyre occurs in the western half of the bay and a counter-clockwise gyre occurs in the eastern half. Figure 4 reveals that a portion of the clear saline Gulf of Alaska water turns to the right and flows northeast along the southern shore of Kachemak Bay. In turn, relatively fresh water containing a substantial river sediment load, flows from the inner bay east of Homer Spit and moves northwest or becomes incorporated in the gyres.

Burbank noted significant variations in the above described surface circulation for outer Kachemak Bay. Apparently, the lunar tidal cycle causes the gyres to change in size and shape, and the counter-clockwise gyre may disappear entirely in the fall. In addition, the surface current (7-8 cm/sec) and, consequently, the net flow associated with the transport of Gulf of Alaska water are proportional to the tidal range. In other words, tides are swifter with a greater net
Figure 4

Net Surface and Subsurface Circulation in Outer Kachemak Bay from Burbank

- Surface only

Scale (m. m.)
1 Kilometer = 50.55 n.m.i.
flow during Spring tides than during Neap tides.

During the first few days of the spill, the shear that forms between the Gulf of Alaska and the turbid inland water masses was observed running parallel to the south shore at a distance of approximately ten kilometers (Figure 5). Inshore of the shear, waters were clear and blue; offshore waters were green in color indicating a suspended load.

When several slicks drifted out of Seldovia Bay on November 9, Dr. Gary Hufford - a Bureau of Land Management Outer Continental Shelf (BLM OCS) staff member assisting the SSC during initial spill response - monitored transport until the slicks dissipated. According to Hufford, a slick 50 m. by 6 m., the long axis trending north-south, was sighted several kilometers northeast of Seldovia Bay and marked with plastic drift cards. The marked slick was tracked revealing a net movement of 6.5 km. in nearly 24 hours (Figure 5b). This average speed of 7cm/sec. in a northeasterly direction is in close agreement with Burbank's measured current velocities.

In another instance, a cluster of small slicks with long axes parallel to shore were observed near this shear about eleven kilometers northwest of Seldovia Bay. Figure 5a shows that these slicks crossed the shear and probably joined the clockwise gyre by drifting west about three kilometers in approximately 24 hours with an average speed of about 3.5 cm/sec.

The average winds recorded at the Homer Weather Station (Appendix I) were from the southeast and the northeast at 18 to 8 miles per hour for November 9 and 10, respectively. A general rule of thumb states
Figure 5

Kachemak Bay Slick Observations
(personal communication, G. Hufford)

Note: Eastern gyre assuming Fall mode.

Slick 5a

Slick 5b

Cook Inlet

Kachemak Bay

Seldovia

Scale

0 1 2 3 4 5
n.miles
1 Kilometer ≈ 0.55 n.mi.
that oil moves under the influence of the wind at about 3% of the windspeed and, in the northern hemisphere due to the coriolis force, at an angle 30⁰-60⁰ to the right of the wind direction (Wright, 1970). Application of this formula to the slick movements described above indicates that the wind force had little effect on oil transport. Apparently, the small, low relief oil patches were controlled by normal surface circulation.

Hufford notes that these observations are in accordance with data reported by Burbank. Behavior of the slicks indicates that both gyres were well established at the time of the spill. Moreover, the Glacier Queen sinking and the period of maximum oil leakage occurred at the end of a Neap tide. Hufford speculates that the combination of minimum current and net flow along the south shore of Kachemak Bay initially slowed the movement of oil from and near Seldovia Bay during the first days of the spill.

Physical Conditions in Seldovia Bay

The spill provided the opportunity to study the Kachemak Bay system and re-examine past studies. It soon became obvious that Seldovia Bay is a distinct system and the physical processes therein had to be considered independently.

The processes that control water circulation also affect the movement of oil in a similar manner. The surface currents were first plotted from oil movement and features such as organic foam lines, the sharp differences in water color at the shear zone in the upper bay area, and beach morphology. As scheduling permitted, drift card studies and two subsurface drogue investigations were performed to test and
refine the initial charting. See Appendix III for specific details regarding these studies.

Over two weeks, the wind and tidal forces affecting Seldovia Bay remained fairly consistent. Predictive capabilities were based primarily upon a matrix of the north-southeast winds expected due to topography plus tidal currents. The four typical conditions observed which appeared to characterize surface circulation patterns are diagramed in Figure 6.

In 6a, northerly winds combined with a flood tide produced an apparent gyre by Rabies Spit which resulted in oiling of the Dan's Cove area on the southeast shore. Discharge from the Seldovia River exerted a northward force which kept oil from the mud flats at the head of the bay. In Figure 6b, southeasterly winds on a flood tide pushed oil towards the western shore north of Rabies Spit. The opposing forces of wind and tide tended to create choppy seas which accelerated the dispersion of oil. In addition, during these conditions, Naskowhak Lagoon was particularly susceptible to oil pollution due to the swift flooding action occurring between the spit and the small islands at the lagoon mouth. Conditions shown in Figure 6c, northerly winds on an ebbing current, also produced choppy seas and a greater tendency for oil dissipation. Oil observed under these conditions generally approached the north side of Rabies Spit or the area near the western tip of Powder Island. Transport from these areas were variable and more difficult to define. In the last case, 6d, southeasterly winds with an ebb tide, often drove oil to the western shore where crenulated portions such as T-boom beach concentrated the stranding oil. Ebbing currents, however,
Figure 6

Four Typical Oil Trajectories

a. Northerly winds
   Flood tide

b. Southeasterly winds
   Flood tide

c. Northerly winds
   Ebb tide

d. Southeasterly winds
   Ebb tide
would wash oil into Kachemak Bay if winds were not particularly strong.

Subsurface currents were not studied extensively and limited data is available only for the area of the wreck. Based on two drogue tests and daily observations, subsurface currents on both ebb and flood tides appeared to be directed onshore southwest of the wreck. Once oil was in close proximity to the shore, ebb and flood conditions transported the oil north and south, respectively.

Observations and Discussions

USCG divers reported that oil leaving the wreck floated directly to the surface. Although no oil was observed sinking, lateral subsurface drifting over short distances did occur due to relatively strong subsurface currents. As it reached the surface, oil generally formed pancakes no larger than 10-12 cm. in diameter. Sheen emanating from the pancakes was easily spotted from the air whereas the small brown oil patches were usually not visible from the air. Sheen, easily visible from the air, was often very difficult to see from a skiff.

Despite a fairly constant emission from the wreck, there was no accumulation of the pollutant on the water surface. Overflights revealed successful boom containment at low tide. However, initially during high tides, oil and sheen leaving the wreck often drifted clear of the containment boom as the pollutant rose laterally to the surface. Subsequent modifications of the containment boom size and placement partially corrected this problem.

In accordance with resource protection priorities, immediate action by the USCG concentrated on installation of the exclusion boom (Figure 2) across the bay to limit oil transport up the bay and to
protect the mud flats and the salmon spawning stream. The exclusion boom was in place by November 10 but on November 12, weather conditions on an ebb tide broke and destroyed portions of the boom. The boom was not reset immediately because adequate lengths of strong boom were not available. When additional boom did arrive, a greater familiarity with the general circulation and the influence of the winds led to other priorities for deployment of the boom. In addition, it appeared that the current from the Seldovia River kept oil away from the head of the bay. Greater amounts of oil and different weather conditions could have combined to impact this area, however.

The positioning of the exclusion boom subjected it to ebb currents constricted by the projection of Rabies Spit. When the boom failed, normal currents of 1-2 knots (pers. comm., Dr. Gary Hufford) had been amplified by strong winds and the river outflow. It is interesting to note that flooding waters did not appreciably stress the boom whereas the receding ebb tide did. This difference was due to the fact that the boom and the surface waters were merely elevated as the dense salt water wedge flooded along the bottom of the estuary, displacing lighter, less saline water while advancing inland. Bay water is largely mixed by the time ebbing occurs. Surface waters then evacuated more quickly by flowing downward as the earth's gravity maintains equilibrium behind the passing tidal bulge.

Calculations with the cross-sectional area and tidal height for the wreck position yielded a maximum tidal current in that location of 0.5 knots, not including the forces of wind and the river outflow (pers. comm., Dr. Jerry Galt, NOAA, Seattle). Behavior of the
containment boom around the wreck and enclosed oil indicated that this was a fairly accurate figure. Thus, two areas within 1000 meters of each other were observed to differ widely under similar environmental conditions.

Oil In Ice

This section is more appropriately termed "sheen in ice" because pollution from the wreck after the first day seldom summed to more than several gallons a day. In any event, on several occasions, ice up to one centimeter thick formed from the mouth of the Seldovia River almost to Rabies Spit. Northerly winds helped to contain the ice growing from the fresh water flowing from the head of the bay.

As ice crystals collected and formed a slush, variable winds herded ice around the upper bay area and helped to compact the slush along shorelines where complete freezing first occurred. Later, as the tide receded, protruding rocks formed crater-like holes in the settling ice layer. Sheen was observed to be concentrated in one of these holes. Larger volumes of oil would also tend to seek such openings in a similar situation.

Another feature observed was a swash-like sheen and emulsion band which was pushed into the accumulating slush pack by the wind. In a situation with greater volumes of spilled oil, the incorporation of the pollutant in ice could facilitate collection of the oil by crews positioned along the growing pack edge. Once frozen in ice of this type, access to the oil "windrow" would still be possible by work skiffs breaking through the thin ice.
Summation

The prevalent north and southeast winds superimposed on the tidal ebb and flood currents identified four conditions which appeared to typify possible surface circulation in Seldovia Bay during the late fall of 1978. A matrix of diagrams showing the wind and tide combinations revealed which shorelines could expect oiling. The predictive capabilities afforded by this four-state model were fortunately not tested under crisis conditions due to the limited amounts of pollutant actually being released. However, experience of the first few weeks which led to this systems description was applied in the deployment of the U-shaped booms north and south of the wreck in preparation for the raising of the Glacier Queen.
Prior Research on Seldovia Bay Coastal Geomorphology

The advance of petroleum resource development into Lower Cook Inlet necessitated a regional look at the inanimate processes which regulate shoreline morphology. Coastal Morphology and Sedimentation—Lower Cook Inlet, Alaska by M.O. Hayes, P.J. Brown and J. Michel, 1977, categorized the shoreline into various subclasses of erosional, neutral, and depositional sedimentary environments. In addition, Hayes et al. correlated previous oil spill field experience with shoreline types found in Lower Cook Inlet. A one-to-ten "vulnerability" scale was produced which ranked primarily the shore exposure to wave energy and the susceptibility of shore morphology to oil contamination. By this method (see Appendix IV), the least vulnerable category, (Class 1), straight, rocky headlands, will quickly shed any oil that reaches it in spite of the presence of a cushion formed by reflected wave energy. On the other hand, the most vulnerable shorelines (Class 10), characterized by protected estuarine salt marshes, will retain spilled oil for 10 years. In this latter case, incident energy is too minimal to aerate the deposit and degradation must occur from unaided chemical and biogenic processes.

Hayes et al, 1977 represents the most complete work to date which touches upon geomorphologic conditions found in Seldovia Bay. Detail for this specific area is understandably limited. A three person team investigated 1,216 km. of Lower Cook Inlet shoreline in 21 days (NOAA/EPA, 1978). Additional increments of precision and detail would have
required disproportionately greater amounts of effort and time. The sinking of the Glacier Queen, however, has provided the opportunity to document in detail the reaction of a small bay environment to minor but continual spillages of oil.

Discussion Format

The Seldovia Bay shoreline, as studied by Hayes et al 1977, is presented below along with a more precise description of the study area noting greater detail in the intertidal sedimentation. The predicted longevity of oil on various shores is discussed and, if necessary, revised based upon observed examples of oil behavior.

Hayes' work is designed for the catastrophic spill that releases massive amounts of oil adjacent to lengthy shorelines. Correlating the Glacier Queen incident to a scale molded to fit a disaster is admittedly precarious and misleading. This spill situation, however, allows us to examine the applicability of the vulnerability index in a small, contained and diverse estuarine system. The processes considered by the scale and the expected affinities of shore types to oil were identified in Seldovia Bay. The estimated residency times for oil on the different shore morphologies, however, had to be scaled downward. In effect, ten or more years residency for a class 10 shore became one week or less for this spill in Seldovia Bay.

Morphologic Units in Seldovia Bay

Figure 7 is a composite of rock type and shoreline morphology maps. Foothills of the Kenai Mountains surround the bay to the south with variably metamorphosed Mesozoic/Paleozoic graywacke and slate bedrock, and younger Triassic and lower Jurassic volcanics
Figure 7
Rock Type and Shore Morphology
(composite from Hayes et al., 1977)

LEGEND - SHORE MORPHOLOGY
(see Appendix IV)
- A1b erosional vertical scarps
- B1a neutral embayed, mountainous
- C1a depositional lobate fan delta
- C2c depositional tombolo spit

LEGEND - ROCK TYPE
- Jv Lower Jurassic tuff & agglomerate
- Rc Upper Triassic: contorted chert & lava
- e Upper Triassic: ellipsoidal lava
- g1 Mesozoic and Paleozoic: graywacke & slate, with some chert, limestone, & basalt.
to the north. These rock types have eroded to near vertical scarps with sand to boulder-bedrock intertidal beaches. Hayes et al. 1977, differentiated four shoreline types which are outlined below. Refer to Figure 8, Detailed Morphology and Sites of Oiling, during the following discussion.

1) **Seldovia River Delta**

At the head of the bay, the Seldovia River formed extensive mud flats. Sandy gravel channels are visible at low tide. The river appears to have projected narrow sand beaches and small spits along the predominantly rocky upper bay shoreline. The Hayes study classified this portion of the bay as a depositional delta. Subclass descriptions indicate that it is a lobate fan delta (C1a) with digitate sediment lobes and low wave action which limits swash bar formation. The area type was assigned a 6-8 vulnerability value but it was mapped 8-10 due probably to its sheltered position at the head of a lenticular bay. Oil from the Glacier Queen never reached this area for reasons given in the physical processes section.

2) **East and West Shoreline Morphologies**

North from the delta to the mouth of the bay, the eastern and western shorelines were classed by Hayes as being neutral (stable), embayed, and mountainous (B1a) dominated by steep valley walls with some low erosional scarps. Sand and gravel pocket beaches are common, minor depositional scarps and deltas occur, and tidal flats are abundant at very low tides. This geomorphological unit ranked an 8-10 risk classification because oil tends to stick to rough, somewhat sheltered, rocky surfaces, and deep penetration and burial in
Figure 8
Detailed Shore Morphology and
Major Sites of Shore-Oil Contact

LEGEND
* bedrock scarp
- cobble, boulder
o cobble boulder patches
- - sandy gravel
- - - sand
- - - - - mud flat
- - - - - - - shore-oil contact
gravel is likely.

Secondary pollution from contaminated sediments was observed in Seldovia Bay soon after the initial phase of the spill. The shoreline southwest of the wreck was contacted by oil along the high tide line on November 19. Strong southeasterly winds on a flood tide pushed about a half gallon of oil onto barnacled rocks. Maximum thickness in the half-meter wide band of dark brown oil was 4-5 mm. For a distance of approximately 120 meters to the north, a 1-2 meter band of sheen was deposited on the sandy gravel beach. A heavy rainfall on the 20th of November allowed the sheen to penetrate 12-15 cm, a depth observed on the 21st. High tides during the following week were lower than the previous week.

Subsequent visits noted no change to the oiled rocks but the depth of penetration lessened daily, and, by the 24th, the beach sheen had disappeared. This rapid dissipation is due to the effects of typically low levels of humidity. Oil on the rocks was removed rapidly after the 26th as high tides again rose higher than the strand line. These rates of removal were observed on other shorelines receiving trace to minor oil contact.

Sand and gravel beaches line the steep topography on the western shore: whereas, the eastern shore consists of thickly wooded, rolling hills and a mostly boulder-bedrock intertidal zone. This difference in sedimentation indicates that strong currents sweep the eastern shore, or that transported sediment never reaches the eastern shore perhaps due to the coriolis force during flood tides and ebb tide flushing in the main channel.

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The dominant physical processes in Seldovia Bay distributed the oil in a relatively characteristic fashion. The eastern shore, with minor sand build-up, was largely untouched by oil, but oil often contacted and lingered on the western beaches. The wind-tide combinations described in the physical processes section appeared to drive oil either 1) to the rocky eastern shore south of Dan's Cove (Figures 2 & 8) or 2) onshore west of the wreck and north of Rabies Spit.

Oil which remained on the rocky eastern shore (case 1) after manual pickup of oiled seaweed and debris disappeared within several cycles of sufficiently high tides. Case 2, on the shore west of the wreck, occurred when prevalent southeasterly winds produced relatively persistent presence of oil blebs, 0.5 - 2.0 cm in diameter, and sheen in the T-boom beach area (Figures 2 & 8). Oil was usually stranded along the small crenulated segments of the western beach. The orientation of the T-boom beach formed the greatest trap for floating oil. This prompted deployment of an absorbent boom off the rock point in the first days of the spill. This boom had a negative effect, however, as it held oil and sheen against the shore instead of letting it circle into and dissipate in open portions of the bay. That area of beach grades from gravel sediment to bedrock cliffs (Figure 8) indicating net erosion from a stacking up of water as currents flow past the rock point.

3) Naskowhak Spit

Point Naskowhak and Naskowhak Lagoon form the western shore at the mouth of Seldovia Bay. Mixed sand and gravel spits have connected
the Point and a lesser island outcrop to the bedrock scarps fronting on Cook Inlet. This area, termed a tombolo spit (C2c), received a 4-6 vulnerability rating because the outer beaches face waves which build up energy over long fetches in Cook Inlet. Burial of spilled oil would occur but continual reworking of the sediment would lower oil residency time to under one year. Station 37 of Hayes, Brown and Michel's work, the station location closest to Seldovia Bay, was situated along the outer beach southwest of Point Maskowhak. The outer beaches of the spit were not oiled.

The lagoon and the inner shorelines were repeatedly polluted during the first several weeks of the spill. Shoreline and substrate types within the lagoon vary considerably. The tide floods vigorously into the lagoon between bedrock islands and the southward projection of the spit (Figure 8). The channel runs north along the mixed sand and gravel spit projection, continuing west along a broad silty sand flat, and finally abraids in mud flats, a small salt marsh, and a fine gravel beach on the western border. Bedrock scarps line the south side of the lagoon.

By the above description, the lagoon is made up of several morphologic units. When considering the area as a small, well protected bay, however, the lagoon readily fits into Hayes' shoreline subclass for tide-dominated depositional systems (C3b). This assigns to the sensitive and biologically rich, low energy environment the 8-10 risk class signifying long term residency of spilled oil.

Actual oilings, however, revealed a brief residency period. In one incident, oil with sheen and emulsion washed into the lagoon on a
flood tide assisted by the easterly winds occurring during that time. The oil, adhering to wood debris and loose seaweed, stranded quickly on the western shore (Figure 8). The emulsion, a light brown, 2 mm thick scum, remained floating in a small gyre in the west corner of the lagoon. The oil, sheen, and emulsion remaining after manual clean-up disappeared naturally within one to two days. Mild winter weather, confined tidal flushing, and the high tides are probably responsible for the rapid evaporation and dispersion of the oil. Fortunately, oil transported into Naskoghak Lagoon did not impact the marsh area found at the northern tip of intertidal shoreline.

This incident is of particular significance biologically. The crab mortalities reported in the Summary occurred during this lagoon oiling. Two partially eaten ducks, one with lightly oiled feathers, were also found in the vicinity at that time. This same Naskoghak Lagoon oiling is discussed in the Biological Observations section.

4) Northeast Shore Morphology

The area including Gray Cliff and the bedrock scarps found on the east shore by the mouth of Seldovia Bay is the bay's fourth morphologic unit defined by Hayes et al. (Alb). The vertical erosional shoreline with a boulder-bedrock intertidal zone is considered to have a 2-4 vulnerability despite the possibility of oil burial by penetration. No oil from the Glacier Queen was observed to contact this shore or linger in the general vicinity.

Summation

The classification of shore morphology and the determination of oiling susceptibility for each intertidal substrate type (Hayes et al.,
1977) was a useful concept to the SSC team working in Seldovia Bay. Oiling characteristics of the intertidal zone were recognized immediately and an accounting of the effects of coastal processes was initiated. The predicted affinity of certain shore environments to oil was observed by this author during weeks of monitoring. Retention of oil was observed to be on the order of days as opposed to the yearly time scale used by Hayes. This abbreviated residency time is proportional to the small quantities of oil actually spilled by the Glacier Queen.

Activation of the NOAA team to monitor spillages of small amounts of oil over a long period of time permitted consideration of Hayes' vulnerability index in a situation that would normally go unstudied. It was possible to observe directly that small volume oilings of coastlines in regions of extreme tidal ranges result in very brief residency times. The degree of beach flushing by tidal action for any contaminated beach should be evaluated before dollars are spent on man-hours and clean-up supplies. It is possible that this type of shore will be cleaned naturally within several days. In addition, heavy oiling of self-flushing shorelines requires clean-up of only the easily collected oil as the rest will likely be removed by natural processes if the formation of weathered asphalt pavement (Hayes et al, 1977) is prevented. Manual response efforts should concentrate instead on more thorough containment of the source and on exclusion or diversionary booming of biologically rich areas. In this way, known priorities may be protected from the possible if not immediate threats of oil contamination.

Speculation in advance of the next pollution incident is difficult.
because every spill scene requires a different strategy. The Glacier Queen sinking, however, will hopefully provide some guidelines for the next oil spill response in Lower Cook Inlet. While the description of shore morphology by Hayes et al, 1977 serves an essential purpose for the region as a whole, a site-specific assessment of coastal processes is necessary in a spill for the OSC to direct response efforts efficiently. In an area where even simple movements are logistically complicated, accurate estimation of the self-cleaning potential of coastlines is a money-saving asset.
Pertinent Information From Selected Literature

Studies of the ecological habitats and species distributions in Kachemak Bay are recent additions to an otherwise limited source of information on the area. Seldovia Bay itself has not been closely examined and available references scarcely mention specific conditions found within the bay. However, a review of regional generalities from descriptive works on Kachemak Bay will present an accurate picture of the ecological environments and assemblages found in the spill area. The biological assets of Seldovia Bay are only a small fraction of the Kachemak Bay Critical Habitat.

When oil development progressed into Lower Cook Inlet during the mid 1970's, outer Kachemak Bay was a designated lease area. Intensive research was initiated in many disciplines. Results of these studies contributed to the growing awareness in Alaska of the real value of the region's commercial and recreational amenities, and all drilling activity was ultimately excluded from Kachemak Bay. The Critical Habitat is considered to be exceptionally prolific and, to date, nearly unblemished.

Environmental Studies of Kachemak Bay and Lower Cook Inlet (L.L. Trasky, L.B. Flagg and D.C. Burbank eds. 1977) is a thorough evaluation of the region's physical and geomorphological processes (cited above), and also includes studies of eight significant biological components and an intertidal hydrocarbon baseline survey (Appendix V). Volume I. Impact of Oil on the Kachemak Bay Environment (L.L. Trasky, L.B. Flagg and D.C. Burbank, 1977) summarizes the eleven research projects.
Volume I provided much of the information contained in the following section.

Commercial and Visible Resources

Fisheries resources harvested by commercial fishermen in Kachemak Bay are king, tanner and dungeness crab, Pandalid shrimp, five species of Pacific salmon, halibut, and herring. Recreational fishing also contributes significantly to the local economy and subsistence fishing, particularly of salmon species, is an essential way of life for many people residing in the area. Seldovia Bay is important for moorage and fish processing facilities which service the Kachemak Bay fisheries. In addition, however, the Seldovia River has consistently been the major pink salmon spawning-escapement stream in the region. The pink salmon harvest constituted approximately 70% of the commercial salmon catch from 1969 to 1975. Shellfish in Seldovia Bay are mostly limited to small populations of dungeness crab and various clam species found abundantly in the lower intertidal flats on the western shore. These resources attract only subsistence gatherers.

Marine birds use inner Kachemak Bay extensively for nesting, feeding and overwintering sites. In addition, many species rest in the area during the spring and fall seasons while migrating from overwintering areas in temperate climates and breeding sites in interior Alaska. The greatest concentration of birds in Kachemak Bay and Lower Cook Inlet occurs during periods of seasonal migration. Seldovia Bay waters are not considered to be particularly important as areas for nesting and overwintering. However, feeding areas, especially Naskowhak Lagoon and the head of the bay are known to attract large numbers of
marine birds. Bald eagles, a conspicuous predator along the bay coastline, consume carrion of birds that succumb to disease or winter starvation.

Marine mammals are found in moderate to high densities in Kachemak Bay on a permanent or transient basis. Sea otters, in particular, are attracted to the region for its abundant food supply and protected nature. Seldovia Bay does not support concentrations of any marine mammal although the highly mobile animals probably are present throughout the area. During the first month of the spill, only several individual sea otters and one harbor seal were seen within the confines of the bay. It is unlikely that these animals were affected by the Glacier Queen spill.

Intertidal Habitats and Biological Assemblages

Detailed investigations and description of intertidal habitats in Kachemak Bay were not undertaken until the mid-1970's when the Bureau of Land Management OSC-related oil development was initiated in Lower Cook Inlet (Dames & Moore 1978). The three main biological beach assemblages present in Kachemak Bay were identified as gravel, sand and mud. Although Seldovia Bay itself has not been studied to date, much can be inferred from the investigations of comparable intertidal substrates in the region. A recent Dames and Moore publication, Ecology of Unconsolidated Beaches in Lower Cook Inlet, provided most of the information for the following discussion.

Gravel, cobble, and boulder beaches are prevalent throughout Seldovia Bay. Cobbles and boulders also occur in patches, particularly in the lower portion of low tidal mud flats of the gravel and sand
beaches. Concentrations of physical energy are responsible for the
distribution of the larger sediment sizes. Furthermore, tolerance to
energy regimes and physical conditions appears to be the major factor
controlling the resident biota. Coarse beaches, created by high
energy conditions, are normally quite impoverished. Amphipods and
isopods, the dominant organisms on coarse beach types, are most
abundant in locations where ground water pools form at the base of
the steep upper beach (Dames & Moore 1978). The cobble and boulder
patches visible on the flats exposed at MLLW support similar species
as well as barnacle and mussel populations which attach to the large,
normally stable rocks. Winter storms upset this substrate and re-
placement of annual species is typical. Predation on these organisms
is by shorebirds, mainly sandpipers, turnstones, and plovers, at low
tide and by diving duck, crab and fish species during higher water.
While the relative significance of predation in the winter season is
generally unknown, observations suggest that the dominant factor in
population control is the high energy level (Dames & Moore 1978).

Sand beaches are also subject to stresses from wave action and
temperature and salinity fluctuations. Winter conditions generally
cause a decrease in species diversity as well as abundance and biomass
which indicate winter termination of annual life cycle for most sand
beach organisms. Dames & Moore report that sand beaches throughout
Lower Cook Inlet maintain roughly similar faunas which include primarily
polychaetes, gammarid amphipods, helmet crabs, and various clam species.
Dissimilarities between study sites reflect a strong dependence on the
region's physical energy gradient. This gradient generally increases
from south to north due to more pronounced tidal currents, higher turbidity, colder temperatures, lower salinities and more ice. Specifically, the study found that polychaete worms decreased and the exoskeletal crustaceans increased in importance to the north. Extrapolation of this infaunal data to Seldovia Bay is not possible without first studying Seldovia's sand beaches. Consideration of the habitat's contribution to the regional foodweb, however, is useful in determining the relative significance of sand beach productivity during winter in the spill area.

According to Dames & Moore 1978, the predation cycle by shorebirds and gulls at low tide, and by diving ducks and fish at high tide is similar to feeding which occurs on gravel beaches. Food is thought to be abundant to infaunal species and, therefore, competition within a sand beach assemblage is considered secondary to physical stress in selection. Physical stress concentrated at the sand-water boundary results in relatively low diversity, biomass, and abundance parameters for most surface-dwelling organisms. Foraging birds, thus, have limited access to most of the infauna which is comprised primarily of adult polychaetes. Characteristics and importance of fish and crab, feeding on the submerged substrate are largely unknown. Scavenging by birds, however, appears to be greatest during spring migration. Even during spring migration, sand beaches are not extensively utilized for the physical reasons discussed above and because of availability of richer food sources in the mud habitats. Productivity and, hence, usage of sand beaches, at least by birds, is further limited in winter.
For these reasons, therefore, sandy gravel and cobble beaches in Seldovia Bay were not considered particularly threatened during the Glacier Queen spill. The low volumes of oil released did not result in damage to the food web structure because winter conditions normally reduce the productivity in these ecosystems. A spring or summer spill could impact one entire generation of organisms, reduce their abundance, and consequently, produce a smaller food supply for higher trophic levels in the following year.

Of shorelines studied thus far, it appears that soft mud substrates are the most diverse and productive intertidal habitat in Lower Cook Inlet (Dames & Moore 1978). Mud flat fauna react as do organisms in coarser grained beaches to changes in seasonal patterns and weather conditions. High percentages of some populations, especially those near surface of the mud are occasionally destroyed by storm activity. In this environment, however, predation and competition for food and space are significant, and biological interaction is on-going throughout the year. Spring bloom is marked by an abundance of larval and juvenile forms, primarily Mya and Macoma, which totaled 90% of the wet biomass and dry tissue weight in the Dames & Moore study. Organisms found to be of lesser importance included an echiurid, a large polychaete, other clam species, crabs and barnacles. Competition for space and food is keen among young organisms while predators variably adapted for foraging on exposed or submerged flats continually feed on the swollen spring populations. Selective predation by shorebirds and diving ducks appear to reduce the Mya and Macoma densities by about 50% and 70% respectively. Other foragers, gulls and Dolly Varden

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trout for example, are known to exploit preferred food supplies as well.

The importance of the mud flat assemblage to the Lower Cook Inlet ecosystem is that it is the major food supply for many of the higher trophic levels in the Inlet. The extent of dependence on the mud habitat is best indicated by the intense concentration of life found there throughout the year. Infauna appear to maintain an increase in biomass well into the summer months (Dames & Moore 1978). Growth then slows as winter darkness begins to limit the formation of plant detritus. During spring and summer, birds, the most conspicuous predators, capitalize on seasonal production. During winter the birds depend on and appear to be sustained by the mud flats. However, normal life cycles, the effects of winter storm energy, temperature, and ice combine to produce a nearly dormant state in the mud flat habitat. Death by starvation and cold shock is common among bird populations.

Discussion on Biological Priority Areas

The preceding review of the region's three basic shore habitats together with Figure 7, the detailed intertidal morphology, provide an indication of the relative significance of various portions of the bay. In addition, Figure 9 shows known clam resources and areas of observed utilization by birds.

These data indicated that several sections of the bay were particularly biologically vulnerable. Three important features are located at the head of the bay- the mouth of a salmon spawning stream, a sandy mud delta which supports clam populations, and patches of eel grass (Zostera Marina), a major source of the detritus energy fundamental to the food web. Protection of this area from oil
Figure 9

Known Biological Resources
from L. Flagg - ADF&G
and personal observations

LEGEND

- bird feeding areas
- clam beds
- mud flats, high density invertebrates
became the first priority of the Coast Guard response. Methods to accomplish this exclusion of oil ultimately failed due to strong tidal currents but the mud flat-stream system was none-the-less spared contamination. Natural river discharge and a deflection of wind driven surface currents to the eastern shore seemed to protect the area. It is theorized that the combination of normally greater seasonal river outflow plus topographic effects would keep oil from the upper bay. In other pollution incidents, however, the flushing and draining capacity of shorelines should be considered in planning clean-up strategies. Experience in Seldovia Bay illustrates the difficulties of booming across tidally dominated estuaries. It is the opinion of this author that unless sufficient time exists to construct a boom which will fully compensate for tidal currents, it may be advisable to implement other protective measures first.

Naskowhak Lagoon was the second priority area according to the Alaska RRT. The lagoon and a small neighboring lagoon are sheltered mud flat and salt marsh habitats and, as such, are highly productive and useful as water fowl feeding areas. The lagoon was the site of the helmet crab mortalities which were observed simultaneously with relatively severe oil contamination. Black splotches were detected in the gill tissues of several crabs. Protection of this area was considered not feasible due to the swift and contained tidal action. Much larger volumes of oil would have necessitated some course of action, however. Diversionary booming would have collected a majority of wind-blown oil within the lagoon if positioned across the main channel from the northern shoreline. In a future event in any location,
placement of boom equipment in anticipation of likely wind conditions would help prevent costly manual clean-up and preclude impacts to an area extremely susceptible to long term residency by oil.

The remaining sensitive habitat in Seldovia Bay is the area along the western shore where mud flats are exposed at low water. This substrate was found to contain very dense clam populations which provide subsistence foods for humans as well as many important marine species. Figure 7 indicates that this area is normally covered by up to eight meters of water. Great volumes of oil would likely strand on these flats but rising tides would probably refloat much of the oil off the typically non-oliophilic mud. Clam syphon holes however would draw in oil, and death or fouling of these organisms would be wide-spread. The difficulty is that the resources in this and similar Lower Cook Inlet locations cannot be isolated by manual booming techniques. It appears, in conclusion, that (conditions permitting) concentrating response efforts on thorough, perhaps concentric, containment booming of the pollution source may be the most effective means to limiting a spreading threat of oil spills.

The SSC Sampling Program and Summation

The various studies undertaken by the NOAA Field team are presented in Appendix VI with a review of the various methods, procedures, and observations made. Figure 10 shows the distribution of NOAA sampling stations.

Sampling was initiated during the early stages of the spill when oil was continually being emitted and while a sudden release of a large volume was a real possibility. Several weeks later, it became apparent
Figure 10

Biological Sampling Stations
See details - Appendix III

LEGEND

*x* benthic grabs
*•* clam sample
**** helmet crab sample
** plankton tows
fresh oil samples
dungeness crab samples
water column samples
that the wreck emission would probably continue to be sheen and very
minor slicks stirred by the salvage operation. Since the spill damage
documented above is not significant and seasonal conditions at the
time of the spill precluded the possibility of any measurable impact.
it is unlikely that most samples taken will be analysed. Collection
of the samples was an essential act, however, in preparation for a
greater release of oil from the wreck. If that occurred, the SSC
would then have available crude but effective early baseline data for
the area. Fresh oil was sampled for the record and for "finger printing"
purposes, if necessary.

Biological sampling was conducted in areas either visibly impacted
by oil or in subsurface localities which would be affected by oil if
present. Intertidal grid sampling centered on a crenulate segment of
the western shoreline which was exposed to oil. Benthic grabs, plankton
tows, and water column samples were all positioned relative to the
apparent directions of tidal currents. Crab sampling stations also
depicted the motion of tidal currents past the Glacier Queen until
the absence of crabs redirected the deployment of pots.

Visual observations were performed daily by the NOAA SSC team
for three to four weeks. Availability of a science oriented person
on-scene, as discussed above, was a useful addition to the Coast
Guard response effort. Having a scientist present to monitor the
wildlife frequenting the bay and to watch for impacts to natural re-
sources permitted the Coast Guard to concentrate on clean-up activities.
Specific observations are discussed throughout this report. One
additional point concerns bird usage in the bay.
A complete survey of marine birds was undertaken during the first days of the spill by ADFG and U.S. FWS personnel (see report in Appendix VII). Approximately one hundred birds, predominantly white-winged Scoters, Oldsquaw and Harlequin Ducks, were observed initially. In the weeks that followed, NOAA and ADEC observers saw relatively few birds. Apparently, human activity or perhaps normal overwintering patterns reduced foraging by birds in the area.

SCIENTIFIC RESPONSE TO OIL SPILLS IN HIGH ENERGY ENVIRONMENTS

Work by Hayes et al. in Lower Cook Inlet identified areas of special concern based on the role of geomorphological processes during an oil spill. That study provided the NOAA Scientific Support Team with a valuable characterization of the physical conditions of Seldovia Bay. The intertidal zones described and mapped by Hayes et al., however, were found to be considerably more complex when observed in detail during the Glacier Queen crisis. Lateral variations and two vertical divisions - an upper and lower beach - were conspicuous. Biological assemblages varied subtly in type and significance along with the morphology and the physical environment. During the Seldovia Bay spill, therefore, the geomorphological susceptibility concept had to be examined in detail together with known and observed biological resource information.

Combination of the coastal morphologic index and the relative vulnerabilities of biological communities for Lower Cook Inlet is one portion of a NOAA-funded study presently nearing completion. In combining the disciplines of geology and biology, a new scale has been
formed by David Maiero and Chris Ruby of URS and RPI companies, respectively, which ranks shorelines according to priorities for oil spill response. The close relationship between the biology and physical energy of an area dictates that, on roughly 90% of the Lower Cook Inlet shoreline, the geomorphological and biological scales coincide (personal communication, David Maiero - URS Company). Response priorities for the remaining 10% have been determined by a combination of other factors such as the feasibility of effective response and seasonal conditions. The completed document will be an invaluable tool for the Coast Guard, providing immediate guidance for setting protection priorities in a spill situation.

On-Scene activity, however, will require a further input from on-site assessment of all seasonal, tidal and weather conditions. Only then can work crews and equipment be properly allocated for specific functions. At the onset of a spill, areas designated as high priority in Lower Cook Inlet, or for an unfamiliar locality, all areas contacted or threatened by oil must be quickly mapped for morphologic type. Depending on the volume of oil impinging an intertidal surface area, the estimations by Hayes et al. of the tendency for oil to remain on various shorelines must be modified to reflect the actual residency periods expected for the oil. In tide-dominated Seldovia Bay, for example, minor (1-3 mm.) coatings of oil would be naturally cleansed from most shorelines within one day to one month depending upon the tidal heights following the oiling.

As these calculations are being performed, the physical effects of topography would have to be noted or predicted when possible (eg.
probable wind/tide currents or seasonal self-protection capabilities of river flushing). Simultaneously, the visible biological resources would be mapped for compilation with the more generalized biological data. Sociological implications and the locations of archaeological sites if any may also require considerable attention.

This type of information assembled for the Coast Guard in advance, if possible, or at the time of a spill allows the On-Scene Coordinator to direct clean-up activities with full knowledge of site-specific conditions. Expenditures of energy on low priority but lightly visible oiled shorelines may not be necessary and could be wasteful. In Alaska, where remoteness is apt to preclude timely mobilization, misdirected manpower and equipment could result in inadequate protection of a high priority biological habitat or resource. Response strategy should first concentrate on the most significant portions of the ecosystem to ensure that actual damages are limited and (wherever possible) that potential "worst case" developments are anticipated and prevented.

With the cost of complete response rising continually, the day will come when only the most significant biological resources will justify clean-up expense and attract the attention of the Coast Guard. In coastal regions with high levels of energy, the environment can be left with the major role of dissipating visible concentrations of oil. The scientific community and the Congressionally mandated response structures must recognize and apply natural cleansing processes. The Coast Guard can then concentrate funds on the containment and clean-up of the source.

In order to keep oil spill clean-up costs at reasonable and publically
acceptable levels, a realistic ratio of cost and effect must be main-
tained. The scientific community can provide guidance in carrying out
cost effective clean-up operations by helping the OSC establish
environmental priorities.

CONCLUSION

Due to quick and efficient response actions by the U.S. Coast
Guard, Seldovia Bay was spared significant or even detectable damage
from spilled oil. Well placed booms and responsive clean-up crews
removed most of the oil from the environment before any detectable
impact did occur. Seasonal factors also played an important role in
the protection of Seldovia Bay. November through January is known
to be a relatively dormant period for many biological species. For
example, salmon were not spawning in Seldovia River at the time of
the spill.

In a situation with greater volumes of oil spilled onto the bay,
tidal waters, topographically controlled wind patterns, and the con-
tinuous flushing action of the river would again assist with the
clean-up and protection response by the Coast Guard. Containment, the
most effective action for preventing spill damage, and cost effective
clean-up will always be challenging learning experiences in regions
of extreme tidal ranges. The U.S. Coast Guard, assisted by the Regional
Response Team, was prepared for any situation of development that might
have occurred. Fortunately environmental conditions and a dwindling
source of pollution averted potentially disasterous oilings of sheltered
and sensitive habitats. A combination of factors, therefore, produced
no negative socioeconomic impacts on the area.

The *Glacier Queen* sinking should not be considered a typical scenario but hopefully the incident will serve to alert and prepare policing and regulatory groups for what might happen again if prevention is not emphasized in the future. As a necessary and unavailable training exercise, the spill was an informative experience for the many response organizations. Other spills in remote environments will incur sizable outlays of money, and in all probability, response will be tempered by this reality. In many situations, the energy inherent in tidally dominated or exposed coastlines will naturally dissipate oil pollution, thereby, reducing governmental response efforts. Reliance upon environmental processes is justified scientifically. Documented observations of the Seldovia Bay incident and other spills will help concerned and responsible government organizations. The importance of this guidance will be future money saved during larger spills. A rational and consistent perspective will make possible a long lasting preservation and protection of the environment.
REFERENCES CITED


-44-

### Local Climatological Data

#### Monthly Summary

**Month:** NOVEMBER 1978  
**Location:** HOMER, ALASKA  
**Source:** NATIONAL WEATHER SERVICE OFC

#### Table: Temperature, Degree Days, Precipitation, Snowfall, Wind, Sunshine

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#### More Observations Per Day at 3-Hour Intervals

- Fastest Mile Winds: Speeds are fastest observed one-mile blows when directions are in terms of degrees. The ° with the direction indicates peak gust speed.

### Summary by Hours

**Average Values**

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**Hourly Precipitation**

- Water Equivalent in Inches

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### Other Information

- Monthly data includes summary for the month.
- Annual data includes summary for the year.
- Monthly summaries are based on seven degrees clockwise from the north. Dates are in days of the month.
- Times are U.S. Eastern Standard Time.

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**NOAA**

**National Climatic Center**

**Environmental Data and Information Service**

**Director:**

**NOAA**

**National Oceanic and Atmospheric Administration**

**Subscription Prices:**

- $2.55 per year including annual summary. Foreign mailing $4.00 extra.
- Single copy 20 cents for monthly or annual issue.
- There is a special charge of $2.00 for each set of self-stocked issues of publications. Make checks payable to the Department of Commerce, NOAA, send payments, orders, and inquiries to National Climatic Center, Federal Building. Asheville, North Carolina 28801.

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**NOAA**

**National Oceanic and Atmospheric Administration**

**Environmental Data and Information Service**

**Director:**

**NOAA**

**National Oceanic and Atmospheric Administration**

**Environmental Data and Information Service**
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**NOTES**

- **CEILING:**
  - UNL = UNLIMITED
  - UNL = UNLIMITED

- **WEATHER:**
  - Tornado
  - Thunderstorm
  - Squall
  - Rain
  - Rain Showers
  - Freezing Rain
  - Drizzle
  - Freezing Drizzle
  - Snow
  - Snow Showers
  - Ice Pellets
  - Mail

- **WIND:**
  - Directions are those from which the wind blows. Indicated in tens of degrees from true north.
  - For east, 18 for south, 27 for west, 36 for north.
  - The direction column indicates calm.
  - Wind expressed in knots; multiply by 1.15 to convert to miles per hour.

**U.S. DEPARTMENT OF COMMERCE**
**NATIONAL CLIMATIC CENTER**
**FEDERAL BUILDING**
**ASHEVILLE, N.C. 28801**

**AN EQUAL OPPORTUNITY EMPLOYER**

**COM-210**

**FIRST CLASS**

**STATION:**

**YEAR & MONTH:**

**U.S. DEPARTMENT OF COMMERCE**

**ASHEVILLE, N.C. 28801**

**COM-210**

**FIRST CLASS**

**-b3-**
### Local Climatological Data

**MONTHLY SUMMARY**

**LATITUDE 59° 29' N LONGITUDE 151° 30' W ELEVATION (GROUND) 65FT.**

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**SUMMARY BY HOURS**

**MORE OBSERVATIONS PER DAY AT 3-HOUR INTERVALS. FASTEST KNOTS AND MILES PER HOUR ARE PREFERED.**

- *Figure for wind directions are..."*
- *Figures for wind directions are..."*
- *This station is closed on the 24th, 21:00 LST to the 29th, 03:00 LST.*

**HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES).**

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**NOTES**
- **WEATHER**
  - **FOG**
  - **ICE CRYSTALS**
  - **SNOW SHOWERS**
  - **SNOW SHOWERS**
  - **ICE CRYSTALS**
  - **FOG**
  - **ICE CRYSTALS**
  - **SUNNY**
  - **SNOW SHOWERS**
  - **ICE CRYSTALS**
  - **FOG**

**OSTERVATIONS AT 3-HOUR INTERVALS**

- **U.S. DEPARTMENT OF COMMERCE**
- **NATIONAL CLIMATIC CENTER**
- **FEDERAL BUILDING**
- **ASHVILLE, N.C. 28801**

**FIRST CLASS**
Seldovia Bay, 7 miles NE of Port Graham, is a secure harbor in any weather. There are several shoals, covered less than 3 fathoms, in the entrance and the inner part of the bay is very shoal.

Point Naskowhak (59°27.3'N., 151°44.4'W.), on the W side of the entrance to Seldovia Bay, is the N of two small high rocky wooded knobs which stand on a low grassy spit surrounding a lagoon. A reef extends nearly 0.2 mile N from the point, and kelp-marked broken ground extends almost 0.5 mile NE. Kelp-marked shoals with a least depth of 2½ fathoms are 700 yards ENE from the point.

Gray Cliff, the E entrance point of Seldovia Bay, is a bare rock cliff 60 to 70 feet high. Gray Cliff Light (59°27.2'N., 151°43.2'W.), 64 feet above the water, is shown from a small house with a diamond-shaped red and white daymark at the S end of the cliff.

Seldovia Point, 1 mile N of Gray Cliff, is a 200-foot-high cliff wooded on top. Kelp extends 0.6 mile from shore in the bight NE of the point.

Red Bluff, 0.2 mile S of Gray Cliff, is high and reddish in color. Foul ground extends 300 yards W from Red Bluff to a rock that uncovers 4 feet. This rock is steep-to on its W side, and is the principal danger in the bay.

Watch Point, 0.6 mile S of Gray Cliff, is a small 30-foot-high grassy head with a few trees and a short low grassy neck behind it. A high pointed rock is near the E shore 300 yards N of the point.

Seldovia Entrance Light (59°26.6'N., 151°43.2'W.), 45 feet above the water, is shown from a small house with a square white and green daymark off the end of Watch Point. Kelp-marked rocks with a least depth of ¾ fathom are between the light and the Seldovia waterfront to the S.

Seldovia, on the E side of Seldovia Bay just S of Watch Point, is a fishing and logging town. It has a cannery, some stores, hotel, hospital, and churches. A local magistrate is in the town.

Dangers.-The March 1964 earthquake caused a bottom subsidence of 3.7 feet at Seldovia. Until a complete survey is made of the area, caution is necessary because depths may vary from those charted and mentioned in the Coast Pilot.

Tides and currents.-The diurnal range of tide is 17.8 feet at Seldovia. (See the Tide Tables for daily predictions.) The tidal currents have an estimated velocity of 1 to 2 knots.

Weather.-Winds in the Kachemak Bay area are predominantly from the NE from late fall to early spring. During the rest of the year, SW winds are the most frequent. Winds are strongest during the late summer and early fall.

Fogs are common to the Kachemak Bay area. Ground fogs occur most frequently in winter with the heaviest fogs reported to be in January. Homer and Seldovia occasionally report fog conditions. The more frequent occurrence is in the summer when it may last for days at a time. It is reported that fog banks frequently hang over the open water after harbors have been cleared.

The annual mean temperature of the area is reported to be about 35°F. July and August are usually the warmest months. The temperature can range from a high of nearly 90°F in the summer to well below zero in the winter.
Drift Card Study #1 (DCS #1)

Date: November 15, 1978

Time: 0932-0940 release

Objective: To determine surface drift pattern during flood tide.

Method: One hundred cards (marked with NOAA series numbers) were divided into stacks of 25 and deployed at four points.

Procedure: Cards were deployed as such:

Serial Numbers:
Group I - A07801 - A07826
Group II - A07827 - A07850
Group III - A07851 - A07875
Group IV - A07876 - A07900

First observation of where and how cards were dispersing was taken at 1100 by aerial observation.

Cards were then collected by boat at 1600 on same day. Cards were found grouped at two areas along the shoreline.
Percent Recovery as of November 17, 1978:

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<tr>
<td>I</td>
<td>20%</td>
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<td>II</td>
<td>52%</td>
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<td>III</td>
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Overall recovery of cards = 54%

Observations:
Aerial observation showed cards to remain in small, tight groups and not disperse. Most of the cards recovered were found on two small areas of shoreline opposite the wreck site (see chart). The observed drift path of the cards does appear to be the same taken by drifting oil during similar tidal and wind conditions. Note: the shore areas at which the groups of drift cards were found were simultaneously contaminated with oil.
Drift Card Study #2 (DCS #2)

Date: November 16, 1978

Time: 1430-1435 release.

Objective: To determine surface drift pattern during ebb tide.

Method: Same as DCS #1.

Procedure: Same drop pattern as DCS #1.

Serial Numbers:
V - A07901 - A07928
VI - A07929 - A07953
VII - A07954 - A07978
VIII - A07979 - A07999

Observations: Only one card recovered as of December 9, 1978. The drop pattern for the drift cards was in open water and not subject to those currents moving oil onshore. Oil moving from the wreck into the open water areas of Seldovia Bay during ebb tide seems to be transported out of the bay to the open waters of Kachemak Bay without making contact with the shoreline.
Current Survey #1 (CS #1)  
Date: November 17, 1978  
Time: 1050 deployment  
Objective: To determine sub-surface current patterns primarily to give advise to the OSC pertaining to boom configurations.  
Method: Current probes were constructed from base material.

Buoys were deflated until no more than two inches floated above the water. The purpose of this was to reduce wind effect on the buoys. Flags were placed with the buoys to aid in aerial observation. Two flags trailed the surface current buoy (anchor at 3'1") and three flags trailed the deep current buoy (anchor at 6'8"). See chart for observations of buoy drift.

Note: At approximately 1500, November 17, Crowley accidentally recovered both buoys. Both buoys were then re-deployed in the original deployment site at approximately 1700 hours.

Procedure: Buoys for CS #1 were deployed approximately 200 meters east of the wreck. Buoys for CS #2 were deployed approximately 200 meters northwest of the wreck.

Observations: See text for discussion.

-b11-
Environmental Susceptibility

On the basis of the two case studies cited above, plus careful study of the literature, a scale of environmental susceptibility to oil spill impacts has been derived. This scale relates primarily to the longevity of oil in each environment. The subtleties of chemical weathering of the oil within each environment have not yet been studied in enough detail to be incorporated into the susceptibility scale. Results of a preliminary study by Rashid (1974) are given in Table 7. He concluded that chemical weathering processes are more active on high energy coasts than on low energy coasts, although the details of his environmental classification are rather obscure. Also, although biodegradation rates are thought to be slower in cold temperatures, little documentation exists to verify that notion.

Coastal environments are listed and discussed below in order to increasing susceptibility to oil spills:

1. Straight, rocky headlands:

Most areas of this type are exposed to maximum wave energy. Waves reflect off the rocky scarps with great force, readily dispersing the oil. In fact, waves reflecting off the scarps at high tide tend to generate a surficial return flow that keeps the oil off the rocks (observed in Spain; Fig. 59).

2. Eroding wave-cut platforms:

These areas are also swept clean by wave erosion. All of the areas of this type at the Metula spill site had been cleaned of oil after one year. The rate of removal of the oil would be a function of the wave climate. In general, no clean-up procedures are needed for this type of coast.

3. Flat, fine-grained sandy beaches:

Beaches of this type are generally flat and hard-packed. Oil that is implaced on such beaches will not penetrate the fine sand. Instead, it usually forms a thin layer on the surface that can be readily scraped.
off by a motorized elevated scraper or some other type of road machinery. Furthermore, these types of beaches change slowly, so burial of oil by new deposition would take place at a slow rate. There are no beaches of this type in lower Cook Inlet.

4. Steeper, medium- to coarse-grained sandy beaches:

On these beaches, the depth of penetration would be greater than for the fine-grained beaches (though still only a few centimeters), and rates of burial of the oil would be greatly increased. Based on earlier studies by our group in numerous localities, it is possible for oil to be buried as much as 50-100 cm within a period of a few days on beaches of this class. In this type of situation, removal of the oil becomes a serious problem, inasmuch as it would be necessary to destroy the beach in order to remove the oil. This was a common problem encountered during the clean up of the Arrow spill in Chedabucto Bay, Nova Scotia (Owens and Rashid, 1976). Another problem is that burial of the oil preserves it for release at a later date when the beach erodes as part of the natural beach cycle, thus assuring long-term pollution of the environment. There are only a few beaches of this type in lower Cook Inlet, which occur off the large arcuate-cuspage fan deltas on the western shoreline.

5. Impermeable muddy tidal flats (exposed to winds and currents):

One of the major surprises of the study of the Metula site was the discovery that oil did not readily stick to the surfaces of mud flats. Also, penetration into the sediments was essentially non-existent. Therefore, if an oiled tidal flat is subject to winds and some currents, the oil will tend to be eventually removed, although not at the rapid rate encountered on exposed beaches. Many of the more exposed tidal flats of lower Cook Inlet fall in this category.

6. Mixed sand and gravel beaches:

On beaches of this type, the oil may penetrate several centimeters, and rates of burial are quite high (a few days in Spain). Most of the beaches of both the Metula site and lower Cook Inlet are of this type. The longevity of the oil at the Metula site, particularly on the low-tide terraces and berm top areas, attests to the high susceptibility of these beaches to long-term oil spill damage.

7. Gravel beaches:

Pure gravel beaches have large penetration depths (up to 45 cm in Spain). Furthermore, rapid burial is also possible. A heavily-oiled gravel beach would be impossible to clean up without completely removing the gravel. Many of the beaches of lower Cook Inlet are of this type.

8. Sheltered rocky headlands:

Our experience in Spain indicates that oil tends to stick to rough rocky surfaces. In the absence of abrasion by wave action, oil could remain on such areas for years, with only chemical and biological processes left to degrade it. Many miles of the sheltered embayments of lower Cook Inlet are fringed by rocky coasts of this type.
9. Protected estuarine tidal flats:

Once oil reaches a backwater, protected, estuarine tidal flat, chemical and biogenic processes must degrade the oil if it is to be removed. Many of the upper reaches of the embayed shorelines of lower Cook Inlet fall in this class.

10. Protected estuarine salt marshes:

In sheltered estuaries, oil from a spill may have long-term deleterious effects. We observed oil from the Metula on the salt marshes of East Estuary, on the south shore of the Strait of Magellan, that had shown essentially no change in 14 years. We predict a life span of at least 10 years for that oil. The upper reaches of the embayments of lower Cook Inlet contain extensive salt marshes.

Applications to lower Cook Inlet

Oil spill susceptibility. - Utilizing a combination of the susceptibility classification just described and the classification of the coastal morphology proposed in Table 4, it is possible to delineate the coastal environments of lower Cook Inlet with respect to oil spill susceptibility. As a generalization, lower Cook Inlet is a high risk area for the occurrence of spills, because so many of the environments have a high susceptibility rating. Furthermore, the inaccessibility of the area renders most normal oil spill clean-up techniques infeasible. Of all the environments, the erosional shorelines are most apt to be cleaned of oil spills by natural processes. The embayed ria shorelines of the neutral class would be extremely high-risk areas. The depositional coasts would be variable, depending essentially upon the amount of wave energy expended and the grain size of the beaches. Problems of oil burial would be much greater in this class than in any of the others. Each of the individual coastal morphology classes are listed and discussed below:

<table>
<thead>
<tr>
<th>Class</th>
<th>% of shoreline</th>
<th>Discussion</th>
<th>(1 - 10) Risk Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ala. High</td>
<td>8</td>
<td>Oil easily removed by wave erosion; some problems in areas where gravel beaches occur.</td>
<td>1-2</td>
</tr>
<tr>
<td>rock scarps</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alb. Low</td>
<td>28</td>
<td>Generally low-risk area except where depositional berms exist; gravel and boulder low-tide terraces subject to long-term oiling; burial possible on beach faces.</td>
<td>2-4</td>
</tr>
<tr>
<td>rock scarps</td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A2c. Scarps</td>
<td>5</td>
<td>Same as Ala.</td>
<td>1-2</td>
</tr>
<tr>
<td>on dip slopes</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A2a. Scarps</td>
<td>3</td>
<td>Same as Alb.</td>
<td>2-4</td>
</tr>
<tr>
<td>in glacial deposits</td>
<td>3</td>
<td></td>
<td>2-4</td>
</tr>
<tr>
<td>Class</td>
<td>% of Shoreline</td>
<td>Discussion</td>
<td>(1 - 10) Risk Classification</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>A2b. Scarps</td>
<td>1</td>
<td>Same as Alb.</td>
<td>2-4</td>
</tr>
<tr>
<td>in deltaic deposits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bla. Embayments with mountaineous shores</td>
<td>30</td>
<td>Almost all areas subject to long-term oil spill damage, especially salt marsh areas; fewer problems at mouth than at head of embayment.</td>
<td>8-10</td>
</tr>
<tr>
<td>Blb. Embayments with hilly and lowland shores</td>
<td>8</td>
<td>Same as Bla.</td>
<td>8-10</td>
</tr>
<tr>
<td>Cla. Lobate fan deltas</td>
<td>1.5</td>
<td>Low wave energy conditions and coarse grain size would allow oil to remain for years; fresh water plume would probably keep oil off delta during periods of high runoff.</td>
<td>6-8</td>
</tr>
<tr>
<td>C1b. Arcuate-cuspate fan deltas</td>
<td>6</td>
<td>Oil would probably be eroded in 6 mos. to one year; penetration and burial possible; if buried, would remain longer.</td>
<td>4-6</td>
</tr>
<tr>
<td>C1c. Arcuate-cuspate asymmetrical fan deltas</td>
<td>1</td>
<td>Lower wave energy (than C1b) and coarse grain size increase length of oil residence (1½ years in similar areas in Chile).</td>
<td>6-8</td>
</tr>
<tr>
<td>C2a. Recurved spits</td>
<td>2</td>
<td>Mostly mixed sand and gravel beaches; 6 mos. to one year residence time</td>
<td>4-6</td>
</tr>
<tr>
<td>C2b. Cuspate spits</td>
<td>2</td>
<td>Same as C2a.</td>
<td>4-6</td>
</tr>
<tr>
<td>C2c. Tombolo spits</td>
<td>0.4</td>
<td>Same as C2a.</td>
<td>4-6</td>
</tr>
<tr>
<td>C2d. Flattened protruberances</td>
<td>1</td>
<td>Same as C2a.</td>
<td>4-6</td>
</tr>
<tr>
<td>C3a. Bayhead beach-ridge plains</td>
<td>2</td>
<td>Variable depending on composition of beaches; gravel beaches more susceptible than sandy areas; oil would tend to accumulate here because of position at head of bay.</td>
<td>4-6</td>
</tr>
</tbody>
</table>
In summary, 45% of the shoreline of lower Cook Inlet was classified with low risk values of 1-4 on the susceptibility scale (1-2 = 13%; 2-4 = 32%), 13.4% was classified with intermediate values of 4-6, and 41.5% was classified with high values of 6-10 (6-8 = 2.5%; 8-10 = 39%). The distribution of these areas in lower Cook Inlet is given on the map in Figure 60. It should be pointed out that wave energy is relatively low in lower Cook Inlet, and that this scale cannot be applied directly in areas with larger waves. Oil that goes ashore in areas with a rating of 1-2 could be expected to be dispersed within a few weeks. Areas with ratings of 2-4 would probably be free of oil within 6 months, and a rating of 4-6 indicates possible pollution of up to one year. A 6-8 rating means that oil could remain in place for several years, and, based on our experience with the Metula, long-term pollution of 10 years or longer can be expected in areas rated 8-10 if no clean-up procedures are initiated. Furthermore, clean-up is extremely difficult in these high-risk environments. Obviously, a concerted effort needs to be made to keep the oil away from areas with a rating greater than 6.

Oil dispersal. - The potential dispersal of oil spills in lower Cook Inlet is discussed elsewhere (Wennekens et al., 1975). The circulation pattern of lower Cook Inlet is such that oil would probably be selectively transported into the Kamishak Bay area (Fig. 6B). Northerly and easterly winds would augment this pattern. The accumulation of tremendous quantities of flotsam in the Kamishak Bay region supports this assumption. The general pattern of oil dispersal would be governed by the strong tidal currents with their superimposed Coriolis deflection to the east on flooding tides and to the west on ebbing tides. Wind regime at the time of oil release is another important factor.

As part of our reconnaissance work, all indicators of longshore sediment transport, such as recurved spits, cuspatate spits, and shoreline protuberances, were plotted on the base map in order to depict regional trends. The results are shown on Figure 61. These trends generally indicate alongshore transport of sediment into most of the embayments, in particular Kamishak Bay and Kachemak Bay. Thus, in places where the oil comes onshore, the part that doesn't strand on the beach immediately will probably be caught up in the nearshore wave-generated currents and be transported toward the heads of the bays, where the oil-spill impact would be greatest.
### TABLE 4. SHORELINE MORPHOLOGY - LOWER COOK INLET

#### A. EROSIONAL SHORELINES (45% of shoreline)

<table>
<thead>
<tr>
<th>Subclass (Description)</th>
<th>Total shoreline (km)</th>
<th>% of total shoreline</th>
<th>Examples (station)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. High vertical scars over 100 m high, beaches coarse gravel or</td>
<td>13.9</td>
<td>3</td>
<td>1. Ursus Head (192)</td>
</tr>
<tr>
<td>b. Vertical scars generally less</td>
<td>15.2</td>
<td>3</td>
<td>2. Fortification Bluff (21)</td>
</tr>
<tr>
<td>than 100 m high, variable bedrock composition; beaches com-</td>
<td>15.2</td>
<td>3</td>
<td>3. Contact Point (26)</td>
</tr>
<tr>
<td>plex mixes of gravel and sand;</td>
<td>13.9</td>
<td>3</td>
<td>4. Chinga Bay (71)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>5. Inlet Bay (16; 17)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>6. Titauna-McCottman Bays (18)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>7. Point Graham Harbor</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>8. Point Chatham Harbor</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>9. Selovisia Bay</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>10. Tutka Bay (29)</td>
</tr>
<tr>
<td>c. Rock scarps of variable heights on dip slopes; beaches coarse</td>
<td>40.8</td>
<td>5</td>
<td>1. Tilted Hills (13; 15)</td>
</tr>
<tr>
<td>gravel on rock platforms; eave-</td>
<td>40.8</td>
<td>5</td>
<td>2. Fortification Bluff (21)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>3. Chisik Island</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>4. Nanuk Island</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>5. North shore of Kachemak Bay (44; 45)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>6. Most of the shoreline between Homer and Kenai (47; 48; 50; 51; 53; 54; 55)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>7. Redoubt Point area (23)</td>
</tr>
</tbody>
</table>

#### B. NEUTRAL (STABLE) SHORELINES (38% of shoreline)

<table>
<thead>
<tr>
<th>Subclass (Description)</th>
<th>Total shoreline (km)</th>
<th>% of total shoreline</th>
<th>Examples (station)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Lobate fan deltas; digitate sediment looses at river mouth;</td>
<td>266.7</td>
<td>30</td>
<td>1. Tuxedni Bay (3)</td>
</tr>
<tr>
<td>low wave action, hence no swash bar development</td>
<td>266.7</td>
<td>30</td>
<td>2. Chinitna Bay (11)</td>
</tr>
<tr>
<td>b. Arcuate-cuspate fan deltas; mixed sand and gravel (sand</td>
<td>74.0</td>
<td>6</td>
<td>3. Inlet Bay (16; 17)</td>
</tr>
<tr>
<td>dominant); margin of delta made up of wave-built spits and</td>
<td>74.0</td>
<td>6</td>
<td>4. Titauna-McCottman Bays (18)</td>
</tr>
<tr>
<td>beach ridges</td>
<td>74.0</td>
<td>6</td>
<td>5. Point Graham Harbor</td>
</tr>
<tr>
<td>c. Arcuate-cuspate asymmetrical fan deltas; mixed sand and</td>
<td>13.4</td>
<td>1</td>
<td>6. Tuxedni River Delta</td>
</tr>
<tr>
<td>gravel (gravel dominant); usually has one main gravel spit</td>
<td>13.4</td>
<td>1</td>
<td>7. Anchor Pt. Delta</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>8. A. W. Testa Delta</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>9. Usor Head Delta</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>10. East Glacier Creek Delta</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>12. Anchor Pt. (46)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>13. Chisik Island</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>14. Point Chatham Harbor</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>15. Selovisia Bay</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>16. Tutka Bay (29)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>17. Sardine Cove</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>18. Halfout Cove</td>
</tr>
</tbody>
</table>

#### C. DEPOSITIONAL SHORELINES (17% of shoreline)

<table>
<thead>
<tr>
<th>Subclass (Description)</th>
<th>Total shoreline (km)</th>
<th>% of total shoreline</th>
<th>Examples (station)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Embayed beach-ridge</td>
<td>22.8</td>
<td>2</td>
<td>1. Crescent River Spit (4)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>2. Glacier Spit</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>3. Seal Spit (12)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>4. Aurora Spit (12)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>5. Homer Spit (46)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>6. Tuxedni Channel Delta (6)</td>
</tr>
<tr>
<td>b. Gravel bars; multiple inter-</td>
<td>21.0</td>
<td>2</td>
<td>1. SW corner of Augustine Island (142)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>2. NE corner of Chisik Island</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>3. SW corner of Kachemak Bay (44; 45)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>4. Entrance to Selovisia Harbor</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>5. McDonald Spit</td>
</tr>
<tr>
<td>c. Tidal lagoons; mixed sand and gravel (gravel dominant);</td>
<td>4.3</td>
<td>34</td>
<td>1. Spit at Spring Lakes (9)</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>2. Entrance to Selovisia Harbor</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>3. McDonald Spit</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>4. Cape Starckson</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>5. Midpoint between Anchor Pt. and Cape Starckson</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>6. Cape Stetson</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>7. Mudflats and salt marshes</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>8. Mouth of the Lower Cook Inlet</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td></td>
<td>9. South shore of Kachemak Bay (44; 45)</td>
</tr>
</tbody>
</table>

### Notes
- Subclass: Describes the type of shoreline.
- Total shoreline: Represents the percentage of the total shoreline.
- Examples (station): Identifies specific examples or stations associated with each subclass.
Figure 11. Areal distribution of geomorphological units described in Table 4.
Figure 60. Vulnerability of coastal environments to oil spills.
Figure 61. Longshore sediment transport patterns in lower Cook Inlet. Based on geomorphic evidence such as recurred spits, cuspate spits, and beach protuberances.
The report "Environmental Studies of Kachemak Bay and Lower Cook Inlet" consists of 12 volumes. Volume I discusses the purpose of the study, background information on the Kachemak Bay environment, problems associated with petroleum development, and effects of oil pollution on the marine organisms and environment of Kachemak Bay. Volumes II-XII present the detailed results of each of the eleven environmental studies undertaken in Kachemak Bay. The results of these studies, summarized in Volume I, are used to document conclusions presented in Volume I.

The subject of each volume is listed below:

Volume I  Impact of Oil on the Kachemak Bay Environment

L. Trasky, L. Flagg and D. Burbank; Alaska Department of Fish and Game.

Volume II  Coastal Morphology and Sedimentation - Lower Cook Inlet, Alaska

M. Hayes, P. Brown and J. Michel; University of South Carolina.

Volume III  Circulation Studies in Kachemak Bay and Lower Cook Inlet, Alaska

D. Burbank; Alaska Department of Fish and Game.

Volume IV  Summary Status on the Distribution of King Crab and Pandalid Shrimp Larvae, Kachemak Bay - Lower Cook Inlet, Alaska, 1976

E. Haynes; National Marine Fisheries Service.

Volume V  Post-Larval King Crab (Paralithodes camtschatica) Distribution and Abundance in Kachemak Bay, Lower Cook Inlet, Alaska, 1976

K. Sundberg and D. Clausen; Alaska Department of Fish and Game.

Volume VI  Food Habits of Shrimp in Kachemak Bay, Alaska

J. Crow; Rutgers University.

-b21-
Volume VII  Benthic Reconnaissance of Kachemak Bay, Alaska

W. Driskell; Alaska Department of Fish and Game/Dames and Moore.

Volume VIII  Distribution, Abundance, Migration and Breeding Locations of Marine Birds-Lower Cook Inlet, Alaska, 1976

D. Erikson; Alaska Department of Fish and Game.

Volume IX  Marine Plant Community Studies, Kachemak Bay, Alaska

Dames and Moore.

Volume X  The Salt Marsh Vegetation of China Poot Bay, Alaska

J. Crow and J. Koppen; Rutgers University.

Volume XI  Baseline Study of Beach Drift Composition in Lower Cook Inlet, Alaska, 1976

A. Cunning; Alaska Department of Fish and Game.

Volume XII  Hydrocarbons in Intertidal Environments of Lower Cook Inlet, Alaska, 1976

D. Shaw and K. Lotspeich; University of Alaska.
Samples of Pollution and Cargo From The Glacier Queen

Dates:
- November 9, 1978 - sheen and emulsion north of wreck.
- November 9, 1978 - oil bleb north of wreck.
- November 18, 1978 - cargo from ceiling of the boiler room.
- November 19, 1978 - cargo from ceiling of the engine room.

Times:
(respectively) 1500
1500
1100
1109

Objective: To obtain, for the record, samples of the source of pollution.

Method:
Surface pollution samples were taken from a skiff by hand dipping a 16 oz. glass jar. USCG divers collected cargo oil in 16 oz. glass jars which were capped under water.

Custody:
Samples were retained by NOAA personnel on-scene and are presently in custody of the SSC.
Intertidal Sample: #1 (IS #1)

Date: November 10, 1978

Time: 1700 - 1750

Objective: To determine hydrocarbon concentrations in the intertidal sediments (and, as a secondary objective, characterize the benthic community).

Method: A "coffee can" core sampler was used to obtain sediment samples. The sampler was worked into the substrate and when in place, a trench was dug around the sampler such that the entire can was exposed and placed into doubled-up plastic garbage bags. The samples were tagged by placing a marker in between the two plastic bags and the bags were individually sealed. The samples were deep frozen immediately after being taken.

Procedure: Samples were taken in the lower intertidal reaches of T-Boom Beach. T-Boom Beach received a significant amount of contamination during the first and second days of the spill (November 9 and 10). Samples were taken immediately following a low tide of 1.3 occurring at 1613. Using a compass, a transect was taken at a heading of 30° which extended 90 yards through the exposed lower intertidal. The length of the transect was measured using a 90 yard length of twine. The beginning and end points of the transect were triangulated using navigation lights on the opposite shore according to the following figure.

Samples were then taken at every 15 yards along the 90 yard transect and were numbered stations 1 through 7.

Custody: The samples were taken into custody on board the USCG Sedge, under command by Lt. Cmd. Erlandson.
Description of the Sampling Area:

*Note:* vertically exaggerated

Dominantly gravel and packed coarse sand. Large rounded rocks occur in random patches. Fucus, Ulva and red algae present. Also some beached Nereocystis.

Observations: No smell or sight of oil present. It was sometimes difficult to sink the core sampler into the substrate because of coarse gravel and rocks. Seas calm. Sky cloudy.
Intertidal Sample #2 (IS #2)

Date: November 13, 1978
Time: 1540 - 1640
Objective: Same as IS #1
Method: Same as IS #1

Procedure: Samples were taken in the mid to upper intertidal reached of T-Boom Beach to complete the intertidal sampling of this area. Samples were taken during the mid-ebb cycle (low @ 1830 of -2.8). The transect established during IS #1 was reestablished and 60 yard transects were taken from stations 1, 3, 5 and 7. The transects were set at 90° from the original 30° NNE transect (bearing 309° NW).

Two samples were taken along each transect at 30 yard intervals. Samples were numbered OA, OB, 1A, 1B, 4A, 4B, 8A, 8B.

Custody: The samples were initially stored in the freezer of the cannery and are now in custody of NOAA SSC.

Description of Sampling Area: Mid-intertidal samples were taken about half way up the beach incline for mid-intertidal stations and at the top of the incline for the upper intertidal stations. The substrate is composed of sand and pebbles with random gravels.

Observations: Oil was not observed at the sample sites; however, some samples had a very slight oily smell on the surface layer. Windrows were present containing large amounts of wood and Fucus - Sky clear. Little wave action.
Clam Sample:

Date: November 14, 1978
Time: 1800 - 1830

Objective: Upon request by Loren Flagg of ADF&G, clam samples were taken in the event that hydrocarbon analysis of body tissues by the U.S. Department of Agriculture was necessary.

Method: Clams were dug during minus tide using a spade and were generally taken from a depth in the sediment column of 6-8 inches. Samples were immediately frozen in double bags.

Custody: The samples initially stored at the Wakefield Cannery Freezer, are now in custody of the NOAAASSC.

Description of Sampling Area: Samples were collected from the lower intertidal zone of T-boom beach in a level area of course sand and pebbles.

Observations: No sight or odor of oil in sample area. Clams spaced evenly about every 6 inches. Very rich bed. Most prevalent was the hard shell clam (Merceneria sp). Cockles and red neck clams were found in very low numbers.
Benthic Sample #1 (BS #1)

Date: November 13, 1978

Time: 1430 - 1630

Objective: To quantitatively characterize benthic community structure around the site of the wreck and to determine analytically the extent of bottom drift of spilled oil (including visual presence of oil and oil smell in sediment).

Method: Samples were taken using a Ponar Grab weighing 40 lbs. and having a grab area of 552 cm² and a total volume of 6292 cm³. Samples were taken in 35-40 feet of water during an ebb tide (low @ 1830 of 2.8). Samples were labeled and stored in polypropylene and glass containers. Samples were preserved in 10% buffered formalin. Samples were taken from the ADF&G, 32 foot "Puffin".

Procedure: Three sampling stations were marked approximately 100 yards from the wreck at 330°, 210° and 90°. Due to the movement of clean-up boats, divers and a large number of bouys and lines, we were not able to permanently mark the station. Three samples were taken at each station (3 reps) and marked 1A, 1B, 1C (330°), 2A, 2B, and 2C (210°) and 3A, 3B (90°).

Custody: Samples were taken into custody by the ADF&G by consent of Loren Flagg. The samples were transported on board the "Puffin" to the ADF&G warehouse in Homer for storage.

Description of Sampling Area: The bottom was fairly well packed sand/clay at station #1 and soft clay and shell fragments at stations #2 and #3. Note: divers reported that the sediment became looser toward shore and that their fins sweeping close to the bottom stirred up sediment. This corresponds with the deposition pattern from the navigational chart.
Observation: No sheen or smell of oil noticed on bottom sediment, nor globules of heavy oil noticed in sediment. Samples smell healthy -- very little H₂S.

Stations located approximately 100 meters from wreck along compass bearing shown.
Plankton Sample:

Date: November 13, 1978

Time: 1630 - 1700

Objective: To qualitatively analyse the damage to the plankton community of Seldovia Bay during the spill. This included an "eye ball" examination of samples to determine if any significant mortality was incurred or if motor impairment of the plankton was obvious.

Method: Samples were taken from the ADF&G 32 foot "Puffin" using an ADF&G plankton trawl.

Two plankton trawls were taken for five minutes each. One trawl was taken at surface and one trawl was taken at approximately two feet below the surface. Trawls were taken at a heading of 180° approximately 400 yards north of the wreck. The trawls were taken during a swift ebb tide. Because we were travelling into the tide, the trawl distance was about 100 yards. Samples were preserved in 5% formalin.

Custody: The plankton samples were sent to the ADF&G warehouse in Homer on board the "Puffin" and are presently in the custody of the ADF&G.

Description of Sampling Area: No surface waves -- little wind, open water, depth of 6-8 fathoms.

Observations: No sight or smell of oil or sheen in sample area. Samples were rich with plankton which seemed to be swimming actively and strongly. Copepods made up the majority of the sample. Also present were a few larval fish, larval shrimp and ctenophorans.
Water Column Samples


Time:
#1 1430 due west of wreck 20 meters.
#2 1500 due east of wreck 150 meters.
#3 1525 due north of wreck 1000 meters.

Objective: To sample dissolved and/or particulate hydrocarbons in the water column.

Method: Field Chemistry Procedure of NOAA/USCG Spilled Oil Research Team. Because the General Oceanics Butterfly Sampler had broken on scene the samples were taken in hexane-rinsed quart glass jars. The jars were opened 6" below the surface of the water and then capped at that depth. The samples were immediately "fixed" with hexane according to the NOAA SOR Team method. The fixed samples were stored in pre-cleaned 20 ml. vials were marked in accordance with chain-of-costody procedures and are presently in the custody of the NOAA Alaska SSC.

Costody: Samples are in custody of the NOAA SSC.
Dunneoness Crab Sampling

Dates: November 24, 1978 to December 7, 1978

Objective: To search for subsurface movements of oil and to sample a valuable bay resource that is likely to contact and retain spilled oil. Deployment of crab pots and ropes also exposed retrievable objects to subsurface oil in an area too congested to investigate such a possibility in any other way.

Method: Six pots measuring approximately 4 feet by 1 foot were borrowed from a local fisherman and positioned as shown in figure a.

Procedure: No crabs were caught in first positioning nor was oil seen. Pots were then continually shifted according to practice common to crab fishermen until crabs were located as shown in figure b.

Custody: Whole crabs were immediately frozen in a sealed container. Gill tissue was preserved in 5% formalin in 16 oz. glass jars and refrigerated immediately. Samples are now in custody of the NOAA SSC.

Observation: Crab populations were found to be extremely localized and a lengthy distance from the wreck. No oil in any form was observed by this method.
On 9 November, 1978, Pat Wennekins, Tom Turner and myself flew to Seldovia to assess the impact of the recent oil spill on wildlife. The spill began, when a barge moored in Seldovia Bay, sank. The oil began leaking on 8 November when the barge sank, and continues to do so at this writing.

The oil from the barge is of two consistencies: a fuel oil which left a thin sheen over much of Seldovia Bay, and oil residues from the bilge which were very viscous and tar-like. The latter was concentrated in the near shore zone and beaches across from the town of Seldovia.

During the night of the 8th, the Coast Guard deployed a boom halfway across the upper 1/3 of the bay to protect the salmon streams. This barrier was completed on the morning of the 10th when additional equipment arrived. At this time, a boom was also placed around the still leaking barge, and a section of absorbent boom was placed in the path of the drifting oil on the shore opposite Seldovia. In addition a small section of boom was placed across the mouth of a lagoon to keep additional oil away from this potentially important clamming and wildlife area. The cleanup of oil undertaken by Crowley Maritime began on 10 November.

Large portions of Seldovia Bay, save the head of the bay, were affected by the oil. A thin sheen of oil was present over much of the area on 10 November. The most heavily impacted area was the western side of the Bay directly across from the town of Seldovia. Not only was a thin layer of oil present on the water surface and beach, but also globs of thick, black bilge residues were floating and washing up on those beaches. The slick of thin oil was also evident approximately 2-3 km out into Kachemak Bay.

An aerial survey, using an amphibious goose, was taken on the mornings of the 9th and 10th to assess the extent of the spill and the wildlife associated with the spill. Two beached bird surveys were completed on the afternoon of 9 November (See Figure). Part of the Seldovia Bay was surveyed by small boat at this time. On the afternoon of 10 November, a small boat survey was taken of most of Seldovia Bay.

Kachemak Bay and the smaller bays associated with it are important wintering areas for scoters, Oldsquaw, murres and marbled murrelets. Other species using these areas during the winter include Arctic and Common Loons, Red-necked and Horned Grebes and Glaucous-winged Gulls. It was my impression that large numbers of seaducks and alcids have yet to move into Kachemak Bay at the time of this oil spill. Nevertheless, small numbers of the above mentioned species, except for the marbled murrelet, were observed in the spill area.
During the aerial survey on 9 November only one male surf scoter and one unidentified cormorant were observed in the oil slick outside of Seldovia Bay. However, approximately 35 white-winged scoters and 5 Oldsquaw were swimming in water directly adjacent to the slick. An additional 15 unidentified scoters and 25 white-winged scoters were observed near a thin slick in Seldovia Bay.

Surveys by small boat and by foot along the beach, revealed that more birds were utilizing the area than the survey by the fast flying goose led us to believe. A group of 40 Oldsquaw were observed in the bay directly in front of the small boat harbor. Other birds observed along the west shore of Seldovia Bay while conducting beached bird surveys include 1 Arctic Loon, 1 Red-necked Grebe, 3 Horned Grebes, 20 Pelagic Cormorants, 24 Black Scoters, 22 Harlequin Ducks and Glaucous-winged Gulls. All these birds were observed in or close to water covered by a thin sheen of oil. The only marine mammal I observed near the spill area but not in oiled water was a Sea Otter in a kelp bed along the outer beach. The lagoon on the west side of Seldovia Bay may be important for birds during the low tide. Approximately 40 dabbling ducks, probably mallards, and 20 Glaucous-winged Gulls were using the lagoon at this time.

Only one oiled bird was observed by me during the entire day. This Common Loon was completely covered by dark oil and spent a considerable amount of time preening. In addition, Howard Kaiser (pers. comm.) reported seeing one oiled Glaucous-winged Gull.

Only one bird was found on the beached bird surveys. The wings of a freshly killed murre were found along with many plucked feathers and bird droppings. This was probably attributable to a Bald Eagle which are numerous in the area. Eagles may be affected by oil in these areas by frequenting oiled beaches and feeding on oiled birds and carrion.

During the night of the 9 November, the oil spread considerably before the barge was contained by a boom. An aerial survey revealed that the oil had spread further into Kachemak Bay. A group of 200 loosely aggregated Glaucous-winged Gulls were observed near the oil slick approximately 2 km. offshore. Two Sea Otters were seen not more than 10m from the oil. Most of the ducks observed from the air, in and outside of the bay (approx. 60) were in non-oiled areas.

By far the most complete survey of the wildlife in Seldovia Bay at the time of the spill was taken by Loren Flagg and myself during an ebbing tide at 1300 on 10 November. Observed in the outer portion of the bay were approximately 60 white-winged Scoters and 30 Oldsquaw. As a thin coating of oil was found in an irregular pattern over much of this area, some birds were undoubtedly swimming in light oil. Fifteen Oldsquaw were observed in a lightly oiled area just off the Seldovia boat harbor. Other birds observed in oiled areas, primarily on the west end of the bay across from town include 1 Common Loon, 1 Red-necked Grebe, 5 Harlequin Ducks and 4 Glaucous-winged Gulls. Birds observed in cleaner portions of Seldovia Bay, primarily near Powder Island, include 1 Pelagic Cormorant, 5 Black Scoters, 8 Surf Scoters, 32 white-winged Scoters, 15 Oldsquaw and 1 Pigeon Guillemot. On the ebbing tide in the lagoon, 58 Harlequin Ducks and 4 Glaucous-winged Gulls were seen. Two Harbor Seals were seen in Seldovia Bay during the survey.
Three oiled birds were observed during the survey: One Common Murre, lightly oiled on the breast was observed in the small boat harbor. An immature Glaucous-winged Gull, lightly oiled on breast, and a Red-necked Grebe were seen on the west side of Seldovia Bay.

At this point, it appears that the Seldovia oil spill has had a small impact on birds and mammals. Undoubtedly, some birds will die from the spill but at this time it is too early to predict the magnitude of the kill, other than its being small.

Oil is still leaking from the barge and will continue to do so until the oil is gone or the barge removed. Bird population in the area will continue to increase through the late fall and early winter. Efforts must be continued to keep oil from spreading, and the beaches opposite Seldovia must be cleaned so as not to act as reservoirs. The lagoon which is of importance to Harlequin Ducks, Dabbling Ducks and gulls must also be protected from further fouling by oil.

At this writing no fouled or dead birds have been found. However, I suggest that at the end of this week, the weekend, or early next week a biologist, preferably me, be sent to Seldovia to re-examine the beaches and the neighboring waters. If the ADF&G whaler is not available in Seldovia, then I suggest we utilize the USFWS Monarch already in Homer.