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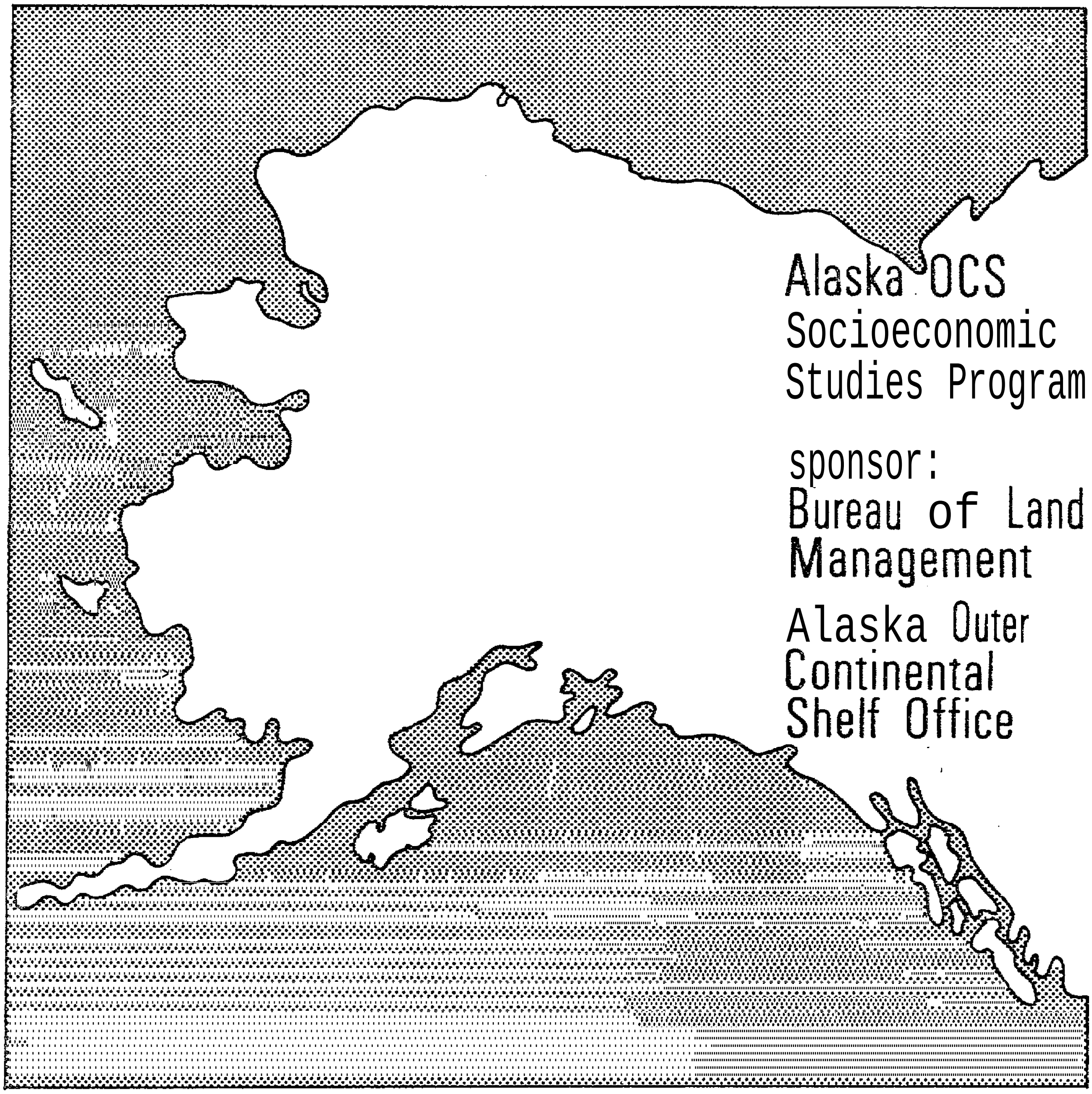

Alaska OCS
Socioeconomic
Studies Program

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Bureau of Land
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Alaska Outer
Continental
Shelf Office

Northern Shelikof Strait
Petroleum Facilities Siting Study

SPECIAL REPORT NO. 2

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ALASKA OCS SOCIOECONOMIC STUDIES PROGRAM

NORTHERN SHELIKOF STRAIT
PETROLEUM FACILITIES SITING STUDY

Prepared for

BUREAU OF LAND MANAGEMENT
ALASKA OUTER CONTINENTAL SHELF OFFICE

Prepared by

DAMES & MOORE

February 1980

NOTICE

ALASKA OCS SOCIOECONOMIC STUDIES PROGRAM
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"NOTE : This study has been included in our "Special Report" series. Originally, it was planned to be an Appendix to Technical Report No. 43.

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NORTHERN SHELIKOF STRAIT PETROLEUM FACILITIES SITING STUDY

I. Introduction

1.1 Purpose and Scope

Us. Geological Survey estimates of recoverable oil and gas reserves of the Skelikof Strait range from a low of 50 million barrels of oil and 50 billion cubic feet of gas. The high find scenario described in Chapter 6.0 assumed reserves corresponding to the U.S.G.S. high estimate while the medium find scenario described in Chapter 5.0 assumed more modest discoveries of 500 million barrels of oil and 500 billion cubic feet of gas. Tract nominations for Sale 60 in Shelikof Strait indicated medium to high interest in the northern portion of the Strait west of Afognak Island while no tracts were nominated in the southern half of the Strait where water depths generally exceeded 183 meters (600 feet).

In the case of significant discoveries of oil in the northern Shelikof Strait, an operator has three principal production options:

1. A long pipeline (approximately 322 kilometers or 200 miles) to existing Upper Cook Inlet petroleum facilities; a portion of this pipeline may be shared with other fields located in Lower Cook Inlet Sale CI or Sale 60.

2. A short pipeline (less than 32 kilometers or 20 miles) to a new oil terminal located on the east or west coast of Shelikof Strait.

3. A medium length pipeline (approximately 61 kilometers or 100 miles) to a new shore terminal located in Lower Cook Inlet shared with other Lower Cook Inlet fields.

The economic analysis (see Appendix A, Section 11.3) indicates that options 1 and 2 are economically more favorable than option 3 while option 2 is the most preferable for the majority of discovery locations in Shelikof Strait. The comparative economic differences, however, are minor assuming a discovery location in the southern portion of Lower Cook Inlet where about 96 kilometers (60 miles) of offshore pipeline and 128 kilometers (80 miles) of onshore pipeline would be required to link the field with existing Upper Cook facilities. Other factors being equal, greater pipeline distances than these would tip the economic scales in favor of construction of a new crude oil terminal at the most suitable shore site adjacent to the field. Other economically related factors will, of course, influence the selection of the production/transportation options, such as the infrastructure that may develop in response to Sale CI in Lower Cook Inlet, the available capacity of Upper Cook terminals and refineries, and the technical, environmental and socioeconomic feasibility of potential sites for shore facilities:

Reflecting the results of the economic analysis, the selected oil scenarios for Shelikof Strait specify construction of a new crude oil terminal and support base close to the field(s) located in northern Shelikof Strait. While the petroleum-related infrastructure (rig tenders dock, oil field supply services, etc.) at Nikiski will provide support for Lower Cook Inlet and Shelikof Strait exploration activities, it is apparent that, once major oil discoveries are made in Shelikof Strait, there will be a need for facilities closer to the fields to assist in both the construction and operational phases (Nikiski is over 320 kilometers from northern Shelikof Strait). This does not necessarily mean that Nikiski or other communities such as Kodiak or Homer will not also play a supporting role. If a new crude oil terminal were not constructed on the shores of Shelikof Strait and instead crude-was pipelined to the Kenai Peninsula, "then the location of a temporary construction support base and permanent service base in Shelikof Strait, would probably be less likely. Our scenarios assume that the construction" support base and, subsequently, the permanent service base for the Shelikof fields are located adjacent to the new crude oil terminal. Such an "assumption is not unreasonable since (1) the siting requirements will be readily fulfilled, (2) there will be economies effected through juxtaposition of sites, and (3) environmental planning may require consolidation of facility sites to minimize the number of petroleum-related facilities.

The purpose of this study is to identify suitable shore sites along Shelikof Strait for major petroleum facilities. This study focuses on oil related facilities since the scenarios specify transportation of Shelikof gas via pipeline to Upper Cook LNG and petrochemical plants rather than transportation to a new LNG plant located along the shores of Shelikog Strait. However, the sites identified as suitable for a new crude terminal would also fulfill the requirements for an LNG plant.

Specifically, this study aims to identify sites for the following facilities:

- Crude Oil Terminal
- Temporary Service Base
- Construction Support Base
- Permanent Service Base

In addition, this study addresses problems of pipeline routings and landfalls in Shelikof Strait.

Because the scenarios specify discoveries in northern Shelikof Strait and tract nominations were limted to this area, the study was confined to that portion of Shelikof Strait lying to the northeast of a line drawn approximately between Cape Uganik at the northwest tip of Kodiak Island and Cape Gull on the Alaska Peninsula (Figure E-l).

This study is intended to provide a preliminary identification and evaluation of shore facility sites in northern Shelikof. Socioeconomic factors (except land status) are not considered although valuable natural resources such as salmon and crab are. Significant data gaps in the areas of biology, geology and natural resources were revealed in the course of this investigation (and are identified in subsequent sections). New data, plus on-site investigations are therefore required for a second level analysis.

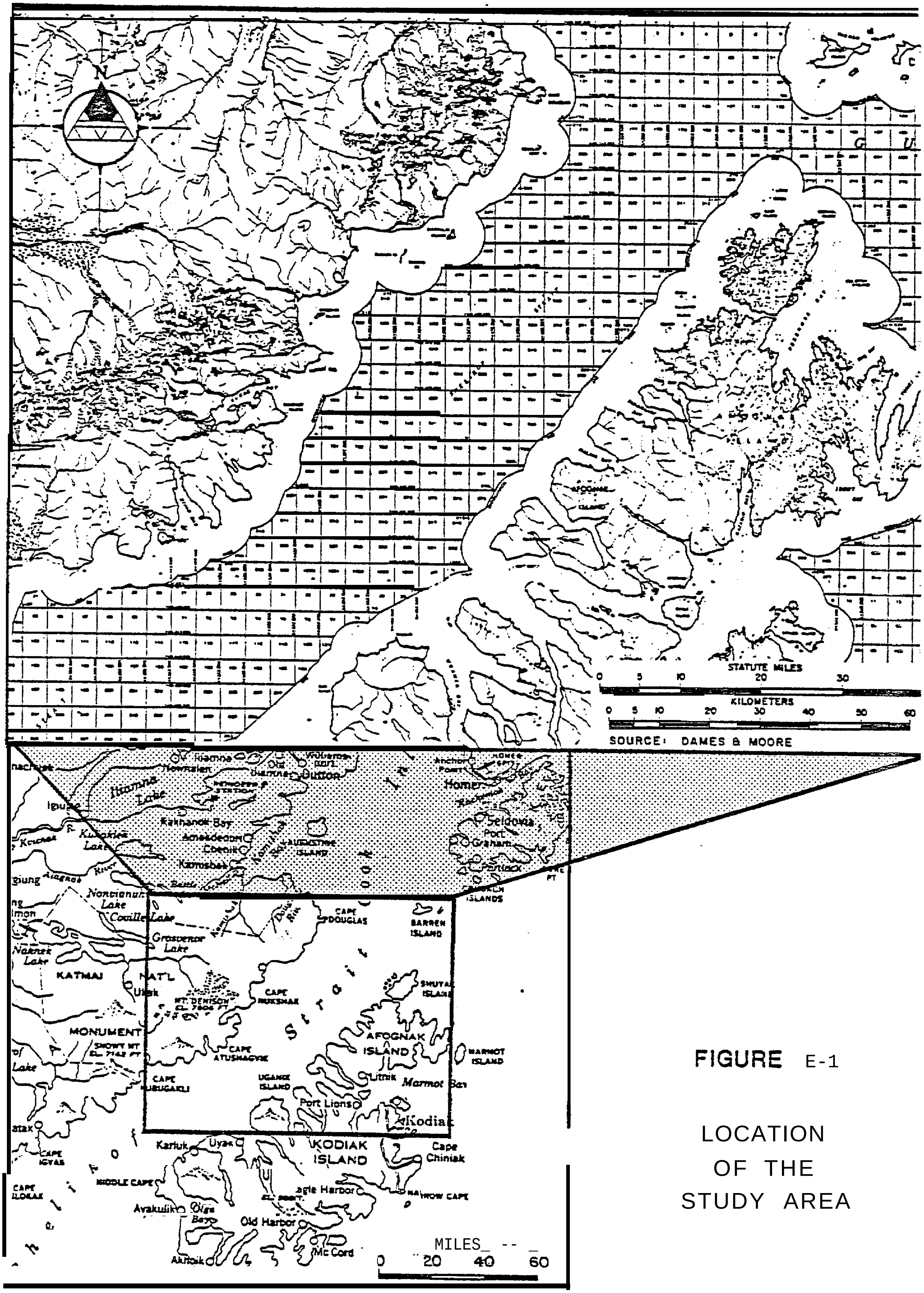


FIGURE E-1

LOCATION OF THE STUDY AREA

I.2 Methodology

A three phase approach was adopted in this investigation:

1. The technical criteria for facilities siting such as land and navigation requirements were defined for various petroleum facilities (see Section III.).

2. The principal oceanographic, geologic, and geomorphic characteristics of the study area that relate to the feasibility of facility siting were identified and evaluated. Essentially, the approach involved consideration of the regional characteristics, followed by sub-regional and finally site-specific. This resulted in the identification of a number of sites that fulfilled the technical requirements identified in the first phase 'of the study. A qualitative ranking of high, medium and low feasibility was applied to these sites through a concensus of the sutdy team. (Since this study was designed to provide " preliminary siting evaluation with a limited data base, no sophisticated or quantitative selection and ranking procedure was adopted.)

3. Data on the marine and terrestrial biology, natural resources (fisheries, etc.) and land status were gathered to establish the environmental sensitivity of the technically feasible sites. Each site was ranked (high, medium and low) according to its environmental sensitivity. A final composite ranking of the sites according to the technical and environmental criteria was established through a consensus of the multi-disciplinary study team. Implicit in this ranking procedure was an informal weighting of the various technical and environmental criteria applied on a site-specific basis.

The organization of this appendix reflects the methodology of this study. At the commencement of this investigation, previous studies on petroleum facilities siting in the southcentral Alaska region, in particular Woodward-Clyde's facilities siting analysis for the Kodiak Shelf, were reviewed to provide, if possible, some consistency in siting criteria and study approach (see Section 1.3).

Section II describes the oceanographic, geologic and geomorphic conditions of the northern Shelikof Strait.

Petroleum facility technical siting criteria are defined in Section III. In Section IV the candidate facility sites are selected on the basis of technical feasibility and evaluated according to environmental sensitivity and a final composite ranking of sites is made. A short description of each site according to technical and environmental characteristics concludes the section.

1.3 <u>Previous Studies</u>

Several studies have been wholly or partially devoted to the problem of selecting sites for petrochemical development. In addition to the Dames & Moore studies (1979a, 1979b) three are particularly noteworthy and warrant additional discussion.

A report prepared by the consulting group of Simpson-Usher-Jones (1977) discusses major issues that need to be considered by oil companies, communities, and state and federal agencies in assessing the impacts of a growing petroleum industry. For the Kodiak lease area it addresses the potential benefits and adversities associated with the location of particular types of petroleum facilities. It attempts to weigh those impacts between the cities of Kodiak and Seward. It concludes that the City of Kodiak would function as the initial air transportation link with field development. Seward would at least initially serve as the site of the marine support base for offshore activities. The level of activity would then dictate whether or not permanent facilities would ultimately be based on Kodiak Island. The location of the service base proably would be in the vicinity of another major -Facility, such as a marine oil terminal. Unlike the Dames & Moore approach, the report only mentioned possible broad areas where such major facilities might be constructed (e.g. Ugak Bay). It did not rank sites on either technical or environmental grounds.

The State of Alaska, Department of Community and Regional "Affairs report (1978a), though strictly addressing potential sites in the northern and western Gulf of Alaska, presents a detailed description of the processes leading up to, and operations involved in, the development of a major petroleum industry. It discusses the State's policy toward such development, and from a historical perspective, both within and outside of Alaska, descibes the potential impacts and the demands of such an industry. Social, economic and environmental options are delineated for the siting and timing of petroleum faclities and activities. This report discusses the requirements for , siting facilities both on the east coast of Kodiak and on the Gulf Coast of southcentral Alaska but not in the Shelikof Strait.

The most favorable sites are selected primarily on the basis of logistics and secondarily on environmental grounds. This selection process produced a set of potential development sites similar to those identified by Dames & Moore in their petroleum development scenario study for the Northern Gulf of Alaska (Dames & Moore, 1979a). In a set of scenarios for the Kodiak area, Dames & Moore (1979b) drew heavily on the results of Woodward-Clyde's (1977) report.

The Woodward-Clyde group were presented with several sites on the eastern side of the Kodiak Archipelago. They were charged with ranking the areas selected by the Alaska Department of Community and Regional Affairs as to their desirability as potential sites for the construction of marine oil terminals and service bases. The Woodward-Clyde study, assumed that both support bases and oil terminals would be located together. Their report seemed to weigh the biological issues particularly heavy, placing emphasis on negative impacts while not considering the possible benefits from industrial development. The report attempted to quantify the impacts considered in the screening process.

II. Natural Physical Setting

This section describes the major oceanographic and geologic characteristics of the northern Shelikof Strait area which relate to the natural physical siting requirements of petroleum facilities.

11.1 Oceanography

As with many areas of the Alaska OCS, there is virtually a dirth of oceanographic information concerning the Shelikof Strait. The only permanent weather station in the area is located at the City of Kodiak which may experience considerably different weather conditions than on the northwestern side of the Island. Winds at Kodiak approach from the northwest. more than from any other direction, however, average wind speeds are greater 'from the west-northwest (State of Alaska, 1975). This could be due to a combination of atmospheric conditions and topographic effects.

There has been only a meager attempt at obtaining oceanographic data from the Shelikof Strait and apparently no effort to study the wave and current regimes. Some measurements of currents have been performed in adjacent bays and channels primarily in association with the efforts of NOAA's tide parties.

In an attempt to bridge this gap in available knowledge we have queried long-time residents of the area. These residents have become familiar with the Shelikof Straight by earning their livelihoods through fishing and crabbing in these waters. The following is a consensus of these observations.

The months that the most extreme weather can be anticipated are between October and March with November and February tending to be less severe than other months during this period. Winds generally parallel the axis of the Stait begin from the southwest in the summer and become north-easterlies in the winter. Winds of 40 to 50 knots are common and can often reach speeds of 80 knots. Northwest winds are also common to the area and these can be particularly severe during the winter. This is due to the fact that such winter winds must come across the mountains on the Alaska Peninsula and in so doing attain extremely low temperatures. Icing, under such conditions, can be dangerous and it is generally prudent to seek shelter until conditions improve. These northwest winds can also present a problem to vessels moving through the Strait as they result in beam and quartering winds and seas which can' produce a strong "rolling" motion. It is more stable for a ship or boat to take seas "head-on."

The combined effects of se's and swell paralleling the axis of the Strait can often produce waves from 4.5 to 6 meters (15 to 20 feet) in height, and it is not rare to have waves in the 7.5 to 9 meter (25 to 30 feet) range.

The northern end of Shelikof Strait usually has more severe weather than the southern part. This may be due to the influences and interactions of Cook Inlet, Kamishak Bay, the Barren Islands, and the passages leading in from the Gulf of Alaska.

Large ice flows coming out of Kamishak Bay can be a hazard to smaller vessels north of Cape Douglas. These floes can be from 40 to 50 kilometers (25 to 30 miles) long and from 6 to 8 kilometers (4 to 5 miles) wide. Being relatively soft beach ice, these floes would not generally create any problems for larger vessels. However, larger bergs, several meters thick, within the floes probably should be avoided by a ship.

Currents in Shelikof Strait can be particularly tricky and can have a pronounced effect on the wave field. Tidal flows out of Cook Inlet can either lengthen (if their directions are coincident) or shorten (should their directions be in opposition) waves within the Strait. The latter situation is very common and produces what is locally referred to as the "Shelikof Chop." High frequency, intense motions can result in vessels shorter than about 35 meters which may require a reduction in speed. Current shear zones, which are areas where differently directed currents meet (often referred to as rips), are common in the Strait and can be sites of large accumulations of floating debris. Such locations probably should be avoided if possible.

Currents enter Shelikof Straits from both the north and south on the flood. The water from the south is of greater density than the incoming northern water, owing to the influence of the Cook Inlet estuary to the north. As a result of the earth's rotation, the southward flowing stream occupies a position close to the Alaska Peninsula while the water flowing north lies to the east (Wright, 1970). The southward flowing current forms a relatively permanent feature and flows past the Kodiak Archipelago along the Aleutian Islands.

The Strait displays relatively uniform depths in traverses perpendicular to its axis. It deepends from north to south, having depths of approximately 145 meters (480 feet) and 180 meters (600 feet) on the northern and southern boundaries of the present area of interest, respectively. No apparent major depth anomalies occur within this region.

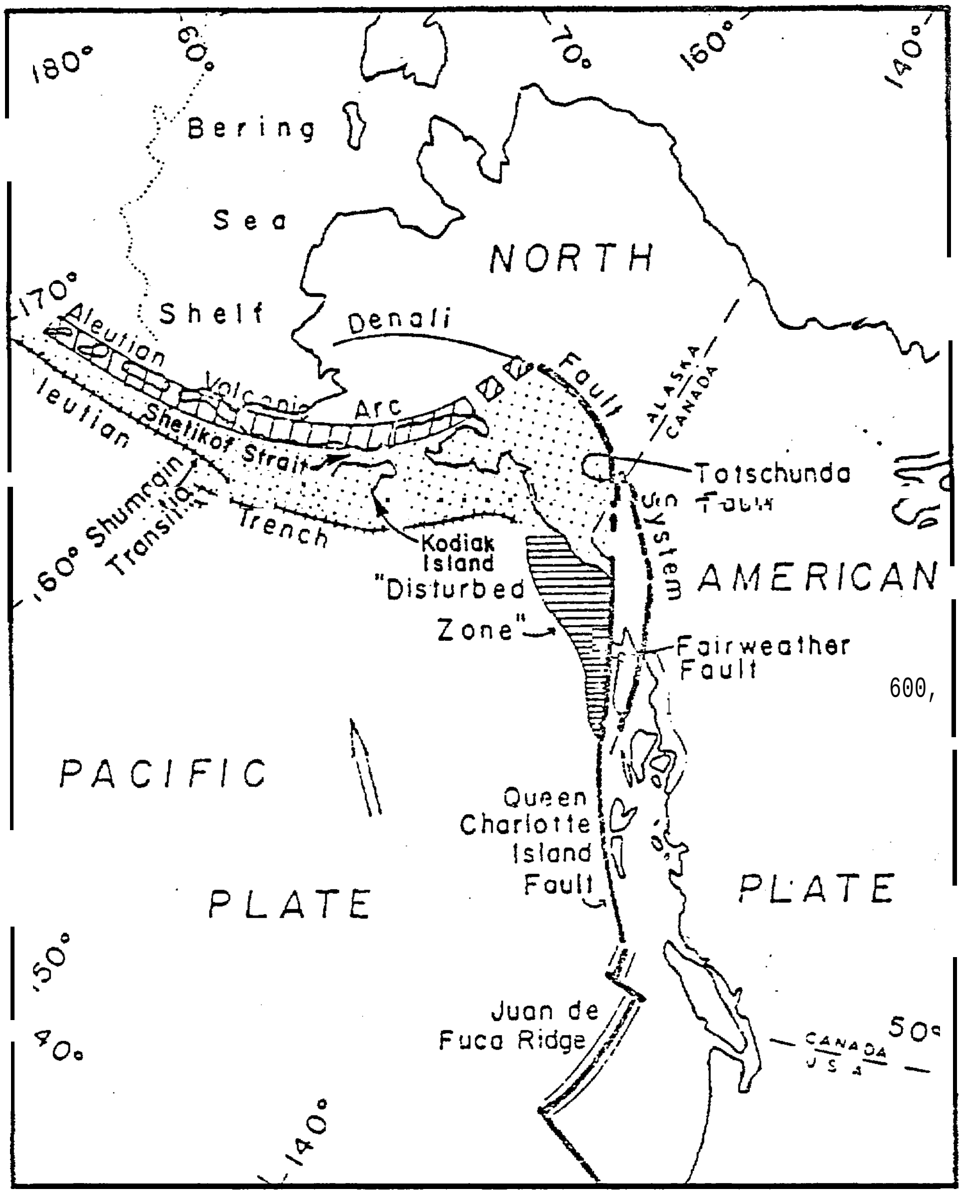
Tides generally increase toward the north (NOAA, 1979a), possibly showing the influence of Cook Inlet as this trend continues to the head of that estuary. However, due to local topographic and bathymetric effects within certain bays and inlets, this trend can reverse locally.

Tidal currents within the Strait probably are under 1-1/2 knots. However, currents in the passages that connect the eastern and western sides of the Archipelago can in places exceed 5 knots, for example, in Whales Passage maximum currents are 5.2 knots (NOAA, 1979b).

11.2 Geology and Geologic Hazards

II.2.1 Tectonic Setting

Shelikof Strait, adjacent to the central Pacific coast of Alaska, is a northeast-southwest trending body of water approximately 40 kilometers (25 miles) wide and 160 kilometers (100 miles) long that separates the Kodiak Archipelago from the Alaska Peninsula (Figure E-l). The region surrounding the Shelikof Strait is considered to be one of the most tectonically active areas in the world. South of the Kenai and Alaska Peninsulas and along the Aleutian Islands the Pacific Plate is believed to be underthrusting the North American Plate north of the Aleutian Trench (Figure E-2). This plate motion



Schematic map of Alaska showing major tectonic features along Pacific-North American plate boundary. Arrow indicates present direction of relative motion between the two plates. Stippled area indicates area above shallow-dipping Benioff zone. After Naugler and Wageman (1973), as presented by Woodward-Clyde Consul tants, 1978.

FIGURE E-2

MAJOR TECTONIC FEATURES IN ALASKA

is suggested by:

- The arcuate system. of islands with associate active volcanoes
- The paralleling oceanic trench seaward of the volcanic island arc
- The dipping zone of high seismic activity (the Benioff Zone) that extends from the trench northward beneath the volcanic island arc

Immediately north of the Aleutian trench, a paralleling anticlinal ridge with slumps along its over steepened south-facing slope, suggest that the Pacific Plate is colliding with the North American Plate and crustal shortening may be occurring.

Tectonism dominates the structural fabric of the region surrounding the Shelikof Strait. The structural features in this area are a physical manifestation of the plate interactions. Elongate structural blocks, standing at different elevations and paralleling the trench-island arc system, are separated by steeply dipping fault planes. Structural relief between a ridge-basin pair can exceed 2500 meters (8200 feet). The Shelikof Strait and its northeastward extension, the Cook Inlet, is probably a fault bounded down-warped graben. Some consider parts of this structural low to be a down-warped syncline. Adjacent to the Shelikof Strait are structural highs; the Kodiak Archipelago (part of Kenai-Chugach Mountains) to the southeast and the Aleutian Range to the northwest.

The surface of the structural blocks have been modified by volcanic, glacial, fluvial, or marine activity or by some combination of the above. The highlands northwest of Shelikof Strait have been dominated by volcanic and subsequent glacial-fluvial activity while the highland to the southwest have been modified by glacial-fluvial activities. Shelikof Strait is a flat-bottomed, steep-walled, submerged glaciated valley. Subsequent to the episodes of glacial activity, the glaciated floor of the Strait has been mantled by accumulations of marine sediment. The average depth of the bottom of Shelikof Strait is on the order of 150 meters (500 feet) to 275 meters (900 feet) with the maximum depth approaching 335 meters (1,100 feet).

11.2.2 Geology

Information concerning the geology of the Shelikof Strait region is available from:

- Studies of bedrock exposue on the structural highs
- Limited onshore drillhole data
- Offshore bottom sampling data
- Reconnaissance-level geophysical surveys

The "at depth" geology of this region can be surmised, in part, by extending into this area 'ion trend structural features" in adjacent areas for which more geologic information is available. A geologic map of the Shelikof Strait region is shown on Figure E-3.

The structural grain of the Shelikof Strait region consists of elongate northeast-southwest trending structural blocks separated by steeply dipping faults. Shelikof Strait is part of a structural low that is bordered on the northwest by the Bruin Bay fault and on the southeast by the Border Ranges fault. This down-dropped structural feature and its northeastward extension, the Cook Inlet, and the Susitna lowland, marks the position of a trench that was active through late Mesozoic time (Woodward-Clyde Consultants, 1978).

The boundary fault to the southeast of Shelikof Strait, the Border Ranges fault, is recognized primarily by the juxtaposition of rocks of differing geologic age and character and not by recent geomorphic indicators or by seismicity. Although historically inactive, the prominant scarps along portions of the Border Ranges fault (Kenai Peninsula area) suggest this fault may have been active through late Tertiary time (Thrasher, personal communication). The boundary fault to the northwest of Shelikof Strait is recognized by the juxtaposition of rock of differing geologic age and character by seimicity. This fault may be active.

The bedrock underlying the Shelikof Strait region includes granitic and volcanic assemblages and metamorphic and sedimentary strata of Paleozoic through Tertiary age.

Northwest of Shelikof Strait, the Bruin Bay fault separates Mesozoic granitics of the Aleutian Range batholith from midly deformed and faulted Mesozoic sedimentary strata to the south. Locally these Mesozic strata have been intruded and flooded by outpourings of late Tertiary to recent volcanics. The volcanic rock is dominated by basaltic and andestic flow and associated pyroclastic deposits.

Interpretation of seismic records for the Shelikof Strait (Magoon, et al., 1978) indicates the presence of up to 2,000 meters (6,560 feet) of folded Cenozoic strata. Seismic reflection from a probably Jurassic surface are returned from a depth of approximately 4,000 meters (13,120 feet). On the southeast side of the Strait, seismic data show Mesozoic strata dipping northwest and truncated southeastward across the Strait by an unconformity at the base of Cenozoic strata (Magoon, et al., 1978). Throughout most of the Shelikof Strait, the bedrock is eroded and the folded upper surface is covered with stratified horizontal sediments that are typically 50 meters (160 feet) thick but may reach a thickness of 200 meters (650 feet) in localized bedrock depressions (Magoon, et al., 1978).

Southeast of Shelikof Strait on the Kodiak Archipelago is a belt of Mesozoic and older, through Tertiary age, rocks that are dominated by argillites and greywackes (Wahrhaftig, 1965). These rock units, having a northeast-southwest trend, become progressively younger southeast across the mountain range. The oldest rocks in the area are Paleozoic and Mesozoic metamorphic rocks chiefly greenstone and schists with associated granitics that are confined to the northwest edge of Kodiak Archipelago northwest of the Border Ranges fault. This rock unit dips steeply to the northwest. Southeast of the Border Ranges and extending beyond the Eagle River fault to the Contact fault is a zone of Mesozoic melange and flyschlike strata (Neil son amd Moore, 1979). The main divide of Kodiak Island is underlain by a granitic batholith of early Tertiary age. Southeast of the Contact fault is a zone of Tertiary rock represented by a highly deformed belt of early Tertiary turbidite and related mafic volcanics and a more oceanward zone of less-deformed, 'later Tertiary argillites.

II.2.3 Seismicity

The Gulf of Alaska - Aleutian Island arc region in which the Shelikof Strait is located is seismically one of the most active areas in the world.

Woodward-Clyde Consultants (1978) has compiled a historic seismicity record for the tectonically active areas of Alaska. Glen Thrasher of the USGS has reviewed the seismicity data compiled by Woodward-Clyde Consultants. According to Thrasher (personal communication, 1979) there is a good correlation between the larger earthquakes (Magnitude 6-8) and tectonic features while the smaller earthquakes (Magnitude 2-6) show less of a correlation. It is likely that correlation difficulty may be attributable to inaccuracies in the assigned locations and focal depths of the smaller earthquake, this being particularly true for the pre-1970 earthquakes (Thrasher, personnal communications).

Although Shelikof Strait is located in a region of relatively high seismicity, Woodward-Clyde considers the Shelikof Strait area to lie within a zone of "minimal seismic exposure". The finding is based upon the maximum expected spectral velocity associated with a 100-year return period earthquake.

A seismicity map and cross section for the site region (Woodward-Clyde Consultants, 1978) are shown on Figure E-4. As shown on the figure, there are three zones where seismic events are concentrated. These zones are described:

- landward of the oceanic trench

- along the northwest dipping zone (Benioff Zone) that extends from the oceanic trench downward beneath the North American Plate

- beneath the volcanic arc area

11.2.4 Surficial Geology

During Pleistocene time (past 2-3 million years) the Shelikof Strait region has been modified through volcanic, glacial, fluvial and marine activities as well as through tectonism.

As described previously, the bedrock floor of Shelikof Strait has been eroded. During the Pleistocene ice ages when sea level was lower than its present stand, glaciers scoured their way down-gradient through the Cook Inlet-Shelikof Strait lowland area towards the Pacific Ocean. Several periods of glaciation are represented by the glacial deposits in the Cook Inlet-Shelikof region. Terminal and lateral moraines, predominantly gravels and boulders mixed with till, are likely to be encountered in the seafloor sediments of Shelikof Strait.

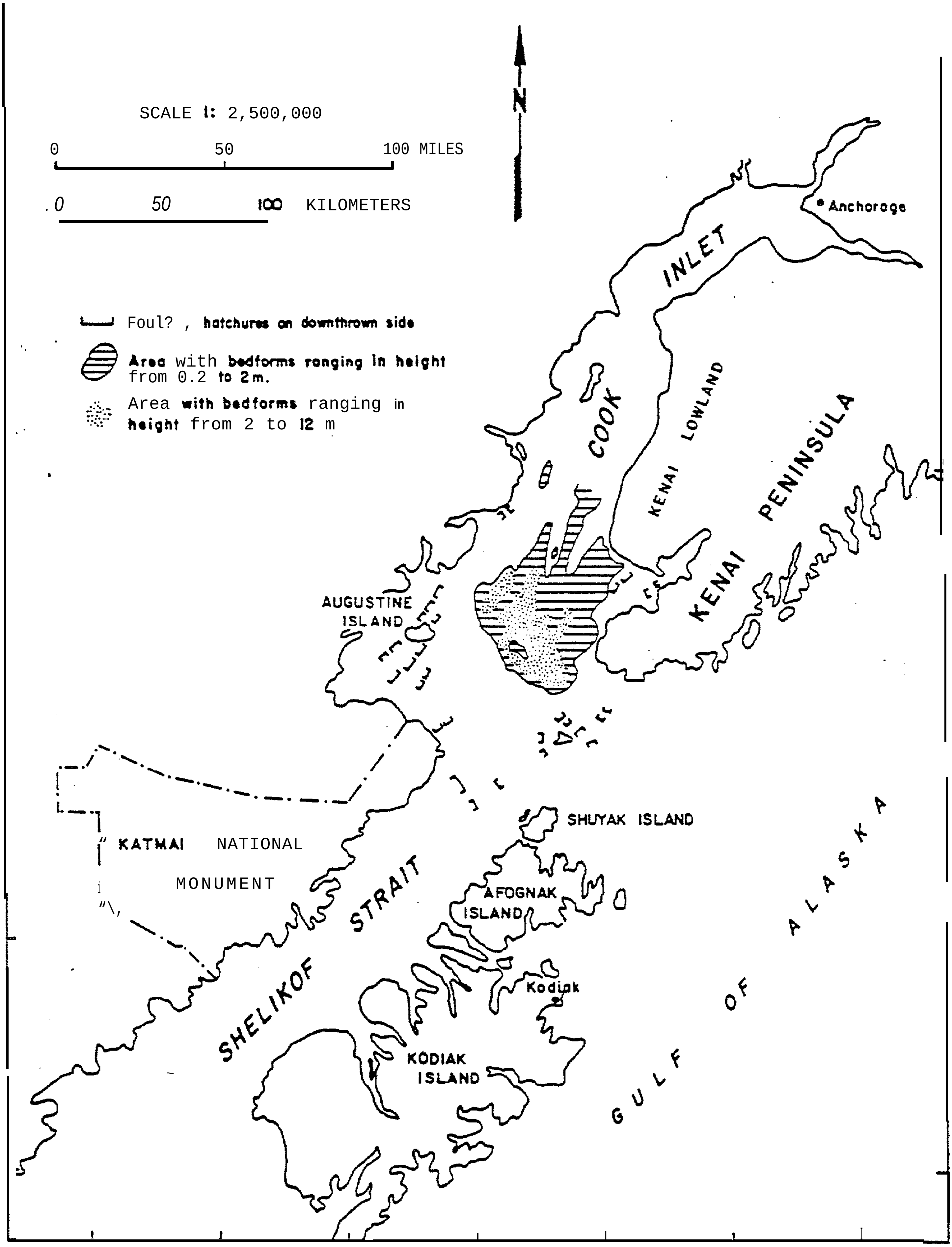
Subsequent to the periods of lowered sea level; when the glaciers were retreating, the sea advanced inland inundating the glaciated valleys. Marine sediments have since blanketed much of the floor of" Shelikof Strait with as much as 50 meters (160 feet) to 200 meters (650 feet) of horizontally stratified deposits. The deck log from a University of Alaska bottom sediment sampling program conducted in the Kodiak Island area (Wright, 1970) indicates that the surficial sediment of Shelikof Strait is dominated by both stiff and very soft grey muds. According to Thrasher (personal communications, 1979) who has sampled similar deposits on the Kodiak Shelf, the stiff grey muds are of probable glacial origin while the softer muds are probably of marine origin.

The highlands surrounding Shelikof Strait also show the effects of glaciation. The volcanic dominated terrain northwest of the Strait and the Alpine Mountains to the southeast of the Kodiak Archipelago have been scoured by advancing glaciers. In post-glacial times alluvial deposits issuing from the glaciated valleys have blanketed the lowland areas. The inlets draining into Shelikof Strait have also undergone glaciation" and subsequent infilling by fluvial/marine processes.

Inspection of the reconnaissance level geophysical records indicates that' the horizontally-stratified, recent sediments within Shelikof Strait are relatively free of fault offsets with the only concentration ocurring in the northern Shelikof Strait (Figure E-5). It is interesting to note that the orientation of the offsets with the downdropped side to the southwest is' oblique to the northeast-southwest structural grain of the area. It is possible that some of the scarps may be depositional or erosional features rather than tectonic. Similar cross-cutting features on the continental shelf off Kodiak have been interpreted as morainal scarps of glacial . origin (Thrasher, personal communication). A shallow, high resolution geophysical survey scheduled by the USGS during the summer of 1979 will run over 2500 kilometers (1600 miles) of geophysical ines in Shelikof Strait. This information, which will add substantially to the existing body of geophysical data for Shelikof Strait, should become available in late 1979 or early 1980.

11.2.5 Geologic Hazards

Geologic hazards in the tectonically active region of Alaska are often associated with seismic events. The 1964 Alaska Earthquake caused widespread damage across much of the southcentral Alaska coastal regions and " Kodiak Island areas. As earthquakes of magnitude 6.0 or greater have been numerous throughout the site region during at least the past 50 years, similar magnitude earthquakes are a virtual certainty in the site region during the next 50 years. Consequently, seismically induced geologic hazards can and should be expected in this region during the design life of the proposed facility.



(Magoon, et al., 1979)

FIGURE E-5

SURFACE FAULTS IN RECENT SEDIMENT OF SHELIKOF STRAIT

The 1964 earthquake, besides rupturing the ground surface and causing regional uplift and subsidence, triggered many landslides and rock falls, caused consolidation and liquefaction of soils, generated destructive seismic sea waves (tsunamis), and induced seiching in enclosed basins. Plafker and Kachadoorian (1966) investigated the destruction on Kodiak Island associated with the 1964 earthquake and found that most earthquake-related damage occurred in areas underlain by unconsolidated, water-saturated sediment while the" least damage occurred in areas underlain by well-indurated rock. This relationship is depicted in Figure E-6, where the Mercalli Intensities (measure of destruction with higher values indicating increased destruction) are plotted over much of Kodiak Island. As shown on Figure E-6, damage was greatest in areas underlain by unconsolidated, water-saturated sediment and least in areas underlain by lower Tertiary and Mesozoic rock. The theory that the severity and duration of earthquake vibrations are enhanced by unconsolidated ground, particularly when it is water-soaked, was borne out by the distribution of vibration induced damage in the area (AEIDC, 1975). "

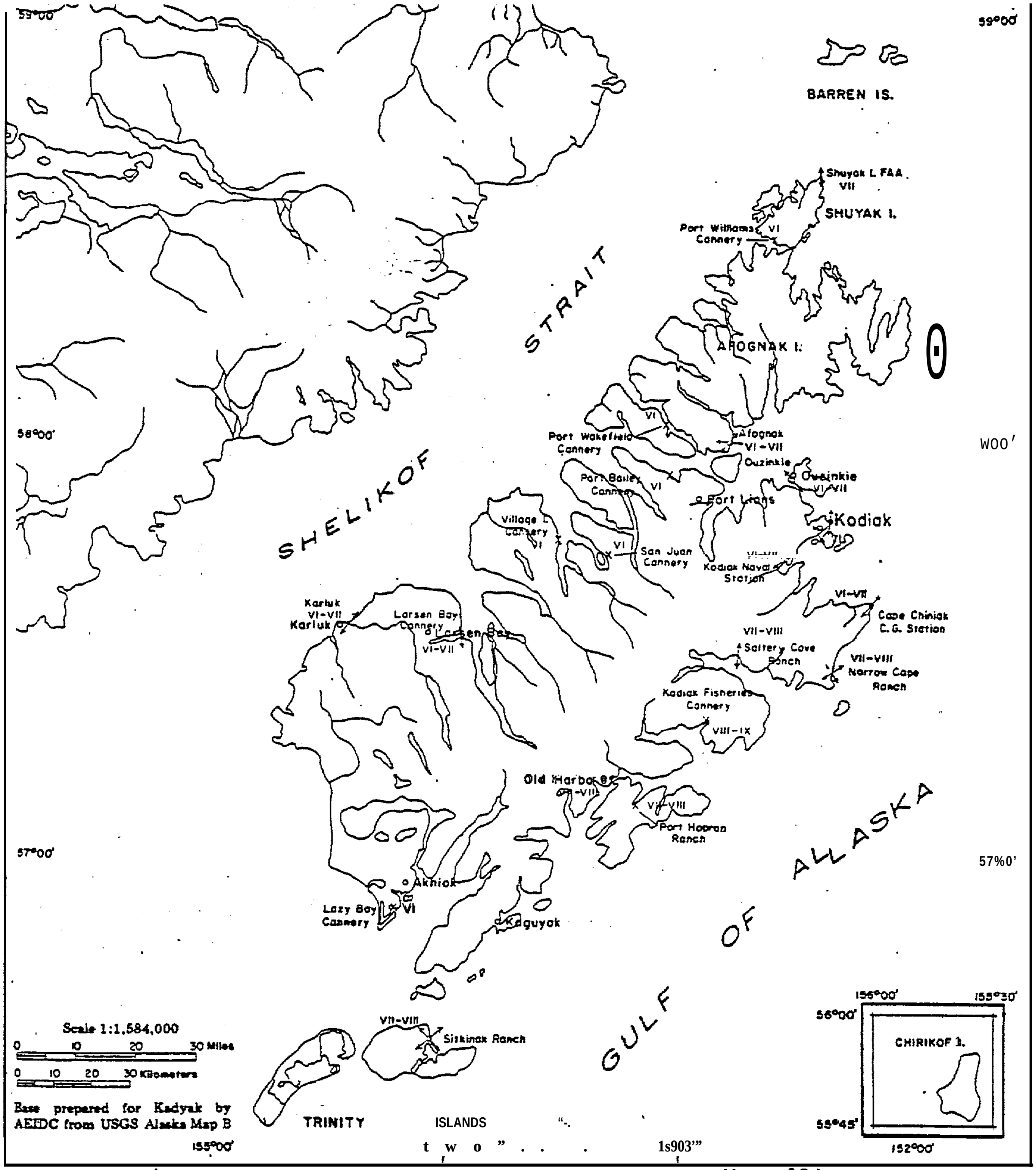
Many geologic hazards may be associated with non-seismic events. Soil instabilities may also result from over-saturating and/or overloading surficial material on slopes. Volcanic flows and ash falls are another non-seismic geologic hazard.

Potential geologic hazards in the site region are described below. The conditions which promote the occurrence of the geologic hazard are discussed as well as any correlation between geologic hazard and physiography, lithology, or region.

11.2.6 Seismically Related Geologic Hazards

11.2.6.1 Ground Rupture

Ground rupture is commonly associated with large earthquakes. Along major fault zones there are likely to be paralleling (en echelon) sets of ruptures. These rupture surfaces may be reactivated during earthquakes.



Reported ground motion, sounds, ground waves, and assigned Mercalli intensities over most of the Kodiak Island Group are shown here. The directions of ground motion are shown by arrows, localities where sound are reported by solid circles, and areas where ground waves were reported by open circles. Roman numerals indicate local Mercalli intensity. Direction of ground motion apparently varied widely. The intensity or destructive potential of the vibrations also varied considerably, and appeared to be closely controlled by the local geological environment. Stronger and longer-lasting vibrations occurred in areas of unconsolidated deposits in contrast to bedrock sites. Adapted from Plafker and Kachadoorian (1966), as presented by AEIDC, 1975.

FIGURE E-6

MERCALLI INTENSITIES, 1964 EARTHQUAKE

Of the three major faults in the Shelikof Strait region -- Bruin Bay, Border Range, and the Eagle River -- only the Bruin Bay fault may be active. The U.S.G.S. (Magoon, 1978) observed some significant surface "offsets in the geophyscial records for northern Shelikof Strait, however, these offsets have not been linked as yet to any known faults. A geophysical survey of Shelikof Strait conducted by the U.S.G.S. in the summer of 1979, should provide additional information on any recent faults. When siting facilities or routing pipelines in the Shelikof Strait area effort should be made to locate these structures well away from active faults.

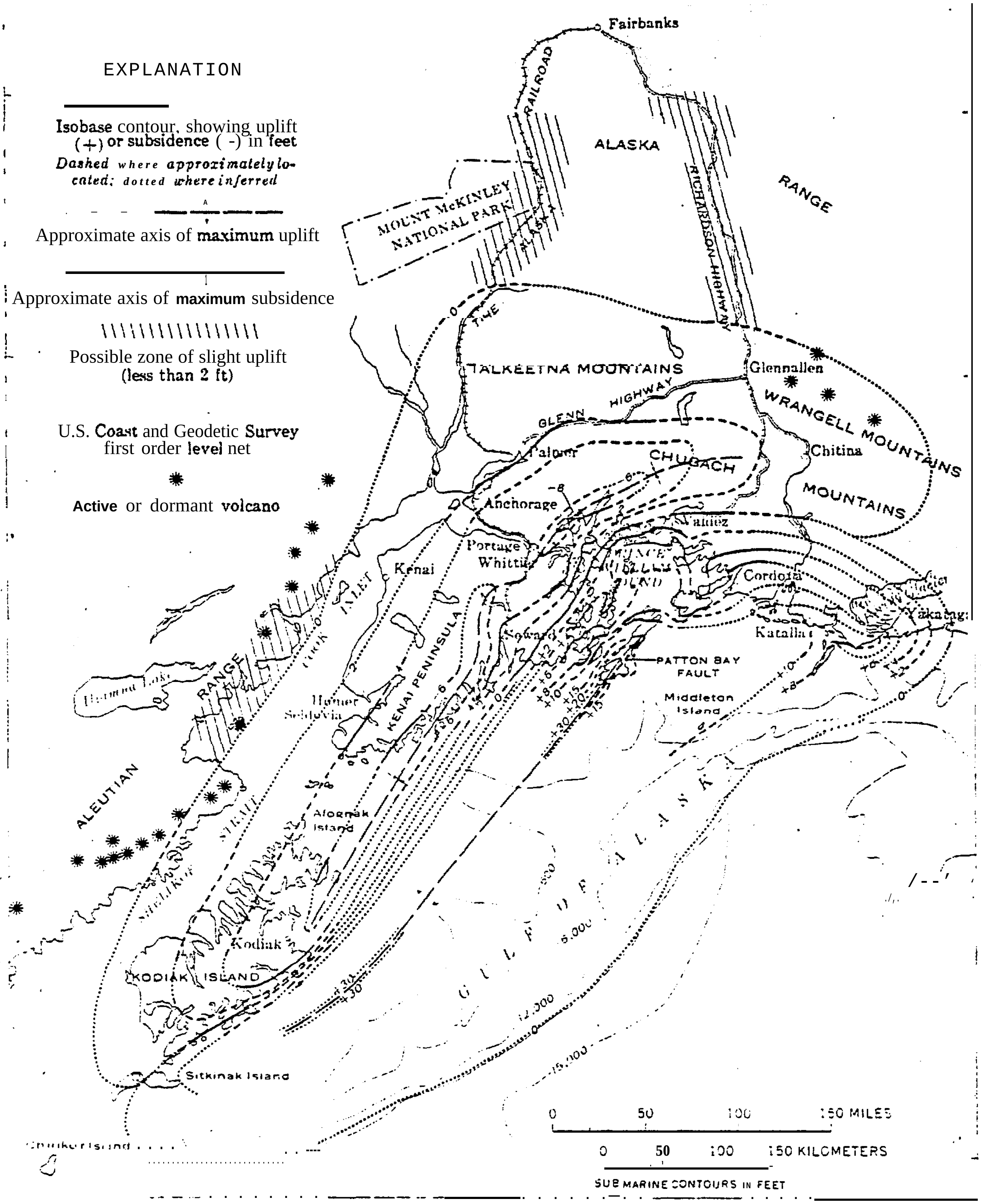
11.2.6.2 Regional Subsidence"and/or Uplift

Major earthquakes may produce uplift or subsidence across broad areas or uplift and subsidence in adjacent areas. The 1964 Alaskan Earthquake caused both uplift and subsidence across broad reaches of the Gulf of Alaska and ajoining lowlands (see Figure E-7). Tectonic displacements as great as 11.6 meters (38 feet) have been reported for the 1964 earthquake (Plafker, 1966) . A significant vertical motion can render a coastal faclity unusable " as it can put the facility out of reach of water or flood the originally dry land or structures (Magoon, 1968).

As shown on Figure E-7, the Kodiak Archipelago is situated in a regional zone of subsistence whose trough plunges northeast roughly along the axis of the Kodiak Range (Plafker and Kachadoorian, 1966). Maximum subsidence of the area is in the 1.8 - 2.3 meters (6 to 7-1/2 feet) range. As yet, there is no way to predict what areas may experience tectonic displacement.

11.2.6.3 Landslides and Rockfalls

-Seismic events can trigger landslides, submarine slides, and rockfalls. Thick deposits of saturated, unconsolidated material on steep slopes can increase the likelihood of a major slide. Commonly, landslides involve surficial material although the zone of potential failure can be deepseated possibly involving the bedrock. Rockfalls commonly occur along precipitous slopes and are promoted by fracturing and low consolidation of the rock mass, heavy rainfall and intermittent freezing conditions.



(Source: Plafker, 1966)

FIGURE E-7

DISTRIBUTION OF TECTONIC UPLIFT AND SUBSIDENCE IN SOUTH-CENTRAL ALASKA

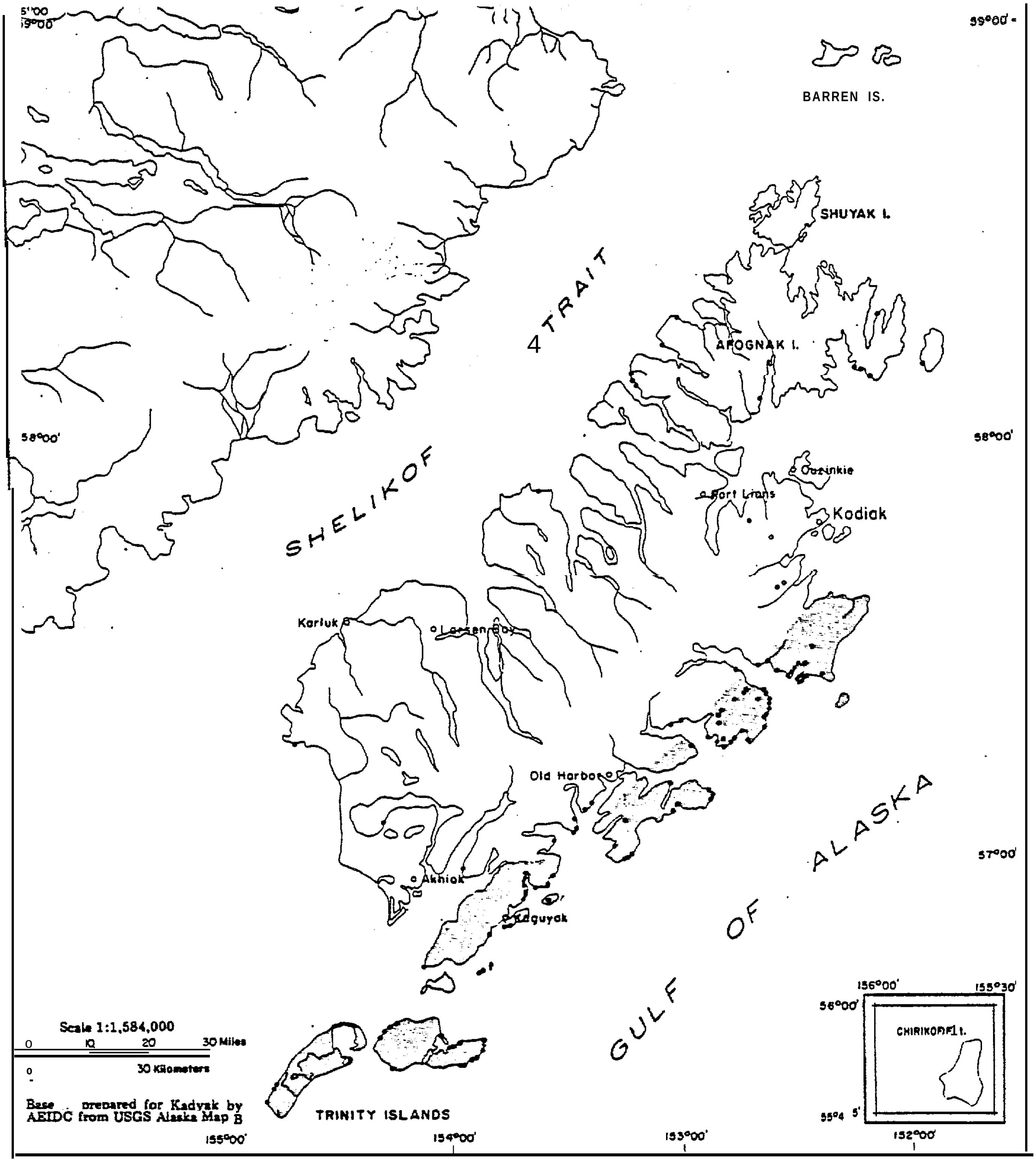
The 1964 Alaskan Earthquake triggered many landslides on Kodiak and adjacent islands (see Figure E-8). As shown on Figure E-8, the landslides were generally limited to a narrow belt of easily eroded Tertiary rocks on the southeast side of Kodiak Island. The zones of pre-Tertiary rock had far fewer landslides. This lower incidence of landslides is attributed to the rocks' greater resistance to chemical and mechanical breadkown. Although no significant submarine landslides were reported in the Shelikof Strait during the 1964 earthquake (AEIDC, 1975), the relatively thick cover of muddy sediment in the Strait suggests that seismically induced submarine slides are possible. There were only isolated reports of rockfalls occurring on Kodiak Island in 1964.

The steep slopes bordering the shoreline on the southeast side of Shelikof Strait may represent a potential geologic hazard. Although this area did not experience many landslides or rockfalls during the 1964 earthquake, these types of events can be expected on the glacially oversteepened slopes in the future. Efforts should be made to locate the facility in areas which do not have a history of recurrent landslides or rockfalls as indicated by recent scarps or soil instabilities. The slopes along the shoreline northwest of Shelikof Strait, because of their lesser gradient, should pose less of a geologic hazard.

The steep submarine slopes flanking Shelikof Strait and along the inlets southeast of the Strait also may represent a geologic hazard. Pipelines should be routed around areas which have any of the following characteristics: steep slopes, unfavorable soil conditions, or a history of previous slides or soil instabilities.

11.2.6.4 Soil Instabilities

Seismic vibrations can induce many types of soil failures. Among them are liquefaction, consolidation, sliding, ground fissuring, and sand intrusion. Most of the soil instabilities associated with the 1964 earthquake were restricted to non-consolidated alluvial and beach deposits. The areas most severely effected were deltaic areas having thick deposits of unconsolidated, saturated sediments. Local subsidence of as much as 3 meters (10



General ized distribution of the larger landslides and soil slips triggered by the March 27, 1964 earthquake on Kodiak Island and nearby islands. Areas underlain by rocks of Tertiary or probably Tertiary age are shaded. Adapted from Plafker and Kachadoorian (1966), as presented by AEIDC, 1975.

FIGURE E-8

LANDSLIDES GENERATED BY 1964 EARTHQUAKE

feet) was widespread in noncohesive granular deposits through compaction, flow, and sliding that resulted from vibratory loading during the earthquake (Plafker and Kachadoorian, 1966). Structural failures in alluvial areas during the 1964 earthquake resulted from vibration as well as from undetermining caused by soil instabilities, principally liquefaction and differential. settlement.

In siting a facility or routing a pipeline in the Shelikof Strait region, areas having thick unconsolidated deltaic, fluvial and/or beach deposits should be avoided. Long reaches of the shoreline on the northwest side of Shelikof Strait are dominated by thick unconsolidated beach and deltaic deposits. There appears to be a general absence of thick alluvium on the southeast side of the Strait except where localized as beach or as deltaic deposits.

11.2.6.5 Generated Waves

There are several types of waves than can be generated directly or indirectly by an earthquake. These include tsunamis, seiches, backfill, and far-shore waves.

Tsunamis (seismic sea waves) are often associated with underwater earthquakes involving vertical displacement of the sea floor. Tsunamis generated by the 1964 earthquake were particularly destructive along the southeast coast of Kodiak Island. The shore was repeatedly hit by destructive waves having run-ups along the exposed coastline of perhaps 12 meters (40 feet) and 2.4 to 3.7 meters (8 to 12 feet) along the protected shores (Plafker and Kachadoorian, 1966). Run-up heights were much less on the northwest and southwest sides of the Island with no damage being reported.

Seiching, the forced oscillation of a body of water, resulted from the sudden tilting (tectonic displacement) of Kenai Lake (McCulloch, 1966). McCulloch reported run-up values of 6 to 9 meters (20 to 30 feet) along the constricted and shallow reaches of the lake.

Backfill and far-shore waves, generally considered to be a special class of tsunamis, are generated by slides. Backfill waves, described by McCulloch (1966) for Kenai Lake during the 1964 earthquake, are created as water propagates inshore to fill a void formed by a sinking nearshore slide mass. Run-up as high as 9 meters (30 feet) were reported for Kenai Lake by McCulloch. Far-shore waves, also described by McCulloch for Kenai Lake are formed by slide masses which enter the body of water forcing a propagating wave ahead. McCulloch (1966) reports run-up heights exceeding 21 meters (70 feet) for far-shore waves in Kenai Lake during the 1964 earthquake.

Miller (1960) investigated the waves generated in Lituya Bay, Alaska by massive landslides. On the basis of the sharp trim lines which marked the upper limit of wave damage, Miller showed that a giant wave reached a maximum altitude of over 518 meters (1,700 feet) and other waves reached a maximum altitude of between 24 and 143 meters (80n and 470 feet).

The coastal zone in the Shelikof Strait area is susceptible to damage by seismically generated waves. These potential geologic hazards can be reduced or eliminated by judicious siting of the coastal facility. Prior to construction of petroleum facilities, a thorough risk analysis would be needed to evaluate the likelihood of these events. Then avoidance procedures and mitigation measures would be made part of the design.

11.2.7 Non-Seismically Related Geologic Hazards

11.2.7.1 Landslides

Landslides may result from saturating and/or overloading of slopes. The slide may involve only surficial slope material or both surficial slope material and bedrock. 'The Pillar Mountain landslide on Kodiak Island has shown continued movement. This landslide is probably driven by a combination "of steep slopes, saturated slope material, and inherent weakness (unconsolidated material with penetrating joint sets) in the bedrock.

11.2.7.2 Volcanic Activitv

The region northwest of Shelikof Strait on the Alaska Peninsula is an area of active or potentially active volcanoes. Many of the volcanoes have erupted in historic times. Volcanic flows and ash falls dominate the terrain. Coastal facilities on the northwest side of the Strait could be threatened by nuees ardentes, volcanic mudflows, and ash falls. Ash falls during past eruptions blanketed most of the Shelikof Strait region, including the Kodiak Archipelago, with several centimeters of ash. Many of the mudslides in the area may result from liquifaction of volcanic ash.

11.2.7.3 Sand Waves

Sand waves with amp" itudes on the order of 12 meters (40 feet) and wave lengths of 30 to 60 meters (100 to 200 feet) have been reported in Cook Inlet . . . . Active sand waves are migrating features. Pipelines laid down across a zone of sand waves may be subject to failures as sections of the pipeline may be undermined and unsupported during sand wave migration.

Sand waves may be present locally in Shelikof Strait. Sediment sampling programs conducted by Wright (1970) indicated that the bottom sediment is dominated by stiff to very soft muds. This finding suggests that sand waves are not a general feature of the Strait. Side scan sonar, as part of the scheduled USGS geophysical survey for Shelikof Strait, should identify sand waves if they are present.

11.2.8 Topography

Topography was considered as a site selection criteria in this analysis although large scale topographic maps with closely-spaced contour intervals (e.g. less than 50 feet or 15 meters) are lacking for this area. Elevations between sea level and 30 meters (100 feet)" were considered as prospective construction areas if sufficient land were available within the contour interval. Areas such as mud flats were excluded. More site specific data are required to assess the flood and tsunami hazard. With respect to the latter, it is assumed that critical facilities (e.g. storage tanks, process equipment) would no doubt be located on the higher ground at a site to avoid exposure to such a hazard.

111. Petroleum Facility Technical Siting Criteria

111.1 Introduction

A combination of several key technical factors generally dictate potential petroleum facility sites. For example, vessels either servicing, or being serviced, by a particular facility have certain draft requirements. Inclement weather can create a substantial amount of lost time in unprotected harbors. Workable transportation schemes must be available to get supplies either to or from particular locations. In addition, technology must be available to mitigate sensitive environmental problems. This aspect will be addressed separately in a later section. Seldom does a single site rate highest in every technical and environmental category. Generally, the final solution involves compromise among economic, environmental and social concerns.

In ranking or weighing site selection criteria, it should be recognized that most limitations can be overcome provided the economics are favorable.

The present discussion considers, in addition to resource proximity, vessel facilities, navigation, and land requirements as the prime technical factors that impact the selection process. Herein, site requirements for the folowing types of facilities will be described:

- Temporary and permanent service bases
- Construction support base
- Marine oil terminals
- Pipeline routings and landfalls

Technical requirements for these facilities and routes are presented in Table E-1.

Locating and constructing a major petroleum facility demands that many factors be considered. A list of these concerns, though certainly not all inclusive, includes:

- Proximity to resource
- Navigation requirements[1]
- Land availability
- Ecological considerations
- Geotechnical concerns
- Land status

Additional concerns have been addressed in reports by Alaska Consultants, inc., (1976), and the New England River Basin Commission (NERBC, 1976). Also an excellent source of information is a recent publication by the State of Alaska (1978a).

(1) Navigational considerations also include the presence of other vessel traffic. Kupreanof Strait, for example, has heavy fishing vessel traffic. If an oil terminal were to be located there, shipping lanes and additional navigation aids would probably be introduced to regulate traffic and ensure safety. As such, the presence of fishing vessel traffic in Kupreanof Strait was not considered as a major adverse criterion in the evacuation of potential Kupreanof Strait sites.

TABLE E-1

SUMMARY OF PETROLEUM FACILITY SITING REQUIREMENTS

Facility	Land Hectares (acres)	Water Depths Meters (Feet				No. of Berths	Minimum Dock Frontage Meters (feet)	Minimum Turning "Basin Diameter Meters (feet)	Comments
		Harbor Entrance	Channel	Turning Basin	Berthing Area				
Service Base[1]	2-16 (5 - 40)	9.1 (30)	6 (20)	6 (20)	5.5 (18)	1 -4	61 (200)	150 - 240 (500 - 800)	
Construction Support Base*	16 - 30 (40 - 75)	"	"	"	"	5-1o	305 - 610 (1000-2000:	305 - 455 (1000 - 1500)	Requires additional 61 meters of dock space for each pipelaying activity being conducted simultaneously and each additional 4 platform installation per year.
Marine Oil Terminal[1,3,4]	30 - 300 (75 - 740)	15 -23 [50 - 75)	14 - 20 (46 - 66]	13- 19 (42 - 61)	12 - 18 (40 - 58)	1 -4	455 - 1030 (1500- 6000)	1220 (4000)	Required space in turning basin can be reduced substantially should tug assisted docking & departures be required.

[1] State of Alaska. 1978a

[2] Alaska Consultants, Inc., 1976

[3] Trainer, Scott and-Cairns, 1976

[4] NEDRC, 1976

Temporary service bases are sited close to the exploration area and preferably at already existing facilities to minimize investment. They require a sheltered harbor with an entrance depth relative to MLLW on the order of 9.1 meters (30 feet). Depths along the dock and in the channel need to be at least 5.5 meters (18 feet) and 6 meters (20 feet), respectively.

Temporary service' facilities probably will not be sited in this area, since using the Northern Gulf of Alaska experience, Seward and possibly Homer"would be suitable and permit a minimum investment.

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111.2.2 Permanent Service Base

As the offshore activities increase and the field operations mature from the exploration to the development phase, temporary service bases generally give way to the permanent service base. Should this occur, it would mean that the exploration phase has been sufficiently successful to warrant additional support facilities. These can often be extensions of temporary facilities. If new facilities are constructed, they are generally located more strategically with respect to the offshore activities than were the temporary service bases owing to the fact that more would be known about the find. Additional acreage and dock space would usually be required and more permanent structures erected. As with the temporary base, these need all-weather, sheltered harbors with similar depth requirements.

111.2.3 Construction Base

Construction bases are used to support offshore pipelining operations and installation of platforms. They are generally temporary facilities but can become permanent should the level of activity warrant such a facility.

Proximity and depth requirements are essentially the same as with the temporary and permanent service bases, approximately 2 hectares (5 acres) are needed for each pipeline spread and for each four platform installations

111.2 Facilities

111.2.1 Temporary Service Base

Temporary service bases are used primarily in support of exploratory drilling. They serve as depots and terminals for the transportation of supplies and personnel between the rig and shore. As with most petroleum facilities, there is a minimum land size that must be available. The minimum space requirement for a single-berth base serving only one exploratory drill rig appears to be about 2 hectares (5 acres). However, should ample space be available, this minimum requirement may be exceeded several times over. While 2 hectares (5 acres) per rig is a reasonable rule of thumb, savings can be obtained from multiple rig operations owing to the fact that services and space can be shared. For example, only 5 hectares (12 acres) might be used to service three rigs (State of Alaska, 1978).

Temporary service bases are sited close to the exploration area and preferably at already existing facilities to minimize investment. They require a sheltered harbor with an entrance depth relative to MLLW on the order of 9.1 meters (30 feet). Depths along the dock and in the channel need to be at least 5.5 meters (18 feet) and 6 meters (20 feet), respectively.

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Proximity and depth requirements are essentially the same as with the temporary and permanent service bases, approximately 2 hectares (5 acres) are needed for each pipeline spread and for each four platform installations per year. A minimum of 61 meters (200 feet) of dock space is required and an additional 61 meters is desirable for each simultaneously operating spread.

111.2.4 Marine Oil Terminal

Should oil be found in economic quantities, it must at some point be brought to shore for processing in preparation for transshipment to other locations. Transportation is either overland through a pipeline or via crude oil tankers. For the latter, which is the type of facility considered herein, ample storage for the crude oil must be provided. The tanker size and the number of ship calls at the terminal are dictated primarily by the throughput capacity of the facility, but also depend on the loading systems being used. For example, often larger ships can be accommodated at offshore "loading bouys rather than being forced to use shoreside facilities with depth restrictions. An example of this type of system is the Drift River terminal on the west side of Cook Inlet. Often, however, this system exposes a tanker to more severe weather than it would be likely to encounter at the dock/terminal combination.

Fixed loading facilities can consist of either shoreside docks or pier-type structures which extend the loading equipment into deeper water. The terminal at Nikiski on the Kenai Peninsula is an example of the latter, and the Valdez terminal exemplifies both types.

Land requirements depend on the terminal throughput, storage capacity and on land availability. Table E-1 lists land and other requirements for a marine terminal. The area required varies between 30 and 300 hectares (75 a'nd 740 acres).

The Valdez terminal, which is one of the largest in the world, uses 360 hectares (900 acres). Storage requirements for a 10-day supply of oil (fif- " , teen 510,000-barrel tanks) occupies most of this area. In addition, three 420,000 barrel tanks for storage of ballast water are present.

Marine docks should be located in deep water shelter as much as possible from wind and waves. Tankers are susceptible to the longer waves with periods of 8 to 10 seconds. The terminal should be sited in areas where these waves do not occur or are attenuated to such a degree as to make them unimportant.

Depth requirements obviously depend on expected tanker size. Figure E-9 shows these requirements for vessels of various sizes.

111.2.5 Pipeline Routing and Landfalls

Owing to the expense of constructing marine pipelines, one of the primary concerns is selecting the shortest distance to shore. This consideration must be termpred however by the presence of possible geohazards and oceanographic constraints. For instance, every attempt should be made to

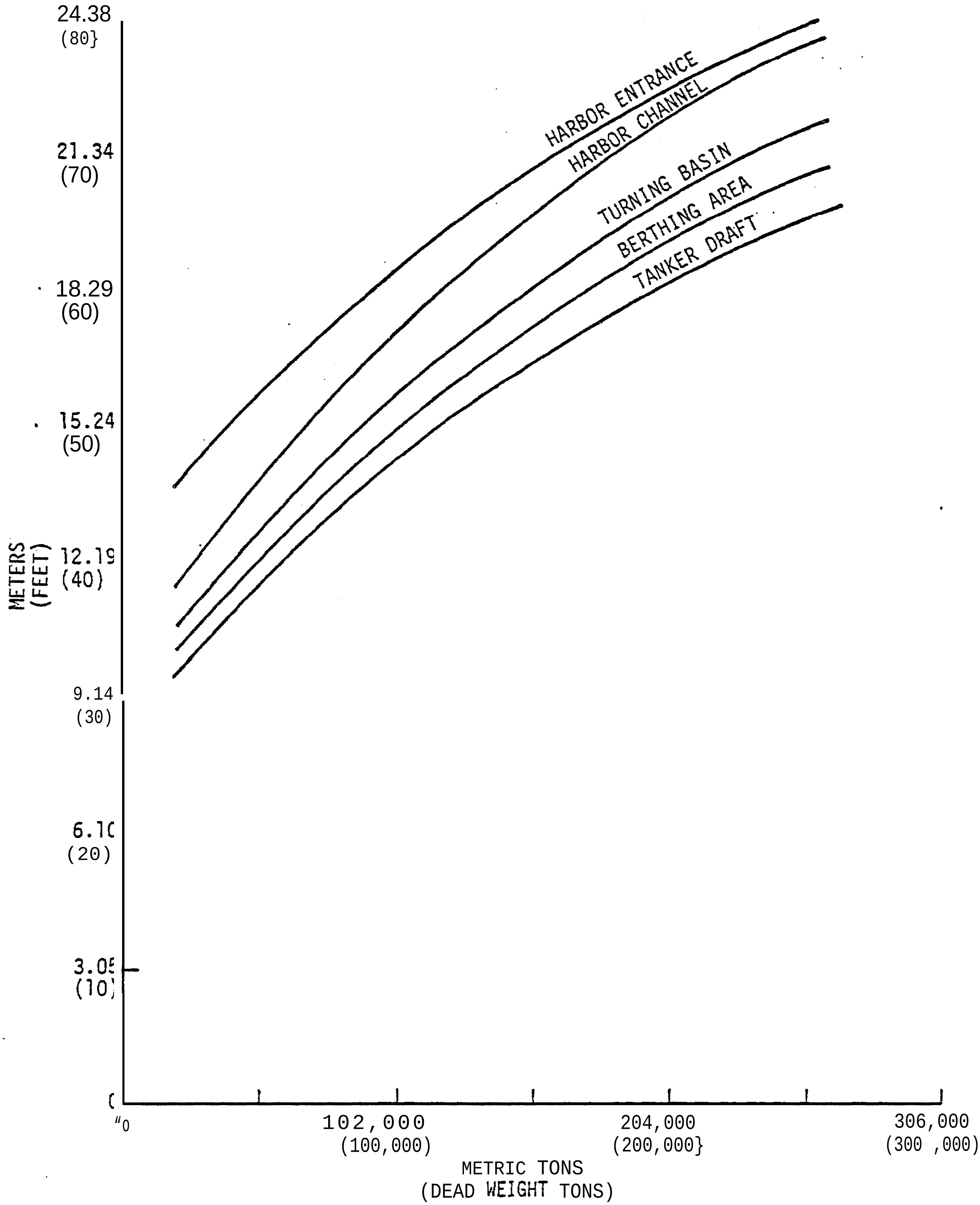


FIGURE E-9

REQUIRED DEPTHS FOR TANKERS AT MARINE TERMINAL

The landfall site should be gently sloping with no steep backshores. Landfalls should avoid areas of active of potentially active erosion. Recommended practices suggest that pipelines be buried under 3.1 meters (10 feet) of sand or shingle to the low-water mark, then 2.1 meters (7 feet) below the bottom, out to the 15.2 meter (50 foot) depth.

Insofar as data is available, our siting analysis has ensured that for each crude oil terminal site there are no excluding limitations for pipeline landfalls and overland pipeline access.

111.2.6 Summary

Most of this section has been devoted to the declination of at least the minimum technical requirements for siting petroleum facilities. However, while such conditions are important, the simple fact that they not exist at a particular site would not necessarily rule it out of consideration. For example dredging can often overcome the vessel draft requirement. Offshore loading operations, as exemplified at Drift River, can also be used to accomodate deep-draft vessels without dredging. Problems arising from inadequate space can be surmounted by extensive excavation as was done in Valdez. Prudent use of available technology can assist in making stream crossings of pipelines compatible with the migration of anadromous fish. Roads linking the facilities with seaports and air terminals, though desirable, are in most cases not mandatory; greater reliance can be placed on locally developed barge and air transport facilities at or near the site. The most economical site probably would not include these limitations, but options are available to accommodate development, at what on the surface, may appear to be highly undesirable locations.

IV. Selection of Candidate Facility Sites

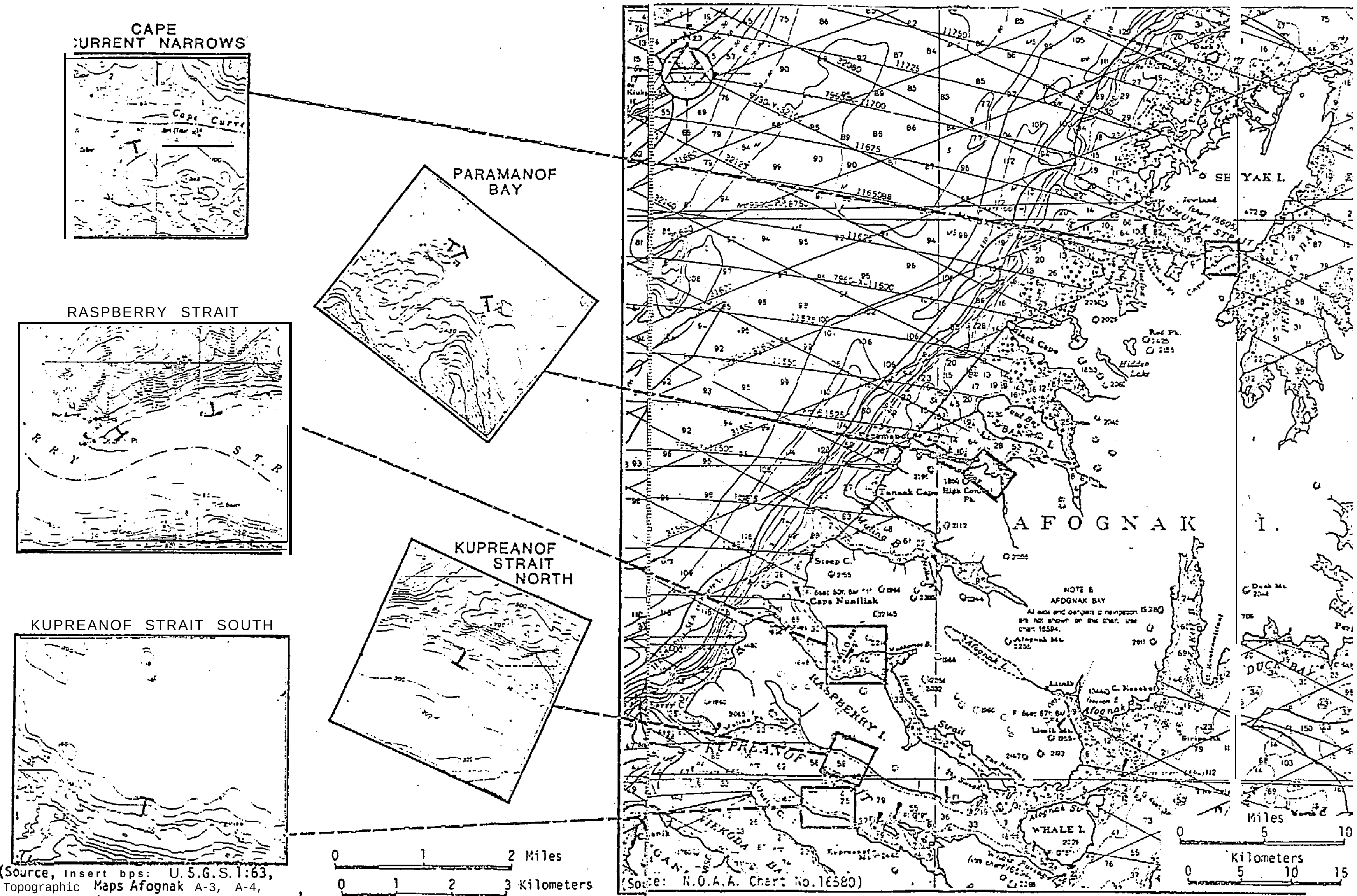
IV.1 Technically Feasible Sites

IV.1.1 Overview

During the site selection process both coastlines adjacent to Shelikof Strait were investigated and evaluated as to the suitability for a coastal facility. The section of coast investigated along the Alaska Peninsula extended from Cape Gull northeast to Cape Douglas, while the section of coast on the Kodiak Archipelago extended from Uganik Island northeast to Dark Island. From a regional perspective, the section of coastline along the Kodiak Archipelago is a more favorable area for a coastal facility.

A number of physical parameters were selected which could be used to evaluate the relative suitability of sites. These physical parameters are described below. Because other physical parameters such as seismicity, exposure to ash fall, sea ice potential, and tidal range display relatively unimportant differences throughout the site selection area, they were not used in the evaluation. The selection criteria included:

- Availability of Relatively flat terrain of sufficient acreage
- Proximity to known faults
- Presence of deepwater near shore (shelf width)
- Absence of navigational hazards
- Lithology/bedding orientation
- Surficial deposits
- Site physiography
- Wave exposure



(Source, Insert Maps: U.S.G.S. 1:63, Topographic Maps Afognak A-3, A-4, and E-3; Kodiak D-4)

LOCATION OF SELECTED SITES
FIGURE E-10

- Orientation of berthing area to predominant winds and currents
- Current speeds
- Nearshore processes

Application of these criteria resulted in the identification of five sites that would be suitable for major terminal facilities. These sites and their physical characteristics according to the selection criteria are presented in Table E-2. The site locations are shown on Figure E-10.

IV.1.2 Selected Sites

The candidate sites presented on Table E-2 are ranked on the basis of the physical parameters. Three levels of relative ranking are assigned -- High, Medium and Low. Accompanying the ranking is a short description of the site. Since a significant portion of the Shelikof coastline, including several major bays, has been eliminated in this siting analysis, even a site given a low ranking has some potential as a terminal site, i.e. the ranking is relative, not absolute.

IV.1.2.1 Kupreanof Strait (south side): High

The site is located on the north side of Kupreanof Peninsula approximately midway between Kupreanof Mountain and Outlet Cape. The entrance to Kupreanof Strait is approximately 14 kilometers (8 miles). There is a wide entrance through the Strait to the site area and only one isolated shoal which may pose a navigational hazard. The 18 meter (60 feet) depth contour is relatively close to shore. There is relatively flat terrain with sufficient acreage available for the proposed facilities. The site is well protected from incoming waves. A shore parallel berthing configurations would offer a favorable orientating to the expected wind and currents within the Strait. The currents in the area are expected to be in the 1 to 2 knot range.

TABLE F-2

SITE SELECTION BY PHYSICAL CONSIDERATIONS

	Kupreanof Strait (north side)	Kupreanof Strait (south side)	Raspberry Strait (north side near Dolphin Point)	Paramanof Bay (south side	Cape Current Narrows (south side)
Ranking (favorability)	High	High	Medium	Low	Medium
Land availability between sea level and 30 meter elevation	≈300 meter wide coastal strip	≈300 meter wide coastal strip	≈150 meter wide coastal strip	≈150 meter wide coastal strip	≈450 meter wide coastal strip
Proximity to known faults	No faults indicated near site	No faults indicated near site	Close to projection of Border Ranges Fault - Fault inactive	Close to projection of Eagle River Fault - Fault inactive	Close to projection of Eagle River Fault - Fault inactive
Proximity to deepwater (distance to 18 meter depth contour)	≈274 meters to 18 meter depth contour	≈300 meters to 18 meter depth contour	≈150 meters to 18 meter depth contour	>450 meters to 18 meter depth contour	≈300 meters to 18 meter depth contour
Navigational hazard status	Wide open entrance - no navigational hazards indicated	Wide open entrance - one isolated shoal indicated	Somewhat constricted entrance. No navigation hazards indicated	Somewhat constricted entrance	Constricted entrance entrance. Some offshore shoals
Unfavorable bedrock or bedding orientation	Marine turbidite sequence. Bedrock dipping steeply to the NW on strike to site	Marine turbidite sequence. Bedrock dipping steeply to the NW on strike to site	Metamorphic sequence. Bedrock dipping steeply to the NW away from site	Metamorphic sequence. Bedrock dipping steeply to the NW on strike to site	Metamorphic sequence Bedrock dipping steeply to the NW on strike to site
Probable unconsolidated sediments underlying site area	Alluvial material; slope wash; possibly some fluvial material?	Alluvial material; slope wash	Alluvial material; slope wash; glacial deposits?	Alluvial material; probably dominated by fluvial material	Alluvial material; slope wash; probably some fluvial materia
Physiography of site region	High relief; steep slopes bordering strait	High relief; steep slopes bordering strait	High relief; steep slopes bordering bay	High relief; steep slopes bordering strait	Low relief; gentle slope bordering strait
Sheltered from wave exposure'	Well protected from incoming waves; internal fetch length ≈13 kilometers	Minor exposure to coming waves	Well protected from incoming waves; internal fetch length ≈8 kilometers	Partial exposure to incoming waves	Well protected from incoming waves; internal fetch length ≈6 kilometers
Probably orientation of berthing area to expected winds and currents	Subparallel to axis of strait and likely winds and currents	Parallel to axis of strait and likely winds and currents	Not parallel to axis of strait. May be oblique to winds and currents	Subparallel to axis of bay and likely winds and currents	Subparallel to axis of strait and likely winds and currents
Currents	Current speed in 1 to 2 knot range	Current speed in 1 to 2 knot range	Current speed probably in the 2 to 3 knot range	Current speed probably in the 0 to 1 knot range	Current speed in the 2 to 4 knot range
Relative activity of nearshore processes	Probably moderately active	Probably moderately active	Probably active	Probably inactive	Probably active

IV.1.2.2 Kupreanof Strait (north side): High

The site is located on the south side of Raspberry Island between Bukti Point and Gori Point. The entrance to Kupreanof Strait is approximately 12 kilometers (7 miles). There is a wide entrance through the strait to the site area with no observed navigational hazards. The 18 meter (60 foot) depth contour is relatively close to shore. There is relatively flat terrain with sufficient acreage for the proposed facilities; The site is moderately protected from incoming waves. A shore parallel berthing configuration would offer a favorable orientation to the expected winds and currents within the Strait. The currents in the area are expected to be in the 1 to 2 knot range.

IV.1.2.3 Raspberry Strait: Medium

The site is located on Afognak Island immediately northeast of Dolphin Point. The entrance to Raspberry Strait is approximately 9 kilometers (5 miles) from the site. The entrance through the Strait to the site area is somewhat constricted. There are no observed navigational hazards in the entrance channel. The 18 meter (60 feet) depth contour is very close to shore. Less suitable acreage is available at this site than at the other sites. The site area is well protected from incoming waves. A shore parallel berthing configuration may be oblique to the winds and currents in the Strait. The currents are expected to be in the 2 to 3 knot range.

IV.1.2.4 Cape Current Narrows: Medium

The site is located on Afognak Island at the eastern end of the Shuyak Strait in Cape Current Narrows. The entrance to Shuyak Strait is approximately 8 kilometers (5 miles). The entrance channel to the site area is rather constricted and several shoals in the area pose navigational hazards. The 18 meter (60 feet) depth contour is relatively close to shore. 'There appears to be sufficient level acreage available for the proposed facilities.

There may be some thick deposits of unconsolidated, saturated alluvial deposits at this site. It is well protected from incoming waves. A shore parallel berthing configuration would be subparallel to the expected winds and currents in the Narrows. The currents in the site area are expected to be strong and in the 2 to 4 knot range.

IV.1.2.5 Paramanof Bay: Low

The site is located on Afognak Island at the southwest corner of Paramanof Bay. The site is approximately 8 kilometers (5 miles) from the entrance to the Bay. The bathymetric chart indicates some constrictions in the entrance channel to the site area. The 18 meter (60 feet) depth contour is relatively far from the shore. There is sufficient level acreage available. Portions of the site area may be underlain by thick accumulations of unconsolidated saturated" alluvial material. Relative to the other sites, this site has the greatest exposure to incoming waves. A shore parallel berthing configuration would be subparallel to the expected winds and currents in the Bay. The currents are probably weak in the Bay.

IV.2 Environmental Sensitivity of Technically Feasible Sites

IV.2.1 Overview

Due to rugged geologic features of the Alaska Peninsula and the Kodiak Archipelago, the coastline of northern Shelikof Strait contains a multitude of diverse and unique habitats. The nearshore areas range from the extreme wind-swept shores along parts of the Alaska Peninsula to the scenic protected bays and fjords of Afognak and Shuyak Islands.

In this region commercial fisheries are highly productive with major emphasis on pink and chum salmon, herring, king crab, tanner crab, dungeness crab and shrimp. Other commercial species include sockeye, silver and king salmon, scallops and a potential new bottomfish industry.'

Marine mammals are-plentiful in the region with especially large concentration of sea otters. Also present are northern (Stellar) sea lion, harbor seal, and various species of whales and porpoises.

The subtidal communities are essentially unsurveyed throughout most of this region but presumably are also as highly productive and unique as their habitats are diverse.

The onshore. habitats are also affected by the topography of this reglen. The islands feature both large stocks of valuable timber resources and wind-swept regions of high brush.

Deer and elk abound as introduced species in the island group while the native brown bear is found throughout the entire region.

With such natural resources, the area is identified with high value recreation uses such as sport hunting and fishing and marine and wilderness travel . Prior to the current transactions in land ownership, much of the region was managed as national refuges, forests or monuments under the Department of Interior. Changes in ownership will probably result in most of Afognak and Shuyak Islands becoming private land.

Land status at the potential sites can only be discussed in terms of probabilities pending final resolution of the land conveyances under the Alaska Native Claims Settlement Act, the Alaska Statehood Act, the Municipal Land Entitlement Act of 1978 and current congressional legislation.

Prior to the passage of the Native Claims Act, Afognak Island was federally managed as "Afognak Forest and Fish Culture Reserve," as part of Chugach National Forest. Under the terms of the Settlement Act, the land entitlements due the various village corporations, deficiency village corporations and the regional native corporation, Koniag, Inc., exceeded the land available for selection in the Kodiak Archipelago. In orderto provide sufficient acreage, selections were extended to certain lands on the Alaska

Peninsula across the Shelikof Strait. However, these selections proved unsatisfactory to the various corporations and a new agreement was formulated. Under Section 1429 of HR 39, referred to hereafter as the Koniag Amendment, the various corporations would agree to relinquish their entitlements to lands on the Alaska Peninsula in exchange for reduced entitlements on Afognak Island. Additionally, seven villages which have been recognized as uncertified will be relinquishing claim to all but a few hundred acres under the Koniag Amendment. This legislation has not yet been approved by Congress but its. acceptance seems probable based on its list of supporters.

Additional selections have been made by the State of Alaska under the provisions of the Alaska Statehood Act and are also pending conveyance. A portion' of these lands have been identified as tentatively approved for conveyance but may yet be claimed as alternate Native selections or Kodiak Island Borough selections (under the Municipal Entitlement Act). The remaining public lands on Afognak Island, including submerged (intertidal) lands, are designated for inclusions into the existing Kodiak National Wildlife Refuge.

The land ownership status described hereafter is based on selection claims as of July 1979 (compiled by Alaska State Department of Natural Resources) and presumes passage of D-2 legislation, the Koniag Amendment and expected conveyance of Alaska state lands.

Under the Koniag Amendment, management of the selected lands would be ". ..subject to the terms of cooperative-management agreements entered into by Koniag, Incorporated, and other affected Koniag village corporation, with the Secretary of the Interior, and such of the state agencies and of the political subdivisions of the State having jurisdiction over any portion of Afognak Island which desire to participate."

In the past, Koniag has favored development-oriented projects. Koniag and the Kodiak Island Borough both appear to favor continued and expanded harvesting of timber resources on Afognak Island. The State Division of

Parks is also identifying selected locations as having high potential as recreation sites.

IV.2.2 Site Evaluation on Basis of Biological and Land Status Issues

The biological characteristics and environmental sensitivity of each site are summarized in Table E-3. Endangered species were not used as a criterion for consideration since a review of existing information indicated that none apparently inhabited these areas (see note Table E-3).

IV.2.2.1 Kupreanof Strait (North and South)

Marine Biology

No specific information regarding the flora and fauna of intertidal and shallow subtidal zones of this area is available at present. Zimmerman (1979) in his reconnaissance of the intertidal areas of Kodiak Island studied only one location, Whale Island, at the far east end of Kupreanof Strait. That site was approximately 19 kilometers (11.5 miles) from the proposed sites. Since invertebrate and algal species are generally discontinuous depending on substrate and currents, site evaluation of these specific areas would be necessary to evaluate the intertidal biota. Sears (1977) did not find any major kelp beds in this region in an aerial survey of the shoreline of Kodiak Island.

Relatively few anadromous fish streams flow into the Strait along the northern and southern shorelines. The closest spawning stream to Site No. 1 on the southern shoreline is Dry Spruce Creek, located 12.5 kilometers (8.8 miles) to the southeast and supports only a very small run of pink salmon and Dolly Varden. The nearest spawning stream to Site No. 2 on the northern shoreline is a small unnamed stream which empties into Onion Bay 7.5 kilometers (4.7 miles) to the northwest. This stream supports a small run of pink and silver salmon and Dolly Varden (Larry Malloy, ADF&G personal communication).

TABLE E-3

ENVIRONMENTAL CONSIDERATIONS FOR SITE SELECTIONS IN SHELIKOF STRAIT

Selected Site	Proximity to Anadromous Fish Stream	Proximity Major Salmon Migration Route	Quality of Habitat Crab	Quality of Habitat Shrimp	Proximity to Seabird Nesting Colony	Eagle Nesting Habitat	Proximity to , Wetlands	Importance as Wintering Area
Kupreanof Strait (south)	very few in vicinity. 12.5 km (7.5 mi.) to nearest - Pinks (100's)	Major salmon movement through the Strait	High - major King and Tanner crab stocks	Poor - no significant concentrations	*	*	No significant wetlands in the vicinity	Possible major wintering area for Crested Auklets and other Alcids and sea ducks. Post breeding populations of Phalaropes
Kupreanof Strait (north)	Very few in vicinity. 7.5 km (4.5 roil.) to nearest. Pink and silvers. (run probably small)	"	"	"	*	*	"	"
Raspberry Strait (East of Dolphin Point)	5 spawning streams in the strait. 5 km (3.0 mi.) to nearest. Pinks major species. 8 - 10,000 total in Strait.	Salmon migrating by will swing into western end of Strait	moderate	"	*	*	"	*
Paramanof Bay (south side)	6 spawning streams in the vicinity. 1 km (0.6 mi.) to nearest. Pinks and Reds major species. Up to 50,000 for Bay.	Mainly fish migrating to stream in the Bay,	Low	Moderate - main harvest area on west side of Afognak	4 small colonies. 488 breeding birds. Glaucous-winged Gull major species. 1.5 km (0.9 mil.) to nearest.	Critical Bald Eagle nesting area. Eagles also winter in lagoon to the East.	" "	*
Shuyak Strait (west of Cape Current Narrows)	Only 1 in vicinity. 6 km (3.6 mi.) s.w. Pink and Silvers possible 100's	Salmon pass through Strait bound for other areas	Low	Poor - moderate some intermittent shrimping effort	4 small colonies in vicinity, 1194 breeding birds. Tufted Puffin major 'species. 2.5 km (1.5 mi.)to nearest	*	"	*

Even though the spawning habitat in the Strait is quite limited, large numbers of adults pass through, generally from east to west, during their migration to other areas. The majority of the salmon fishing effort in this Strait is directed toward these fish. Purse-seining is conducted throughout the Strait with gillnetting permitted only along the southern shoreline (ADF&G, 1978).

The Kupreanof Strait region is also an important spawning area for Pacific herring, but specific spawning sites vary greatly from year to year. More productive spawning areas are located to the south (ADF&G, 1978).

All major commercial crab species are present in the Strait, but the king and tanner crab stocks are of the greatest concentrations. The most productive area for king crab on the west side of the Kodiak Archipelago begins in Kupreanof Strait and extends southward along Kodiak Island (Rod Keiser, ADF&G, personal communication). Kupreanof Strait is used as a major index area by the Alaska Department of Fish and Game in the assessment of crab populations in this region (ADF&G, 1978).

Tanner crab are present in large commercial quantities, but the west side of Kodiak and Afognak produces only 10 percent of the total catch from the Kodiak area. Kupreanof Strait also serves as a rearing area for tanner crab (Alaska Department of Natural Resources, 1979). Dungeness crab inhabit most all bottom areas above 91.4 meters (300 feet) in this vicinity and are harvested to a moderate extent in the Strait. A portion of the fishing effort is presently being concentrated in the bays on the western side of Kodiak.

The western side of Afognak and Kodiak Island is not a major producer of shrimp, but is does receive rather continuous effort throughout the year. Kupreanof Strait receives relatively little fishing pressure, thereby indicating low standing crops of shrimp species (Bill Nippies, ADF&G, personal communication).

TABLE E-3 (cont.) .

Selected Site	MARINE MAMMALS Proximity to Major Areas of Concentration - Sea Otter -	Proximity to Major Areas of Concentration Sea lions - Seals -	Proximity to Major Areas of Concentration - Cetaceans -	TERRESTRIAL MAMMALS Importance as Deer Habitat	Importance as Bear Habitat	Importance as Elk Habitat
Kupreanof Strait (south)	Sea otters present number low	Seals and sea lions present in low number	Common	Moderate deer winter range	Low	Absent
Kupreanof Strait (north)	"	"	"	"	"	Moderate winter Range
Raspberry Strait (east of Dolphin Point)	"	High density seal Cape Nuniliak at the mouth of the Strait	More common off the mou th	Good deer winter range at the head of the Strait	Moderate	Moderate winter elk range
Paramanof Bay (south side)	Moderate densities in Bay	Cape Paramanof - intermittent Sea lion hauling out ground. High density seal at mouths of streams	"	Good deer winter range along Paramanof Red Creek and south side of Ban Island	High - high density around streams. Upland area used for denning	High - WI nter range. Moderate summer range
Shuyak Strait (west of Cape Current Narrows)	Highest density in Kodiak region just to the east. Exporting population	High density for both seals and sea lions in vicinity of site	High concentration of DA1l Porpoise observed during summer months	Low - small deer wintering area near Cape Current	Low	Low ,

* On site evaluation needed, no present data

NOTE : Peregrine falcons are occasionally observed in these areas but they are believed to be the coastal subspecies (Falco peregrinus pealei) which is not considered endangered. (Dan Benfield, Fish and Wildlife Service).

Source: Dames & Moore

A major data gap exists with regard to seabird nesting areas along the northern side of Kupreanof Strait. Dick and Nelson surveyed most of Afognak Island in 1976 but were unable to complete the portion on the west side south of Paramanof Point. The nearest bird colony to the Kupreanof Strait (south) site is located 4 kilometers (3.5 miles) to the east on a small island west of Bare Island. The major species at this colony are the black-legged kittiwake (3,500) and the tufted puffin (1,200) (USFWS, 1978). Winter distribution of birds is largely undocumented for Kupreanof Strait. One observation during the winter of 1977 of large numbers of crested auklets (approximately 6,000) boarding a fishing vessel while it was passing through the Strait suggests that this area may be an important wintering area for this species (Dick and Donaldson, 1978). Large post-breeding flocks of northern and red phalaropes have also been observed throughout the Strait in late summer (Donaldson, ADF&G, personal communication). Winter bird surveys farther south along the west side of Kodiak Island in 1973 and 1975 suggest that this entire area may be a major wintering area for up to 30 species of seabirds and sea ducks (ADF&G, 1976). More data is needed to evaluate possible impacts.

Marine mammals, such as the northern sea lion, harbor seals and sea otters, are found seasonally throughout the Strait but no breeding area or major hauling-out grounds are located in this area (Calkins, ADF&G, personal communication).

Terrestrial Biology (south site)

, Much of the vegetation of the surrounding area is of the high--brush type. The low areas near the shoreline provide good winter range for the Sitka black-tailed deer which were introduced from Southeast Alaska in 1924. . This area is also a favorite deer hunting spot for local residents (Roger Smith, ADF&G, personal communication).

Brown bear utilization of this region is slight, largely due to the absence of major salmon spawning streams. However, bear are occasionally observed in the area (Roger Smith, ADF&G, personal communication).

Terrestrial Biology (north site)

Much of the vegetation in this area is of the high brush type but is interspersed with small Sitka spruce. The coastal region along this side of Raspberry Island provides moderate wintering habitat for deer and occasional wintering habitat for about 200 elk which is one of the largest herds on Afognak Island.

Brown bear usage is again slight due to the lack of salmon spawning streams (Roger Smith, ADF&G, personal communication).

Land Status (south site)

This area has received tentative approval for conveyance to the State of Alaska. Although the site has not been identified directly in the recreation planning of the State Division of Parks, it is in close proximity to Dry Spruce Islands and Bay, a potential scenic recreation area. For the Dry Spruce area, a Division of Parks study (Troll, 1979) has 'recommended (with the assumption of conveyance to Port Lion, Inc.):

> "Management . ..should stress protection of the scenic quality as viewed from a boat. When development activities occur such as timber clearing, or building construction, mitigating measures as to location, color, form and texture of the construction should be required and undertaken. For management of dispersed recreation, Port Lions, Inc. and the
>
> Division of Parks should explore cooperative management options. Port Lions, Inc. or the Kodiak Island borough should consider a 200-foot greenbelt classification for lands abutting the coast."

This area will not be affected by the status of the present Koniag Amendment. Tideland management will remain under State jurisdiction.

Land Status (north site)

This site has been selected by the village corporation of Port Lions under the terms of the Koniag Amendment. Nearby, Onion Bay has recently been suggested for potential development as a state park with the emphasis on marine wayside and trail-related uses (Troll, 1979). The tidelands will remain under State jurisdiction.

IV.2.2.2 Raspberry Strait

Marine Biology

Surveys of the intertidal or shallow subtidal biota have not been conducted in Raspberry Strait; however, the area was mapped for substrate and kelp beds from aerial surveys (Sears and Zimmerman, 1977). No major kelp beds were located in this area.

A total of five anadromous fish streams flow into Raspberry Strait supporting a run of about 9,000 to 10,000 fish in peak years. Pink salmon is the major species and is present in all streams. The major spawning stream in this system is Selief Bay Creek which supports a relatively small run of sockeye, silver, and pink salmon.

Salmon bound for other areas can be found in the mouth of the Strait during migration but then continue on (Larry Malloy, ADF&G, personal communication).

Raspberry Strait is also an important spawning area for herring during the late spring.

Halibut are fished in the Strait as in much of the areas along this side of Shelikof Strait (18.3 to 61.0 meters depth, i.e., 60 to 100 feet), but this area is not believed to be a major producer (Bill Nippies, ADF&G, personal communication).

There is little fishing effort for shrimp in Raspberry Strait and probably reflects a low standing crop.

Three commercial crab species are present in the area, but fishing pressure is believed to be moderate. The major effort is the king and tanner crab at the west end of the Strait, whereas dungeness is fished throughout the Strait in areas of proper depth (ADF&G, 1978).

Raspberry Strait is unsurveyed as far as seabird nesting colonies, and no information is available as to the distribution of wintering bird species in this area.

The common marine mammals such as northern sea lions, harbor-seal and sea otters are found seasonally through this area in low concentrations similar to much of the coastline along the western side of Afognak. No breeding or hauling-out areas are located in this area (Calkins, ADF&G, 'personal communication).

Terrestrial Biology

The vegetation along the shoreline in this region is again of the highbrush type and supports a substantial population of deer. The coastal areas toward the east end of the Strait provides good winter range for deer and are intermittently used by elk during the winter months (Roger Smith, ADF&G, personal communication).

Brown bear utilization of the area is generally moderate with highest concentrations found along the spawing streams. An area of high utilization in the spring and fall is located 6 kilometers (3.7 miles) to the east of the proposed site, south of Muskomee Bay (ADF&G, 1978).

Land Status

The site is located on land covered under the Koniag Amendment but has not yet been officially filed as an individual native selection. The area is not identified in state recreation planning.

IV. 2.2.3 Paramanof Bay

Marine Biology

No survey of the intertidal or shallow subtidal biota has been, conducted in the vicinity of Paramanof Bay. An aerial survey by Sears and Zimmerman (1977) did locate kelp beds along the southern shoreline about 4 kilometers (3.5 miles) west of the proposed site, but no data are available to indicate the extent of these beds.

Four major anadromous fish streams are located within the Bay. The major spawning stream is Paramanof Red Creek which empties into Paramanof Bay approximately 1 kilometer (0.6 miles) east of the proposed site. Escapement varies but may reach peak numbers of over 30,000 pink and 1,000 sockeye salmon. A small run of chum salmon are also known to use this stream. Other major streams in the vicinity of the site include Paramanof Creek East (4 kilometers [2.4 miles] to the northeast) which supports a small run of 500 to 1,000 pink and about 100 sockeye salmon, Paramanof Creek South (head of the south arm) which supports a healthy run of about 10,000 to 15,000 pink and some silver salmon, and Paramanof #4 (head of east arm) which supports a run of 8,000 to 10,000 pink salmon and a small number of silver salmon (Larry Malloy, ADF&G, personal communication).

Peak salmon escapement for Paramanof Bay could reach over 50,000 fish. Commercial catch effort is presently confined to an area along the southern shoreline just outside the mouth of the Bay.

Juvenile pink and chum salmon leave the spawning streams in the spring and migrate into the coastal estuaries for several months before going out to sea. The juvenile sockeye and silver salmon are much larger when they move into the estuaries and can proceed directly to sea but do spend a short "amount of time in the near shore areas (Science Applications, 1979). Numbers of juvenile salmon in Paramanof Bay during the spring and summer months are probably very high.

Paramanof Bay is an important herring spawning area but is not utilized as extensively as bays farther to the south (ADF&G, 1976).

Halibut are found in commercial quantities in this area as in most of the inshore waters along this side of Afognak Island.

King and dungeness crab are distributed throughout this area, but king crab numbers are believed to be low. The tanner crab fishing effort focuses more offshore into" Shelikof Strait but some tanner are undoubtedly present in the Bay (ADF&G, 1976).

Paramanof Bay is one of the more important shrimp areas along the west side of Afognak Island. Although poundage is low compared to the bays on the east side of Kodiak and Afognak, the fishing effort is essentially continuous throughout the year (Nippies, ADF&G, personal communication).

Four small seabird colonies are located in the vicinity of the proposed - site. The closest colony to the site, Paramanof (4) is located 2 kilometers (1.2 miles) to the northeast. The major species are the glaucous-winged Gull (250) and the tufted puffin (28). The other colonies are smaller and number less than 100 individuals, mostly gulls and terns.

The bay to the north of Paramanof, Foul Bay, has numerous small colonies located on small islets throughout the Bay and have similar species" composition to the Paramanof colonies (USFWS, 1978).

Winter distribution of birds in this area is not known, however, large concentrations of bald eagles are known to winter along Paramanof Red Creek just 1 kilometer (0.6 miles) east of the proposed site (Roger Smith, ADF&G, personal communication).

"<u>Terrestrial Biology</u>

The vegetation type of this area is predominantly spruce with the upper slopes predominantly high brush (Alaska Department of Natural Resources, 1979). The southern shoreline of Paramanof Bay and the heavily forested lowlands around the mouth of Paramanof Red Creek provide very good winter range for deer and moderate winter range for elk. Elk hunting is very popular in this area. In 1976, 30 percent of the elk taken on Afognak Island was from this district (Roger Smith, ADF&G, personal communication).

Brown bear are found concentrated around the spawning streams during the summer months and utilize the upland areas for denning ground's during winter (ADF&G, 1978).

Within Paramanof Bay, relatively high concentratinos of harbor seals can be found seasonally at the mouth of the major salmon spawning streams. Sea otters are also found in relatively high numbers throughout the Bay. Sea lions and other marine mammals are occasionally observed foraging in waters off the Paramanof Bay (Division of Parks, 1979). Foul Bay, to the north, is documented as a major area of high harbor seal density (ADF&G, 1978).

Land Status

The proposed site has been selected by Litnik, Inc., but may be relinquished under the Koniag Amendment. In such event, it is probable that another village corporation would select this area.

An Alaska State Division of Parks study (Troll, 1979) has suggested for recommended management:

> "Once ownership is determined, the Department of Fish and Game should evaluate, with the owner and concerned parties, the possibility of establishing a cooperative management program for this area as a Research Natural Area of similar designation. Emphasis on management should be on maintaining and enhancing the marine and terrestrial wildlife habitat and on monitoring ecological changes, while providing for wilderness recreation."

IV.2.2.4 Cape Current Narrows

Marine Biology

No intertidal or shallow subtidal surveys have been conducted in the vicinity of the Cape Current site. Kelp beds were found by aerial survey in the strait near the proposed site, but no information is Available as to the extent of these beds (Sears and Zimmerman, 1979).

Only two anadromous fish streams are identified in Shuyak Strait, Red Fox southwest and Red Fox southeast. These streams are located 7 kilometers (4.4 miles) west of the proposed site and support only a very sma.11 run of pink and 'silver salmon. Salmon bound for other areas pass through the Strait during spring and summer periods.

The three major commercial crab species are present in the Strait, but fishing effort is slight and mainly focused on the dungeness.

Three main bird colonies are located in Shuyak Strait to the west of the proposed site but all are relatively small (200 birds per colony). Species composition of these colonies is somewhat similar with tufted puffins, horned puffins, pigeon guillemots, and glaucous-winged gulls being the major species. The largest colony and the closest to the proposed site is located 3 kilometers (1.9 miles) to the northeast and supports approximately 600 birds (mostly tufted puffins) (USFWS, 1978).

Like most of the other areas on Afognak Island, the winter distribution of birds is largely unknown.

Eagles may nest along the Strait, but surveys would be needed 'to evaluate this area as a nesting habitat.

The marine waters just east of Cape Current Narrows support the largest populations of sea otters on the Kodiak Archipelago. Here otter populations are expanding and exporting animals to areas farther south. High densities of northern sea lions and harbor seal are known to occur throughout this area (Catkins, ADF&G, personal communication).

Terrestrial Biology

The vegetation of the area surrounding the proposed site is typical spruce forest and generally does not provide good habitat for wildlife. There are no major concentrations of deer in the vicinity of the proposed site, but there is occasional utilization by elk during the winter (ADF&G, 1978).

Land Status

This proposed site has been selected by the village of Port Williams (Shuyak, Inc.) under the terms of the Koniag Amendment.

This site has not been identified in any recreation inventories.

IV.3 Elimination of Alaska Peninsula Shoreline

Current land status essentially precludes development of petroleum facilities along Alaskan Peninsula shoreline of northern Shelikof Strait.

The boundary of Katmai National Monument encompasses practically "the" entire western coastline of Shelikof Strait from Shaw Island to Cape Kubugakli. The land use objectives of National Monuments preclude all industrial development.

However, the Russian Orthodox Church holds land patents on three mission sites which were abandoned following the eruption of Katmai in 1912. The sites are each approximately six acres in size and are located at Katmai Bay, Kukak Bay and north of Hallo Bay at Kaguyak.

Despite this land status, the study team did not immediately preclude the Alaskan Peninsula shoreline from consideration. However, review of the, natural physical characteristics (oceanography, geology, etc.) of the area revealed significant physical limitations to siting of a major terminal on this section of coastline. Only a few sites with low potential probably requiring expensive engineering to develop were identified. The physical reasons this coastal region was excluded are:

- It is in close proximity to active volcanoes and consequently any coastal facility may be threatened by volcanic flows, volcanic mudflows, and ash falls.
- It is along the volcanic arc system, a zone of higher seismicity.
- Broad reaches of the coastline are dominated by non-consolidated, water saturated beach and deltaic sediment.
- Beach" processes appear to be more active along the coastline.
- A wide shelf is present along most of the coastline.
- The coastline is generally more exposed to wave attack.

Biologically, the western shoreline of Shelikof Strait differs considerably from the east side of the strait. From Cape Douglas south to Kukak Bay there are no major protected bays in comparison to the extensive fjords and islands on Kodiak and Afognak. These sections of coastline are also devoid of major kelp beds (Sears and Zimmerman, 1977).

Over 96.5 kilometers (60 miles) of major razor clam habitat is located along this portion of Shelikof Strait including the only beach certified for commercial harvest in the Kodiak region, Swikshak beach (ADF&G, 1978).

The river systems along this area of the Strait are excellent salmon producers with chum salmon the dominant species. The largest salmon spawning stream is the Swikshak River with chum production in the hundreds of thousands. Other major river systems in this area with total salmon escapements of over 100,000 include Big River and Kukak River. There are only two major red salmon runs on this side of Shelikof. The major run goes up the Swikshak River (15,000 to 20,000) with a small run utilizing the Kalfka River (approximately 10,000) (Larry Malloy, ADF&G, personal communication).

King and tanner crab are fished along this side of the Strait but numbers decrease south of Hallo Bay. This district is the major tanner crab producer in Shelikof Strait.

The west side of Shelikof is one of the major fishing grounds for dungeness crab. In the recent past, production has been low but appears to be 'making a comeback (ADF&G, 1978).

This region is also a major producer of commercial quantities of shrimp and has contributed a significant percentage of the total catch until 1978 when production fell. The main areas ished are Kukak Bay and the northern district just south of Cape Douglas.

The distribution of seabird breed ng colonies is not well documented but major sites have been identified by the U.S. Fish and Wildlife Service (1979). The distribution of birds during the winter months is a major data gap but data from nearby areas suggests that it may be an important wintering area for severa? species of sea ducks and alcid (Gill et al., 1979).

Marine mammals occur all along this coastline with several major areas of high harbor seal density located mainly at the mouths of salmon spawning streams. The major hauling grounds for the northern sea lion are located at Cape Gull, Cape Nakshak and Cape Ugwek. The only significant concentrations of sea otters are found off Cape Douglas and Shakun Inlets:

Because of the adverse land status, technical and biological characteristics of the Alaska Peninsula shoreline, it was eliminated from consideration in the siting analysis.

IV.4 Ranking of Sites

Table E-4 shows the technical, biological, and land status rankings and final composite ranking of the five technically feasible sites along the northeastern shorelines of the Kodiak Archipelago.

TABLE E-4

SITE SUITABILITY RANKINGS FOR CRUDE OIL TERMINAL

Site	Technical Ranking	Biological Ranking	Land Status Ranking	Final Composite Ranking
Kupreanof Strait North	High	Medium	Medium	High
Kupreanof Strait South	High	Medium	Medium	High
Raspberry Strait	Medium	High	High	Medium
Cape Current Narrows	Medium	Low	High	Low
Paramanof Bay	Low	Low	Low	Low

A final note of explanation should accompany the final composite ranking of the five sites. At the outset, the study team felt that the final ranking should be on a relative basis. That is, of the candidate sites selected, one could be designated best in comparison to the others, and, similarly, another could be chosen as the least favorable. By prescribing a ranking of high to a particular site, we do not view this on an absolute scale without any" restrictions or constraints to be placed on it. All of the sites are, in one way or another, pristine areas with important, if not crucial habitats. On this basis alone all could be ruled out when matched against many sites outside of the present study area. Also the entire area is known to be susceptible to earthquake activity and severe oceanographic and meteorological Conditions. If the exercise called for these sites to be ranked on an absolute scale, assuming it would even be possible, the rankings could be dramatically different than those presented herein.

V. Conclusions

It was assumed in this study that economic quantities of oil and gas reserves would be found in the northern Shelikof Strait and the resource development would follow, resulting in the need to find suitable sites for several petroleum facilities. The site selection process was conducted through an elimination process with sites being ruled out initially for technical reasons. The five sites that remained after this screening were then evaluated as to their biological importance and land status issues. The study produced the following results:

1. Sites on the northwest side of Shelikof Strait are less desirable than sites within the Kodiak Archipelago.

2. The entire Kodiak Archipelago is a sensitive area biologically and physically which will impose severe constraints to development.

3. Significant data gaps exist in all areas which could seriously affect the final ranking as well as require reevaluation of previously discarded sites.

4. Kupreanof Strait, with two of the five sites, is more favorable overall than the other locations.

5. Paramanof Bay is the least acceptable.

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