OIL SPILL VULNERABILITY, COASTAL MORPHOLOGY, AND SEDIMENTATION OF OUTER KENAI PENINSULA AND MONTAGUE ISLAND

by

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I. Abstract. This report discusses the results of an extensive study of the geomorphology, sedimentology, and oil spill vulnerability of the outer Kenai Peninsula and Montague Island shorelines. Major emphasis is placed on the application of an Oil Spill Vulnerability Index (O.S.V.I.). Large segments of the shoreline are high risk environments with respect to oil spill residence time. Nearly 60% of the study area falls into O.S.V.I. classes 6-10, which indicates any oil spilled would have residence times from one to more than ten years. The remaining 40% of shoreline falls into classes 1-5, which are considerably lower risk areas. Any oil spilled in these environments would be cleaned by natural processes quite rapidly.

II. Task Objectives. This project falls under Task D-4 which is to: evaluate present rates of change in coastal morphology, with particular emphasis on rates and patterns of man-induced changes, and locate areas where coastal morphology is likely to be changed by man's activities, if any. The relative susceptibility of different coastal areas will be evaluated, especially with regard to potential oil spill impacts.

111. Field and Laboratory Activities. Included in the body of this report.

IV. Results. The results have been summarized in the text of this report as well as on the set of basemaps included in the Appendix. The original set of basemaps is being sent under separate cover.

V. Preliminary Interpretations. Does not apply.

VI. Auxiliary Material. Original set of 31 U.S.G.S. Quadrangle maps with the number coded Oil Spill Vulnerability Index.

VII . Problems Encountered. None.

INTRODUCTION

This report contains the results of an extensive field and laboratory study of the coastal region from the westernmost tip of Kenai Peninsula to Montague Island, approximately 2157 km of shoreline (Fig. 1). . The purpose of the investigation was to describe the morphology and sedimentology of the coastline and delineate the vulnerability of the area to massive oil spills. This work was done to aid any agency charged with the responsibility of handling a massive crude oil spill in the region. The major emphasis of this report is placed on the application of the Oil Spill Vulnerability Index (O.S.V.I.) to the study area. The O.S.V.I. is a scale which rates a particular type of shoreline's vulnerability to oil based on the residence time of oil in that particular environment. The O.S.V.I. ranges from 1, for coastlines having the lowest vulnerability, to 10 for coastlines that are the most vulnerable to oil spills (see section on Oil Spill Vulnerability).

Included with this report are 31 standard United States Geological Survey Quadrangle Maps with O.S.V.I. classes labelled for the entire study area. Reductions of these maps are found in Appendix I. Also included in the Appendices are a list of all survey stations visited and the tasks completed, reproductions of all beach profiles run, and summary statistics on all grain size analysis.

This is our final report for the project entitled "Oil Spill Vulnerability, Coastal Morphology and Sedimentation of the Outer Kenai Peninsula and Montague Island."

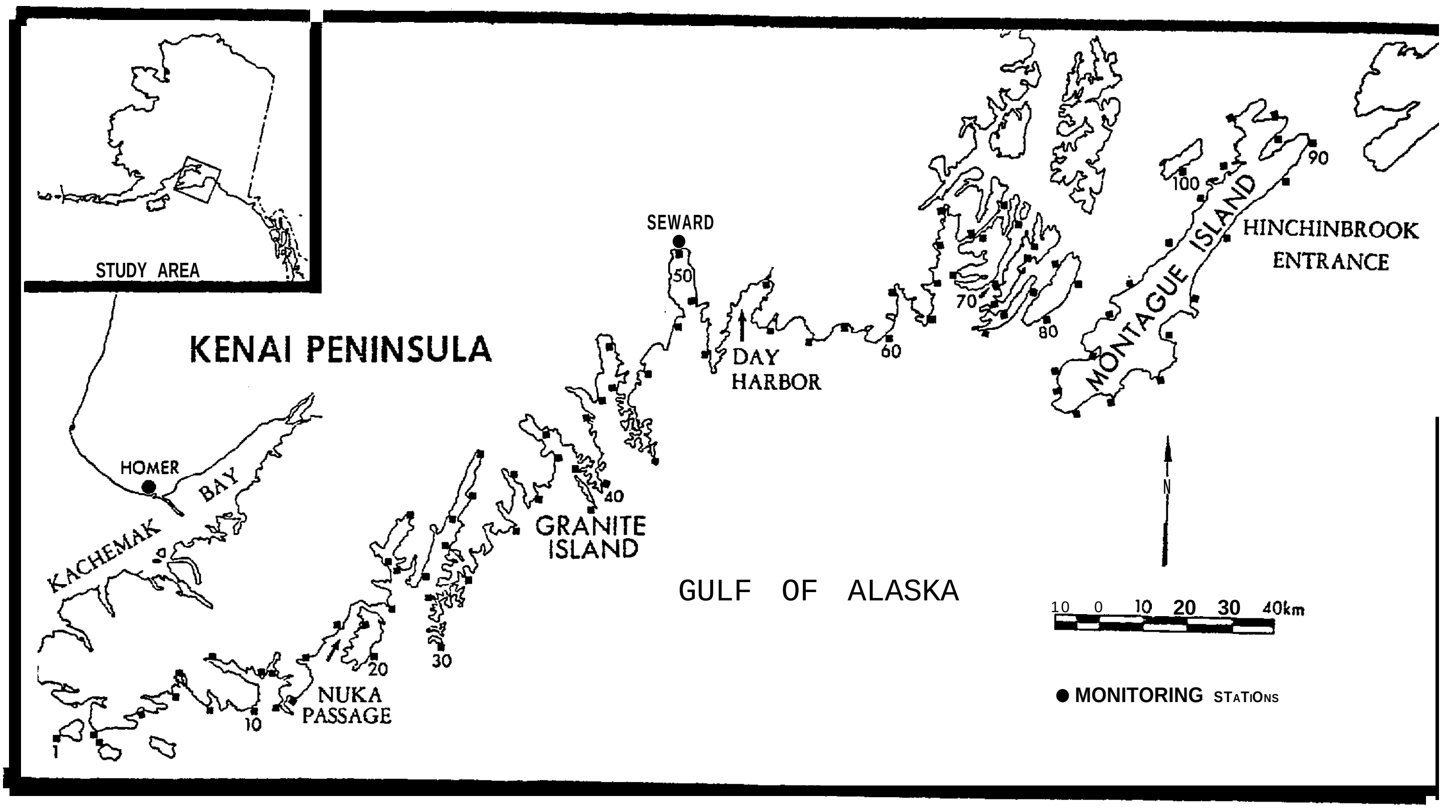


Figure 1. Map showing the location of the 100 stations monitored for this report along the outer Kenai Peninsula and Montague Island. Every 10th station is numbered. The index map (upper left) shows the relative location of the study area within southeastern Alaska.

GEOMORPHIC SETTING

General

The study area consists of 2157 km of shoreline bordering the Gulf of Alaska and Prince William Sound in south-central Alaska (Fig. 1). The area extends northeast from Elizabeth Island at the mouth of Cook Inlet to Hinchenbrook Pass and includes: (a) the southern part of the Kenai Peninsula coastline fronting the Gulf of Alaska; (b) the coastlines of Bainbridge, Evans, Elrington, Fleming, and Latouche Islands in the southeastern tip of the outer Kenai Peninsula; and (c) Montague and Green Islands coastlines in the southwestern part of Prince William Sound. Resurrection Bay and the town of Seward provide a precise geographic center for the area of investigation, dividing it into two halves of almost equal shoreline length. Seward is the only town in the study area with a year-round populace. The entire region is largely pristine and incredibly beautiful with only a minimal man-induced impact of the environment.

Outer Kenai Peninsula

The Kenai Peninsula is divided into two major physiographic units. The northern half of the peninsula is a region of rolling lowlands that border Cook Inlet. The southern or seaward-facing portion of the peninsula is comprised of the rugged Kenai-Chugach Mountains. The Kenai Mountains are underlain by rocks of Mesozoic age and form a ria type shoreline made up of deep embayments flanked by sheer rock cliffs. This section of the coast comprises roughly four-fifths of the study area. The region is cut extensively by streams and several large glaciers whose related moraines and outwash features are relatively abundant.

High segments of the Kenai-Chugach Mountains are dominated by east-trending ridges, 2,100 to 4,000 m high. Lower segments consist of discrete massive mountains from 1,000 to 1,800 m high, separated by a system of valleys and passes 1 to 2 km wide that have eroded along joints and bedding planes (Wahrhaftig, 1965). Such jointing and bedding patterns can play an important role in the bedrock control of shoreline orientation. The entire mountain range has been heavily glaciated. Many areas along the outer Kenai Peninsula are dominated by horns, aretes, cirques and U-shaped valleys.

Southwestern Prince William Sound

Montague Island is the largest and most southerly of five long narrow islands that trend northeast across the south side of Prince William Sound (Fig. 1). The island, which is 82 km long by 6 to 20 km wide, consists of a mountainous backbone ridge with an average summit altitude of 730 m and a maximum altitude of 866 m (Plafker, 1971). The other four islands, Latouche, Elrington, Evans, and Bainbridge, vary from 18 to 26 km in length and 2.5 to 7.2 km in width. They are also topographically lower with average summit elevations of roughly 300 m.

Bainbridge, Evans and Elrington Islands all have highly irregular shorelines dominated by large, deep, fjord-type embayments. The islands are separated by long, narrow, quiet water passages typical of a ria type of coastline. Montague and Latouche Islands display similar trends in coastal morphology. Both islands are more regular in outline with a dominance of erosional coastal features on their eastern shorelines. High vertical bedrock scarps and wave-cut platforms are especially prominent on the eastern and southern shorelines of Montague Island. Shallow, quiet water coves, small bays, tidal flats and fine- to coarse-grained sand beaches typify the more depositional western shorelines of Montague and LaTouche Islands. Unlike the outer Kenai Peninsula, the shorelines of these five mountainous islands have only a very minor contribution from glacially derived sediments. The dominant control on the shoreline morphology of the Prince William Sound Islands is the active tectonic uplift in the area.

TECTONIC SETTING '

Regional

The entire study area is underlain by rocks that are part of an extensive arcuate belt of thick Mesozoic and Tertiary marine deposits that extend through the Chugach-Kenai-Kodiak Mountains (Fig. 2). In terms of their tectonic settings, the outer Kenai Peninsula and Montague Island shorelines are examples of young mountain range coasts (Hayes, 1964), or continental collision coasts (Inman and Nordstrom, 1971; Davies, 1973). Rapid tectonic uplift related to Cenozoic erogenic activity typifies this type of shoreline. The coastline is characterized by high rugged cliffs and a narrow continental shelf.

The outer Kenai Peninsula and Prince William Sound areas have undergone tectonic change for millions of years. Broad areas of wave-cut platforms in the eastern half of the study area (uplift) and numerous drowned glacial valleys (downwarp) in the western part are common, It is . obvious that tectonics plays a major role in the formation and modification of the island and peninsular shorelines both in the long-term geologic sense and on a much shorter historical time scale.

Earthquake Activity

Sudden, often violent, earthquake activity is associated with continental collision coasts and can exert a strong influence on local morphology and shoreline orientation. This fact was documented within the study area by the sudden tectonic movements, both vertical and horizontal,

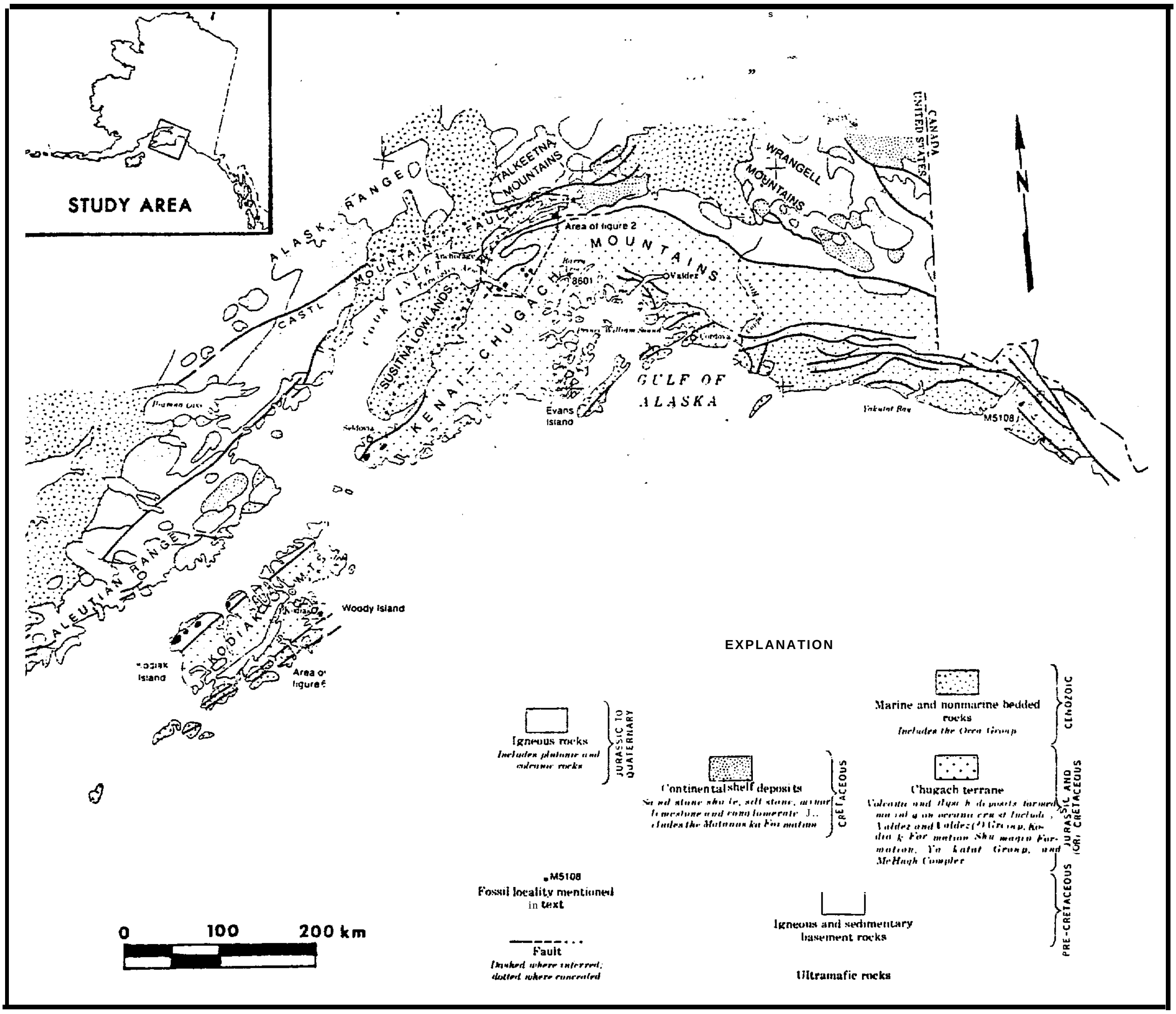


Figure 2. Structural setting and tectonic framework of the Kenai Peninsula and Montague Island within the southern Alaska island arc system (King, 1969; modified from Jones and Clark, 1973).

associated with the 1964 Good Friday Earthquake. Regional deformation produced by this earthquake occurred over an area of at least 112,000 square kilometers in south central Alaska from Kodiak Island to Prince William Sound. The study area for this report lies entirely within this area. Evidence of this tectonic activity is a major zone of uplift to the northeast of Day Harbor (Fig. 3) and a major zone of subsidence to the southwest of Day Harbor.

The zone of subsidence includes most of Kodiak Island, Cook Inlet and roughly four-fifths of the outer Kenai Peninsula. The axis of maximum subsidence within this zone trends northeast along the crest of the Ko-disk-Kenai-Chugach Mountains intersecting-the study-area along the western margin of Nuka Island (Fig. 3). A maximum downwarp of 2.3 m was recorded on the southwest coast of the Kenai Peninsula (Plafker, 1971). Montague Island lies within the 1964 earthquake focal region and is along the axis of maximum tectonic uplift (Fig. 3). Surface faulting and regional warping produced by the earthquake elevated the southwestern end of the island by as much as 11.5 m (Plafker, 1971). Southwest of Montague Island, the nearshore shelf may have been uplifted more than 15 m based on pre- and post-earthquake bottom soundings (Malloy and Merrill, 1971).

Kenai Peninsula and Montague Island have undergone tectonic change (both uplift and submergence) for millions of years. Geologic data (Plafker, 1966) indicates that the 1964 earthquake-related movements were but the most recent pulse in an episode of deformation that probably began in late Pliocene time and continued intermittently to the present.

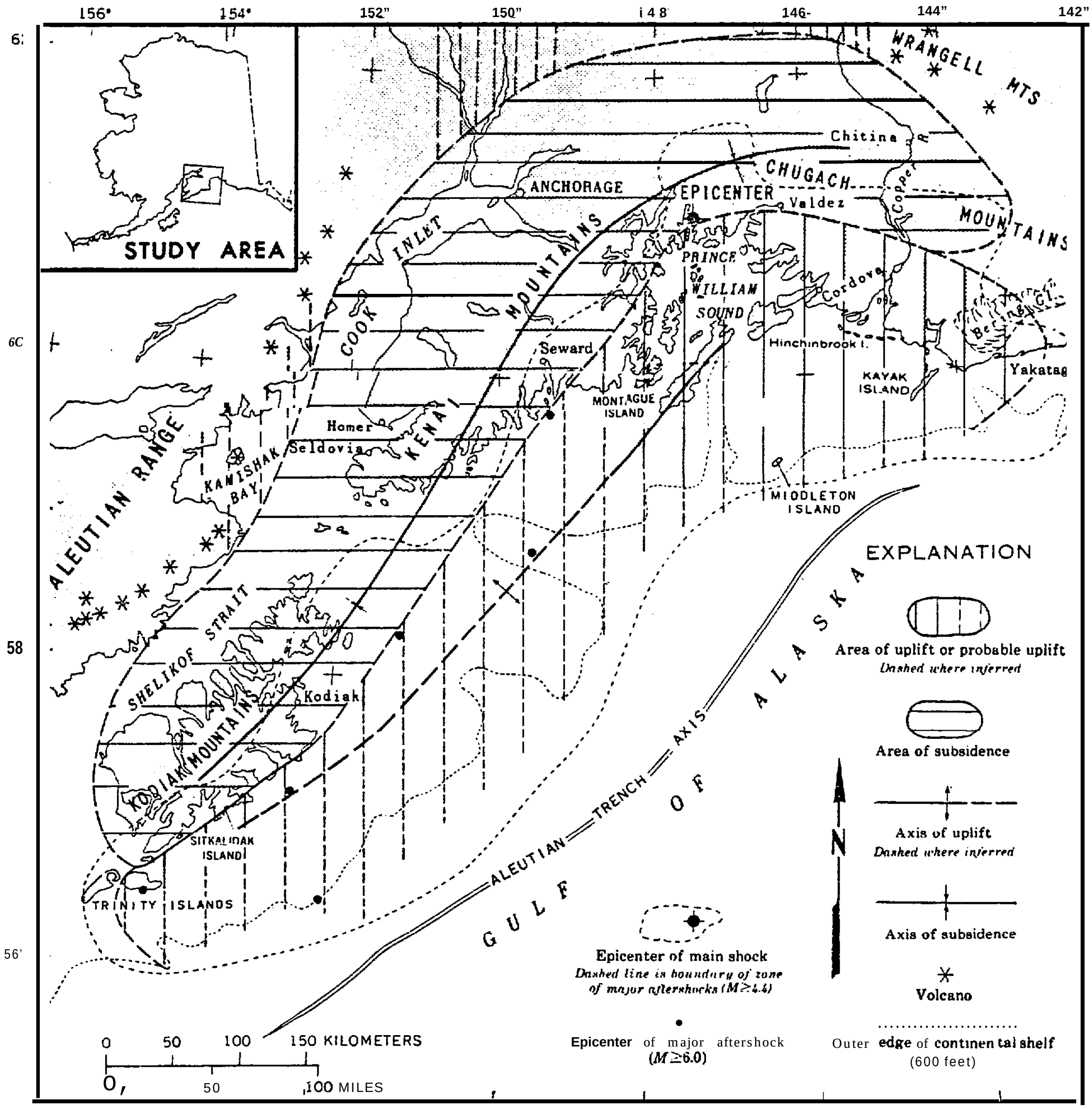


Figure 3. Regional setting of the Kenai Peninsula and Montague Island with respect to tectonic deformation and seismicity that accompanied the March 27 "Good Friday" earthquake, 1964. Note that the axis of maximum uplift parallels the eastern shoreline of Montague Island, while the axis of subsidence intersects the study area at Nuka passage (stations 17-18; see Fig. 1 for locations). (From Plafker, 1966).

GEOLOGIC SETTING

Regional

The Kenai Peninsula and western Prince William Sound Islands are located within the central margin of the continuous Kodiak-Kenai-Chugach mountain belt (Fig. 2). The Kenai-Chugach Mountains are composed chiefly of dark-gray metasandstone, slate and argillite of Mesozoic and Tertiary age (Plafker, 1966; Wahrhaftig, 1966). The main mass of the mountains is primarily Jurassic and Cretaceus bedded rocks with a narrow, discontinuously exposed section of older rocks along the northern flanks. (Clark, 1972). Almost all of the rocks in the Kenai Mountains are mildly metamorphosed and cut in a few places along the southern peninsular coast by granitoid masses. Montague and other Prince William Sound islands contain large bodies of greenstone in association with the argillite and greywacke.

Lithologies

The geologic units in the Kenai Peninsula and Prince William Sound areas shown in Figure 2 include: 1) the Valdez Group, a sequence of eugeosynclinal rocks that comprise the vast majority of the outer Kenai Peninsula; 2) the Orca Group, a sequence of early Tertiary age rocks which can be divided into a lower volcanic unit and an upper sedimentary unit (Case et al., 1966). Elrington, Evans, Latouche, Green, Montague and the eastern half of Bainbridge Islands are all comprised of rocks from the Orca Group (Fig. 2). These rocks are faulted into contact with the Valdez Group of the outer Kenai Peninsula along a north-south line that divides Bainbridge Island into two halves (Fig. 4); 3) bodies of intrusive granitic rocks found within the Valdez Group along the outer Kenai Peninsula in the vicinity of Granite Island (Figs. 2 and 4); 4) unconsolidated sediments and marine deposits of Quaternary age. These are the sediments that comprise the beaches, spits,

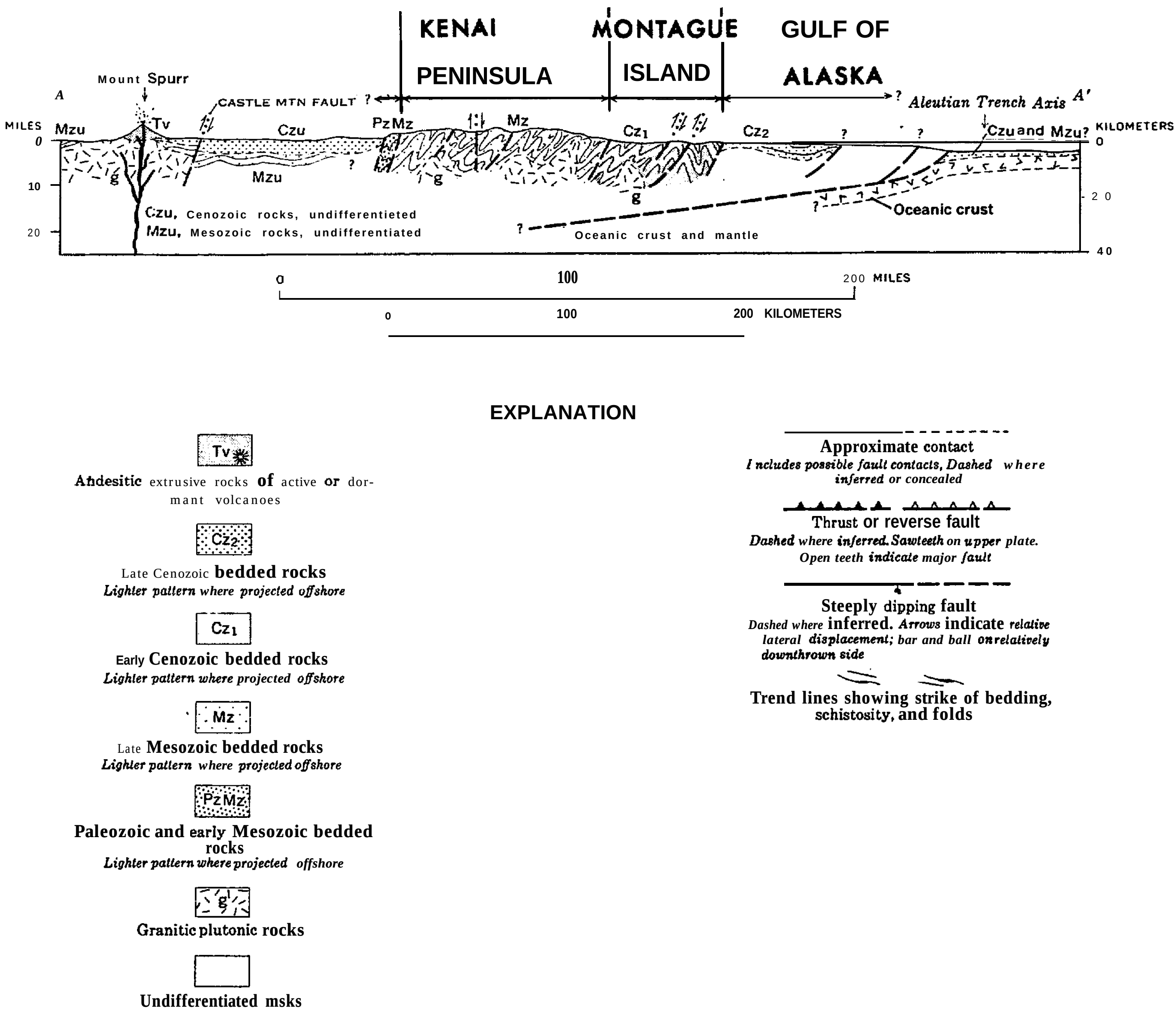


Figure 4. Idealized vertical section through Kenai Peninsula and Montague Island showing selected rock units and structural features of south central Alaska. Note that the structural-tectonic setting is dominated by the subduction of oceanic crust beneath the over-riding continental rocks (collision coast). (After P. B. King, 1969; modified from Plafker, 1966).

and other depositional features in the study area. A more detailed description of the lithologies within these units is given below.

Valdez group. - A thick unit of metasandstone (mostly metagreywacke), metasiltstone, and argillite is exposed over four-fifths of the outer Kenai Peninsula (Clark, 1972). Those rocks are part of a belt that extends more than 600 km through the Kenai-Chugach-Kodiak Mountains (Payne, 1955; Burk, 1965; Moore, 1971). The sequence is characterized by thin to thick beds of light-grey or tan, poorly-sorted sandstone of greywacke type interbedded by dark-grey to black argillite and slate (Case et al., 1966). The Valdez Group is a widespread flysch sequence that in some areas retains sedimentary features associated with turbidites (Clark, 1972).

Orca group. - The predominantly volcanic unit that forms the lower part of the Orca Group crops out in a discontinuous-belt within the study area on Elrington, Evans and Bainbridge Islands (Fig. 5). This unit consists of altered, green-black basaltic lava flows, pillow lavas, flow breccias, and coarser textured diabase intrusive collectively termed "greenstone" (Case et al., 1966). This volcanic unit is of Tertiary (probably mid to late Eocene) age (Plafker and MacNeil, 1966).

The sedimentary unit that comprises the upper part of the Orca Group includes the rocks that occur on all of Montague, Green and Latouche Islands and most of Evans, Elrington and Bainbridge Islands (Fig. 5). The sequence consists mainly of thin to thick beds of greywacke sandstone and minor amounts of light-colored arkosic, carbonaceous, tuffaceous, calcareous and conglomeratic sandstones (Case et al., 1966). The unit is distinguished from the Valdez Group by a more variable lithology and slighter degree of metamorphism.

EXPLANATION

Recent — QUATERNARY

Qu

Unconsolidated deposits

UNCONFORMITY

Eocene — TERTIARY

gr

Granitic rocks

Granite and quartz diorite in stocks, dikes, and sills that intrude Valdez and Orca Groups

Tos

Sedimentary rocks of Orca Group

Slightly metamorphosed and complexly folded marine sandstone and dark-gray to black or reddish-brown hard siltstone and argillite. Includes minor amounts of conglomerate, limestone, and basaltic lava flows. Contains plant material of Tertiary age and nondiagnostic marine megafossils

Tov

Volcanic rocks of Orca Group

Gently to moderately folded, greenish-black slightly altered basaltic flows (greenstone) that commonly exhibit pillow structures. Intertongues with massive conglomerate and breccia and thin-bedded argillite and sandstone. Contains marine megafossils of probable middle to late Eocene age

UNCONFORMITY

JURASSIC(?) AND CRETACEOUS

KJv

Valdez Group

Tightly folded and metamorphosed marine graywacke and dark-gray & black slate containing minor amounts of argillite and conglomerate

Glacier

Contact

Dashed where approximately located; dotted where inferred

U

Fault

Dashed where approximately located; dotted where inferred. U, upthrown side

Explanation for Figure S.

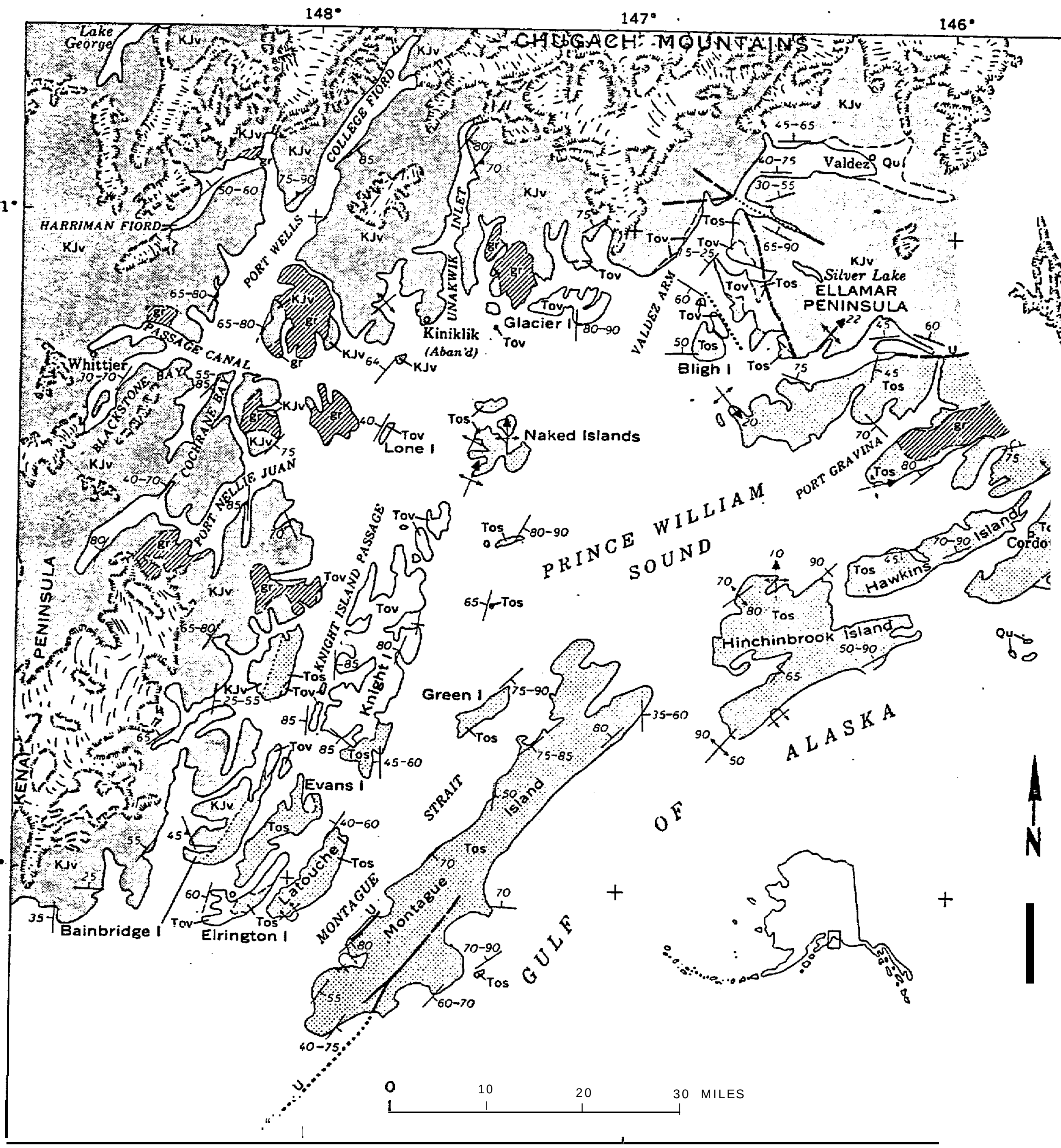


Figure 5. Generalized geologic map of the Prince William Sound region, southeastern Alaska. Note the sharp break in bedrock lithologies from the easternmost Kenai Peninsula (KJv) to Evans, Elrington, Latouche and Montague Islands (Tov and Tos). The nature and composition of bedrock can play a very important role in shoreline orientation and morphology (From Case et al., 1966)

Intrusive. - Granitic rocks intrude the Valdez Group within the study area in the vicinity of Granite Island (Fig. 2). The intrusive rocks are highly resistant to weathering and marine erosion, producing highly irregular trends in shoreline orientation. These rocks consist mainly of pinkish-gray biotite granite and quartz diorite (Clark, 1972).

Unconsolidated sediments. - Flat lying fluvial, glacial and marine deposits of gravel, sand and mud overlie the Mesozoic and Tertiary rocks in the study area. These sediments comprise all the depositional features discussed in this report.

Bedrock Influences on Shoreline Morphology

The structure and lithology of the bedrock along a section of shoreline can play a major role in the weathering patterns and orientation of the coast. In their study of Kodiak Island, Ruby et al. (1979) made the following observations on the bedrock compositional and structural control of beach morphology:

> Highly bedded rock types like slates and shales can form a variety of scarp configurations, dependent on the dip of the bedding planes. Where bedding planes are nearly horizontal, the scarps will be very irregular and wave-cut platforms will be quite flat and uniform. If the bedding planes are near vertical, the scarps will be uniform and wall-like, broken and displaced by fracture and fault patterns, while associated wave-cut platforms will be very irregular containing numerous tidal pools. Bedding planes dipping from near vertical to about 50 or 600 will often result in a dip-slope scarp. These scarps are flat and slope downward at the angle of dip of the bedding. Dips from 50° to about 20° will usually result in an irregular scarp and an irregular wave-cut platform.
>
> Bedded rock types yield platy fragments to the beachface. Thus, gravels, cobbles and boulders will generally be flat regardless of their degree of rounding. Very well rounded gravels will look like discs and are referred to as discoidal gravels.
>
> Unbedded rock species like quartz diorite have a more uniform strength and thus the shape of scarps and wave-cut platforms becomes a function of fracture and fault patterns in the rock rather than their own internal structure. The scarps usually appear rather massive and rather steep. The wave-cut platforms

at their base are moderately uniform with undulatory surfaces and scattered tidal pools. Gravels and boulders of this rock type will usually be equant in shape regardless of the degree of rounding. Well rounded gravels will be spherical.

Slate and quartz diorite are two end members of rock species which control scarp and platform shapes as well as gravel shapes, Most other rock types will fall behaviorally somewhere between them. Thus, scarps, platforms and beach sediment can take an extremely wide variety of shapes.

OCEANOGRAPHIC AND METEOROLOGIC SETTING

Tides

The Kenai Peninsula to Montague Island coastline has semi-diurnal tides with a strong diurnal component. Mean tidal ranges, recorded in the Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska, Volume 1 (1977), vary from 2.4 meters at the eastern limit of the study area (Patton Bay, Montague Island) to 3.2 meters at the western limit of the study area (Picnic Harbor, Rocky Bay), There is some amplification of tidal ranges within the embayments, but this is limited due to the relative deepness of most of the fjords,

Wind and Wave Regime

The positioning of two major fronts, the Pacific Polar and pacific Arctic fronts, largely govern the wind patterns and resultant wave energy flux of southeastern Alaska (Hayes et al., 1976), The high frequency and intensity of storms produced by both of these fronts make the maritime region of the Gulf of Alaska the most severe cyclogenetic region (during winter) in the Northern Hemisphere (Petterssen, 1969). During the summer, cyclonic activity decreases markedly, and storms are of less intensity. Wind and wave data taken from the 1970 Survey of Synoptic Meteorological Observations (SSMO) and the Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska, Volume I (.1977) indicate a prevailing and predominant wind frequency distribution out of both the east and west (Fig. 6). The average wind regime for the Gulf of Alaska over a seven year period from 1963 to 1970 demonstrates that both dominant and prevailing winds are aligned with the general trend of the shoreline (Nummedal and Stephens, 1976). In some instances, fjords generate local wind systems, especially near their heads. They are usually backed by relatively high mountains which can generate catabatic winds which blow downslope toward the mouth of the fjord.

The combination of wind frequency distribution with observed wave heights and periods (SSMO data) provides a wave energy flux value which can be directly related to longshore sediment transport rates (Coastal Engineering Research Center, 1973). The resultant wave energy flux vector for the study area (Seward data square) points northeast. The direction of this vector should correspond to the direction of net coarse sediment transport on adjacent exposed beaches. In the Gulf of Alaska, calculations show a convergence of wave energy toward Montague Island and Prince William Sound (Nummedal and Stephens, 1976). The Seward data square contains the highest average annual wave energy flux value among those computed for the Gulf of Alaska (Nummedal and Stephens, 1978). These values range from 1.5 to 5.7 x 10^{10} ergs/m sec (Fig. 6).

Ocean bathymetry rapidly deepens off the coastline within both the Gulf of Alaska and the numerous fjords along the outer coast of the Kenai Peninsula. Depths of 120 to 300 m are common within one kilometer of the shoreline. There is tremendous variability in relative wave energy from one area to another. This is due to the variable fetch distance as well as the orientation of the shoreline with respect to incoming waves.

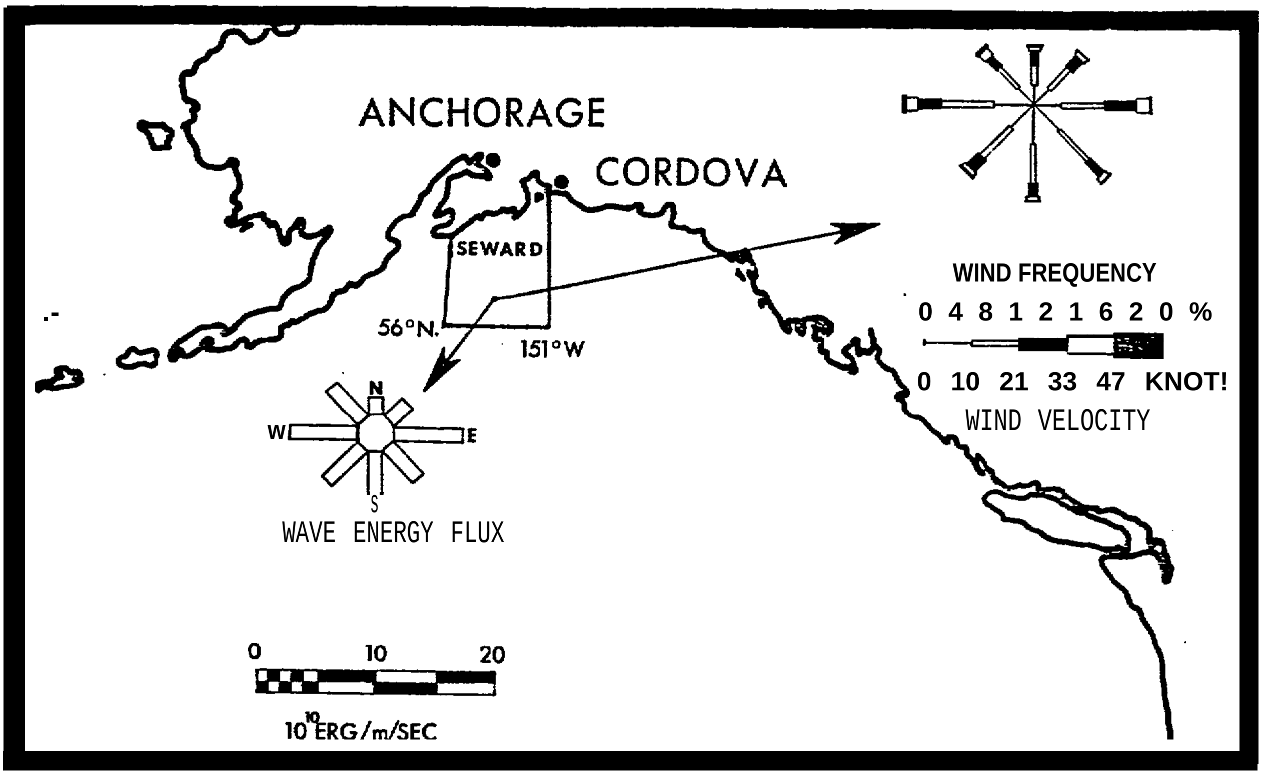


Figure 6. Wind frequency and wave energy flux distributions taken from SSMO data (1970) for the Seward square in south-eastern Alaska. Note the difference of winds out of the east and west and resultant wave energy flux (from Nummedal and Stephen, 1976).

In general, there is a uniform decrease in wave energy as the fjord heads are approached. The exposed shorelines usually have well developed high depositional berms indicative of frequent large *storm* waves. The more protected fjords have much lower, generally vegetated berms, indicative of lower wave energy. Many of the fjords, as well as the other numerous protected areas on the outer Kenai coastline, have exceptionally low wave energy at their heads.

METHODOLOGY

In order to survey large sections of coastline in a reasonable amount of time, a modified zonal method of field study was utilized. The zonal method *was* developed by the Coastal Research Division at the University of South Carolina (Hayes et al., 1976). Essentially, the method has the following steps:

1. Preceding field work, aerial photographs, maps and charts of the area and pertinent literature are studied.

2. Field work is begun by an aerial reconnaissance of the study area during which:

a. Detailed oblique aerial photos are taken using both color and infra-red film.

b. Coastal morphologic features such as beaches, cuspate spits, bedrock cliffs, etc., are mapped on 1:63,360 topographic maps.

c* Changes in coastal geomorphology, which have taken place since the original topographic mapping, are added to the base maps.

d. A detailed description of the general geomorphology and sediments is recorded verbally on tape.

3. Based upon observations made during the aerial reconnaissance, equally spaced survey stations are chosen for more detailed work. For the present study, a 20 km interval was selected.

4. For the remainder of the field work, each station is photographed in detail from the air and, where feasible, visited on the ground.

5. At most of the ground stations, the following is done:

a. A transit line of the active beach zone is made to delineate beach morphology. These profiles are plotted by computer.

b. Sediment samples are taken using a 10 cm coring tube in the upper, mid and lower beachface.

c. A field sketch of each site is made to show surrounding geomorphology and geology and to aid the field observer's perception.

d. Ground photos of the profile site and sediments are taken.

e. A tape-recorded description of the site and its surrounding geology, geomorphology, sediments and marine processes is made.

6. Oil spill vulnerability classes are recorded on 1:63,360 topographic maps. This is done in the field to allow questionable areas to be rechecked.

Standard laboratory techniques (settling tube and Ro-tap) are used for determination of the textural qualities of sediment samples collected in the field. All samples are analyzed for composition, grain size, sorting, skewness and kurtosis. The beach profiles are computer plotted and studied to help determine the morphology of the beaches. Aerial and ground photographs are reviewed and cataloged. In many instances, where taking samples is impractical due to the large size of the material, photographs are taken of the sediment (i.e. , boulders). Grain size and other textural properties are then determined from the photographs..

COASTAL MORPHOLOGY

General

The Kenai Peninsula to Montague Island coastal region is an extremely diverse area that is strongly influenced by tectonic activity, marine processes and glaciation. Recent tectonic activity has resulted in the study area being divided into distinct morphologic zones. The coastline west of Day Harbor to the western tip of Kenai Peninsula (approximately 1180 km of shoreline or 55% of the total study area) shows dramatic evidence of submergence (Fig. 3). The dominant features in this region are high vertical scarps cut into bedrock which are often fronted by narrow gravel and boulder beaches. There are also numerous pocket beaches located in small (less than 1 to 2 km) indentations in the scarps. Other indicators of submergence found west of Day Harbor are: 1) wave-cut notches into bedrock; 2) dead tree lines along beaches backed by forests; and 3) subtidal bedrock platforms. East of Day Harbor, the coastline shows strong evidence of uplift, especially in the Montague Island area. This 880 km stretch of shoreline (41% of the study area) is characterized by uplifted wave-cut platforms, stranded gravel beaches and infilled lagoons.

The coastline is strongly affected by the wave regime. Areas that are exposed to the open ocean or have a large fetch fronting them are subjected to relatively large waves. These exposed areas typically have high vertical bedrock cliffs (often greater than 100 to 200 m). In more sheltered areas, bedrock scarps tend to have low relief. Sheltered or protected areas have more depositional features such as wide sand and gravel beaches, stream mouth deltas, tidal flats and salt marshes.

Glacial activity has also influenced the coastal morphology. Extensive Pleistocene glaciation cut deep fjords that dominate much of the study area. Present glacial activity, although very limited, locally supplies a great deal of sediment, forming deltas, tidal flats and large bayhead beaches.

Due to the processes discussed above, the coastline along the outer Kenai Peninsula and Montague Island is dominated by four main morphologic types (Table 1). These include: 1) exposed bedrock shorelines; 2) sheltered bedrock shorelines; 3) beaches; and 4) river mouth delta-tidal flats and salt marsh systems (Table 1). In the following section, each one of these environments and their subenvironments will be discussed and typical examples given.

Exposed Bedrock Shorelines

Bedrock cliffs. - Exposed bedrock cliffs comprise 678 km (31%) of the shoreline. They are most abundant in the western portion of the study area where maximum submergence has occurred. The cliffs range in height from a few to over 250 meters (Fig. 7). Generally, bedrock cliffs directly exposed to large waves have maximum relief. In high energy areas, the cliffs are often fronted by sea stacks and large talus slopes (Fig. 7). Exposed bedrock cliffs in emergent areas may have narrow boulder beaches at their base.

Exposed bedrock cliffs are subjected to wave attack, even at low tide. Consequently, these features will clean themselves in the event of an oil spill within a few weeks. In addition, waves reflect off the vertical scarps and tend to “push” floating oil away from the rocks. Therefore, any oil that may be spilled in a coastal area composed of exposed bedrock cliffs would not remain there for very long. These environments are assigned an O.S.V.I. value of 1, the lowest class (see section on Oil Spill Vulnerability).

Table 1. SHORELINE MORPHOLOGY - KENAI PENINSULA TO MONTAGUE ISLAND

	ENVIRONMENT	TOTAL SHORELINE (KM)	% OF TOTAL SHORELINE
1.	Exposed Bedrock		
	A. Bedrock scarps	678 km	31%
	B. Wave-cut platforms	212 km	10%
II.	Sheltered Bedrock	529 km	24%
III.	Beaches	556 km	26%
	A, Continuous linear	Abundant	
	B. Pocket	Abundant	
	C. Bayhead	Common	
	D. Spits	Rare	
	E. Uplifted	Rare	
IV.	River Mouth Deltas-Tidal Flats Systems	81 km	4%
	Tidal Flat-Salt Marsh Systems	101 km	5%
	TOTALS	2157 km	100%

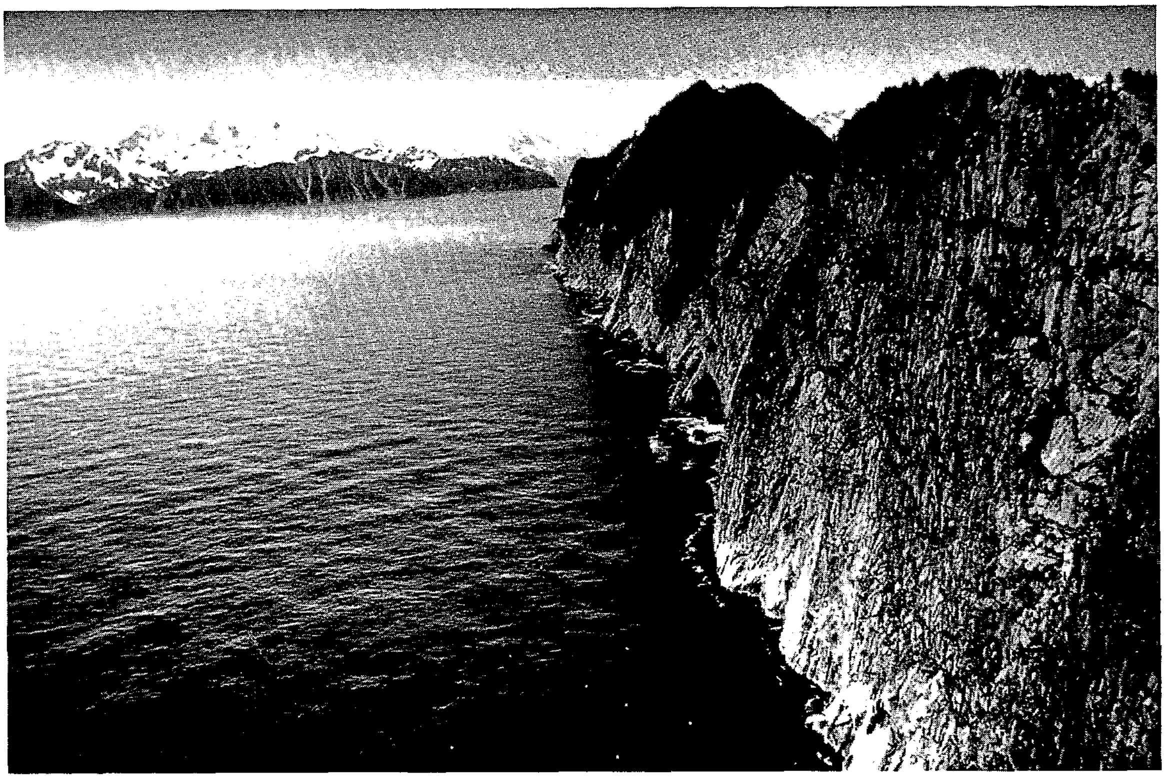
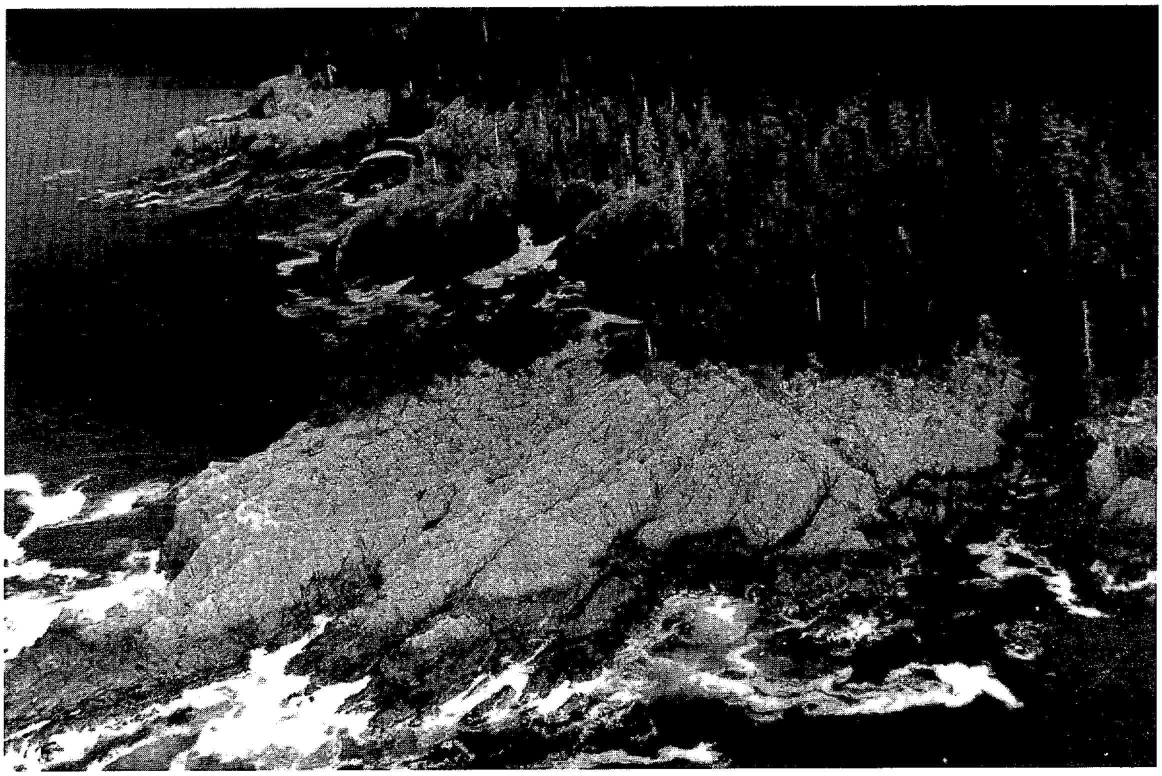
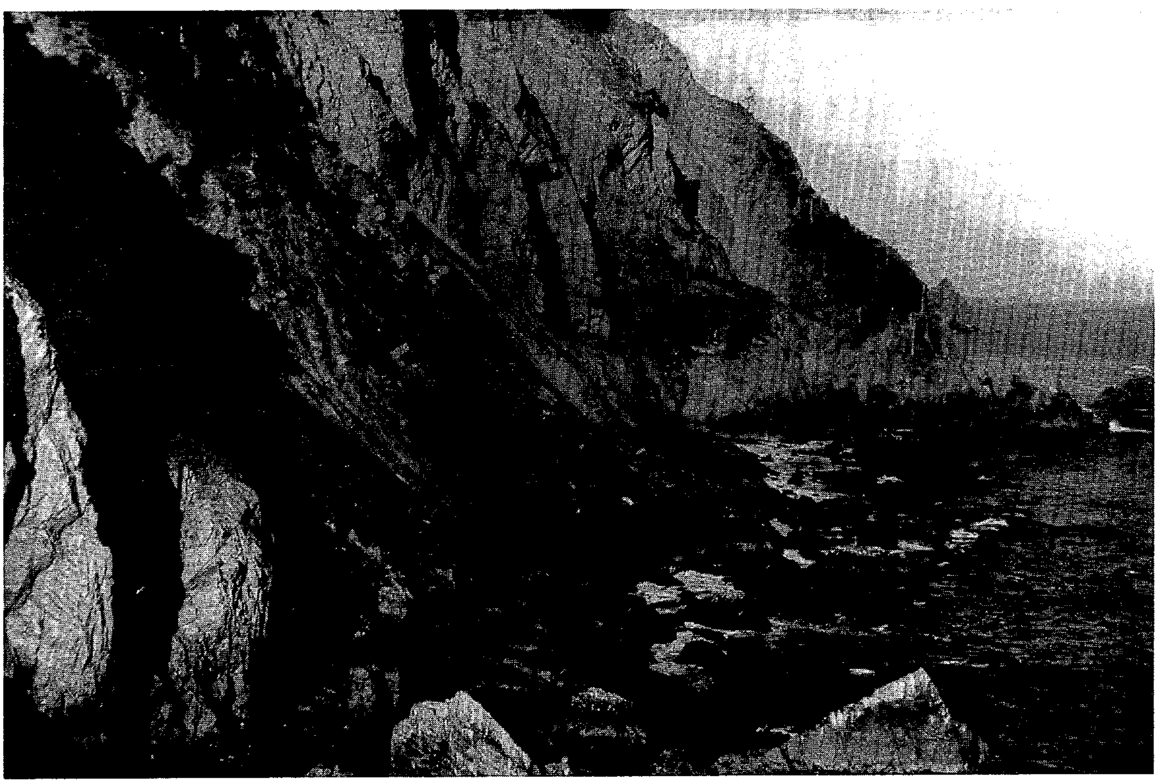


Figure 7. Typical examples of exposed bedrock cliffs. These features are very common within the study area and display extreme variability in slope and relief. The near vertical bedrock cliff shown above (Sta. KNP-39, Granite Island) is over 250 m high. The more gently sloping bedrock cliff at Barrington Point (following page, top) has a relief of only 5-10 meters. In uplifted areas, sediment from avalanche fans and talus slopes form narrow boulder, cobble beaches at the base of the cliff (following page, bottom). Bedrock cliffs are directly exposed to high wave energy. Thus, they are assigned an O.S.V.I. of 1, the lowest class.





Examples of exposed bedrock cliffs are survey station numbers: KNP1, 3, 10, 14, 18, 20, 23, 24, 29, 30, 31, 32, 33, 35, 38, 39, 40, 42, 44, 45, 46, 47, 48, 49, 51, 42, 53, 54, 55, 58, 60, 62, 63, 67, 69, and 84.

Wave-cut platforms. - Wave-cut platforms constitute 212 km (10%) of the study area, being most abundant in locations that have undergone maximum emergence (i.e., Montague Island) . Very often, these features are backed by erosional scarps that were uplifted out of wave action. The wave-cut platforms are composed almost entirely of bedrock, but may have a scattering of very coarse, angular gravel and boulders (Fig. 8).

Wave-cut platforms have abundant intertidal life that would suffer from the initial impact of a massive oil spill. Despite this, they are assigned an O.S.V.I. value of 2. Exposure to wave attack causes any oil that may impact one of these areas to be removed relatively quickly. As the O.S.V.I. is based on residence time of the oil, exposed wave-cut platforms are given a low classification.

Examples are survey stations KNP-9, 77, 80, 83, 85, 88, 89, and 90.

Sheltered Bedrock Shorelines

Bedrock cliffs found in sheltered areas (locations that have little or no wave activity) comprise 528 km (25%) of the study area. These scarps typically have an average relief of less than 5 to 10 meters, but may be backed by relatively high, steep vegetated slopes (Fig. 9). Narrow gravel beaches (less than 10 m wide) are often found at the base of the scarps, especially in uplifted areas (Fig. 9). Sheltered rocky shorelines, unlike exposed bedrock shorelines, are assigned a high O.S.V.I. Lack of significant wave energy reduces natural cleansing processes, and any oil that may impact the area would remain for a long period of time. In addition, the relatively coarse nature of the beach sediments often

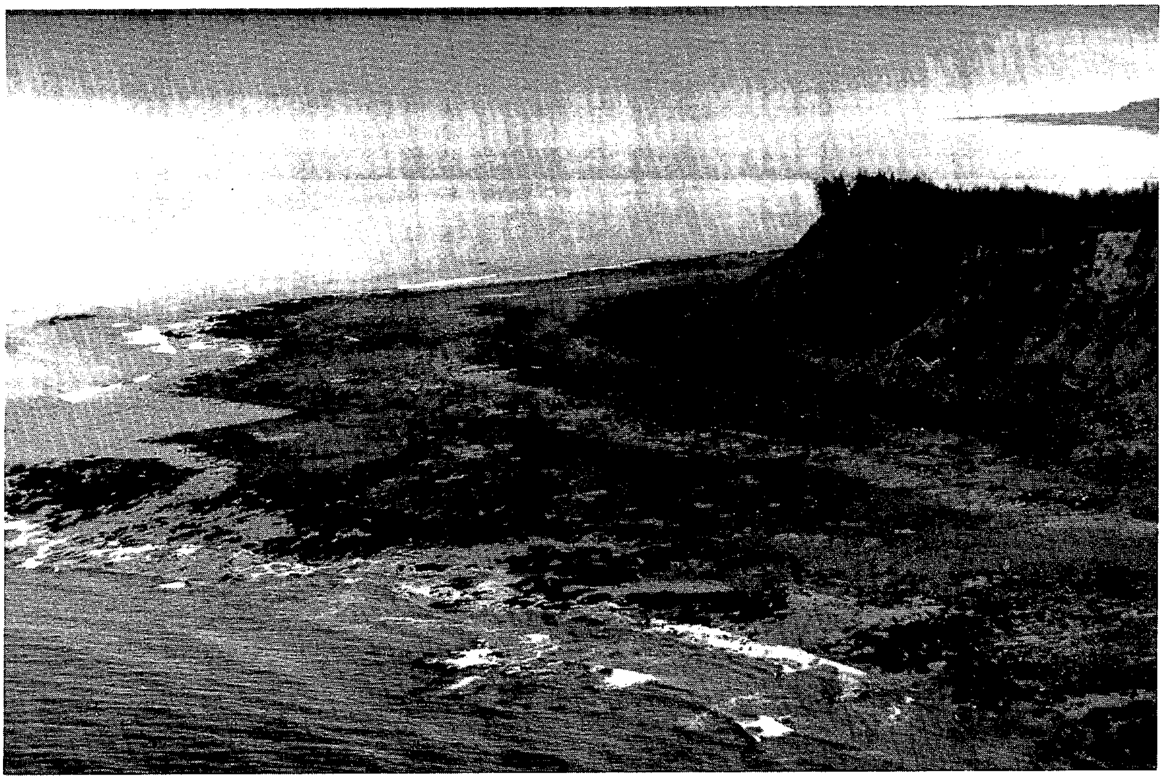


Figure 8. The southwestern end of Montague Island is one of the best examples of an uplifted wave cut platform (above). The features are backed by erosional scarps and composed almost entirely of bedrock. However, they may have a thin, discontinuous scattering of angular gravel and bedrock (following page, top). Rock platforms of this type generally have quite low oil residence times due to their impermeable character and high wave energy. However, as shown in the sketch of station KNP-9 (following page, bottom), the coarse beach face is more sensitive to oil spill impact where a heavy intertidal biota coats the bedrock.

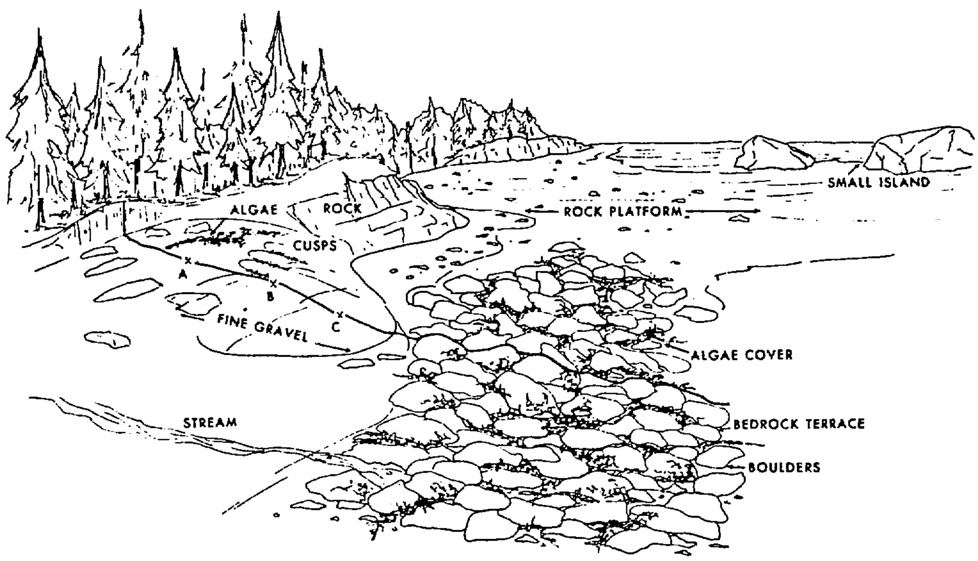
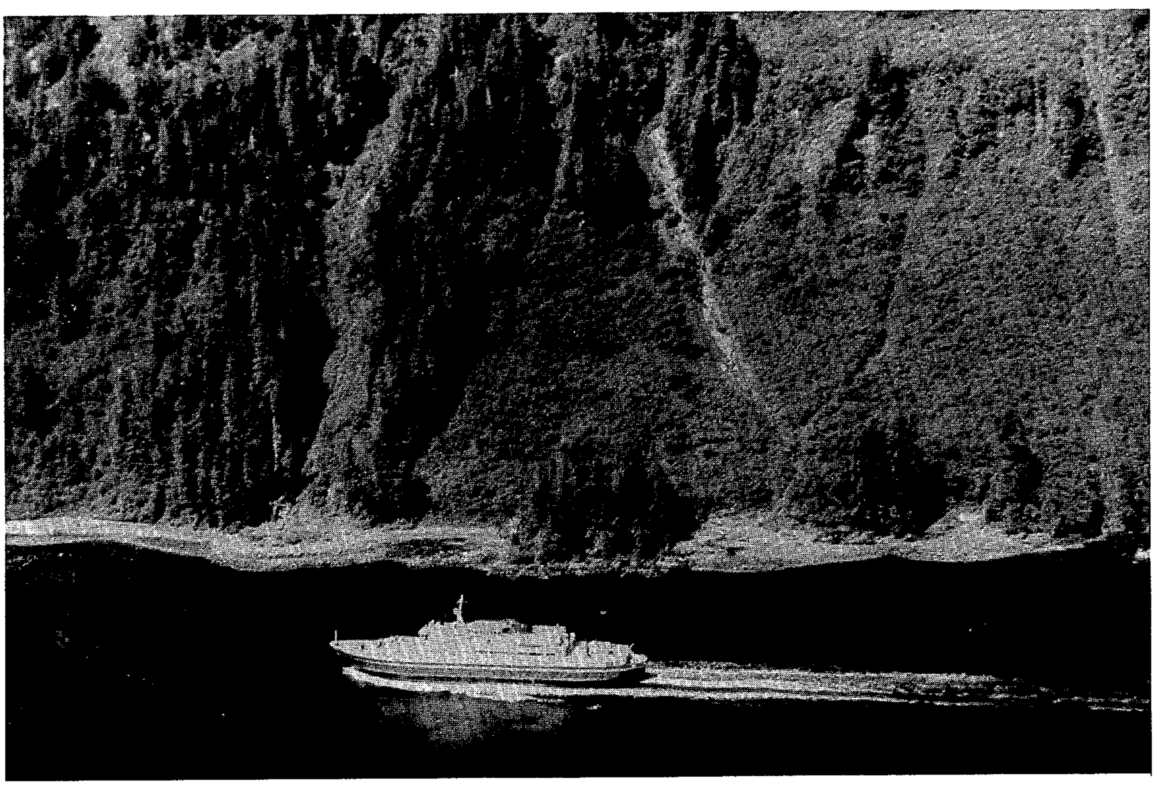

ALGAE
ROCK
CUSPS
A
B
C
FINE GRAVEL
SMALL ISLAND
ROCK PLATFORM
ALGAE COVER
STREAM
BEDROCK TERRACE
BOULDERS

Figure 9. Sheltered bedrock cliffs are found in areas of little or no wave energy and typically have an average relief of only 5-10 m. They are often backed by a steep vegetated slope (Sta. KNP-73, above) or fronted by a narrow gravel beach (KNP-68, below).



associated with these features allows oil to penetrate the substrate, increasing oil retention. The diverse and abundant intertidal life that characterizes these areas would be severely damaged by oil impact. Sheltered bedrock shorelines have an O.S.V.I. of 8.

Examples are survey stations KNP-8, 12, 16, 21, 65, 68 and 72.

Beaches

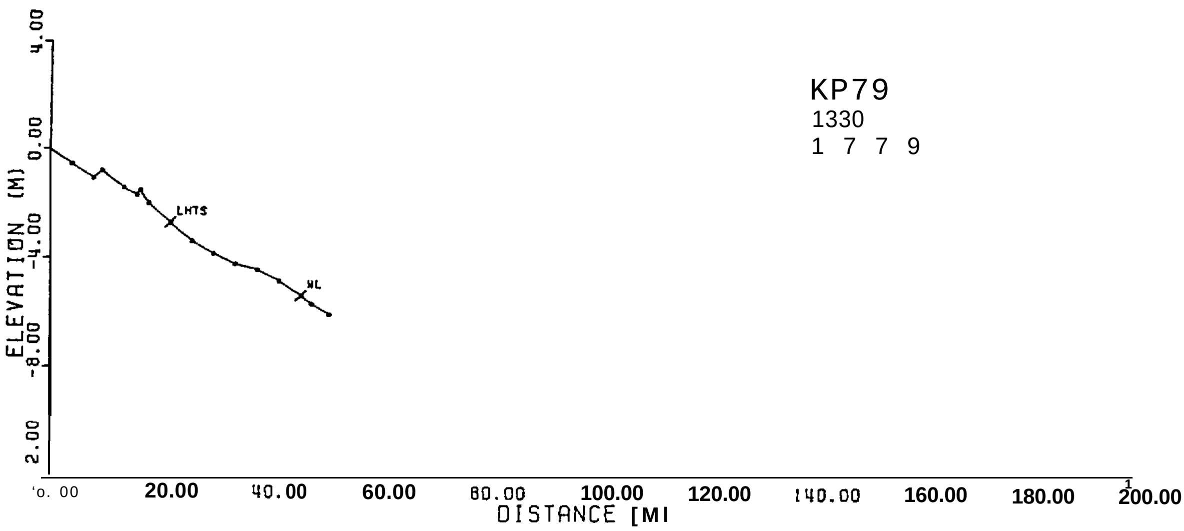
In total, beach environments comprise 556 km (26%) of the shoreline. There are five morphologically distinct types of beaches commonly found within the study area. They are discussed separately below.

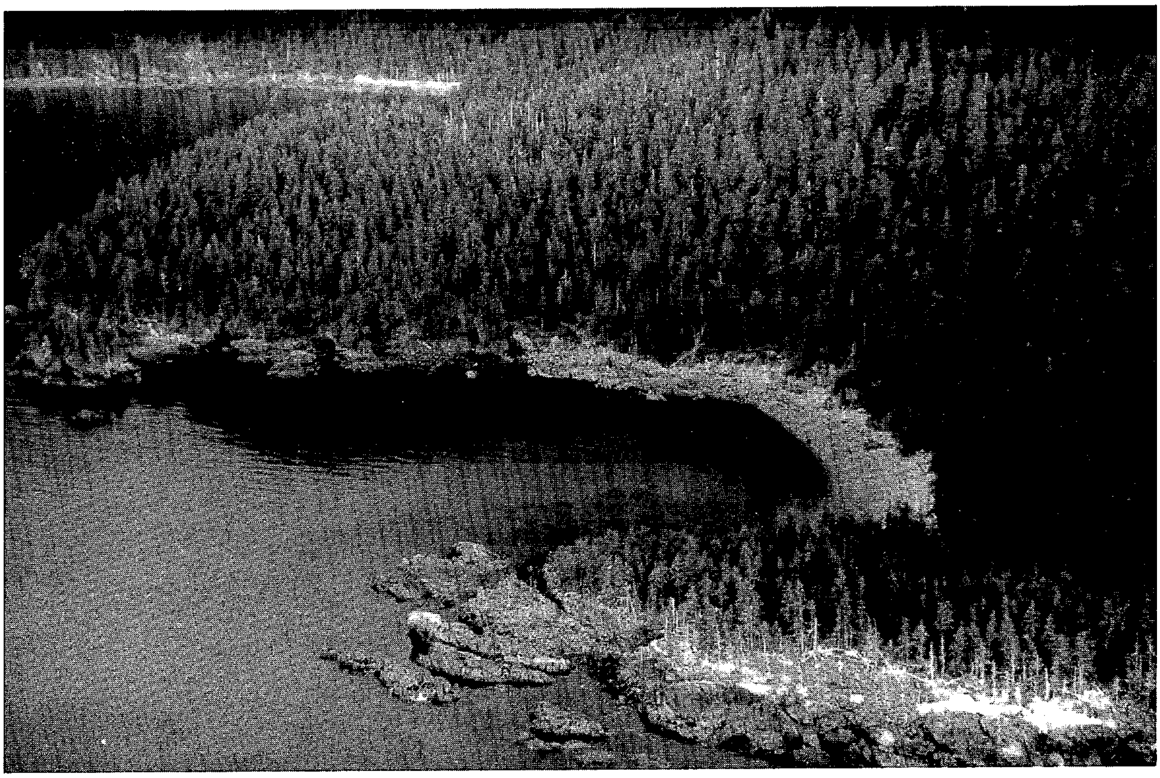
Continuous linear beaches. - These features are extremely common and are the most abundant type of beach in emergent areas. Continuous linear beaches are found fronting sheltered bedrock scarps, glacial till deposits and even high energy exposed scarps in uplifted areas. They normally are narrow, less than 5 to 10 meters wide, but may extend laterally for several kilometers (Fig. 10). Sediment sizes range from gravel in sheltered areas to cobbles and boulders in exposed areas. Continuous linear beaches are assigned O.S.V.I. values of 4, 6, or 7, depending on the texture of the beach. A 4 is assigned to pure sand beaches, 6 to mixed sand and gravel beaches, and 7 to pure gravel beaches. Higher O.S.V.I. values with increasing grain size is due to the relative permeability of the sediments. Normally, coarser sediments have higher permeabilities, increasing the residence time of oil and the O.S.V.I.

Examples are KNP-4, 9, 61, 70, 75, 78 and 79.

Pocket beaches. - Pocket beaches are ubiquitous in the study area, being found in both exposed and sheltered environments. They normally are located in small indentations in the shoreline and are bounded on either end by bedrock scarps (Fig. 11). Sediments are locally derived

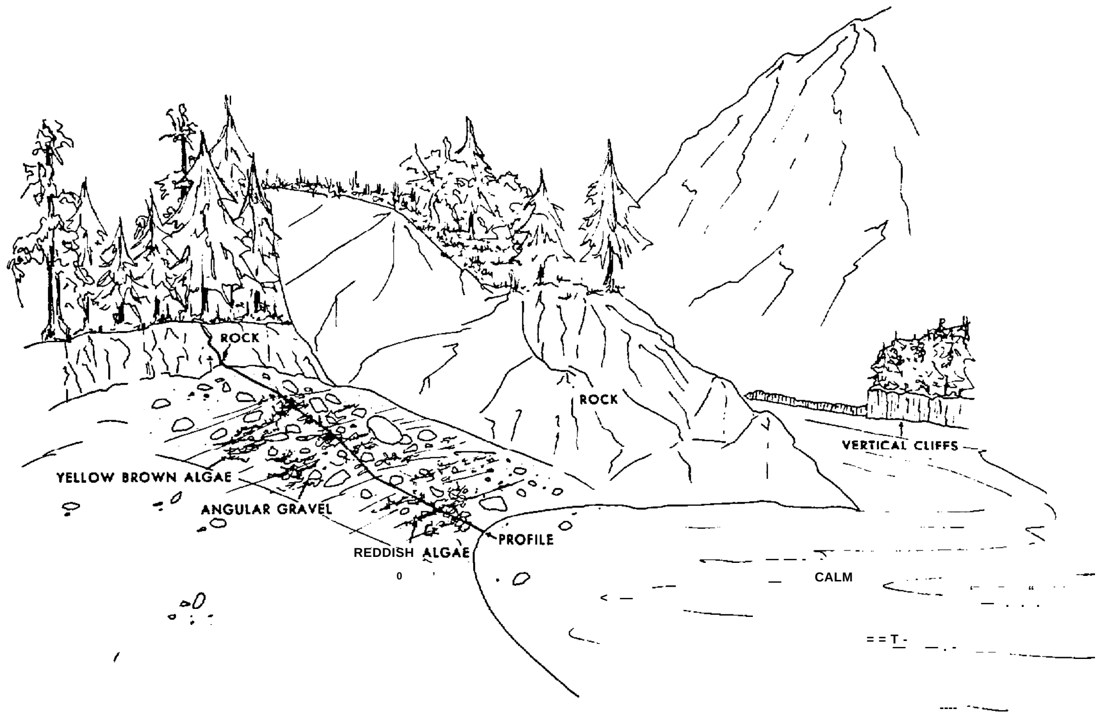
Figure 10. Continuous linear beaches are most common in the uplifted portions of the study area and are found fronting both sheltered and high energy bedrock scarps and glacial till deposits. As shown above, these beaches are normally 5-10 m wide, but may extend laterally for several kilometers. Sediments range from gravel to cobbles and boulders, and are typically angular to subangular (KNP-39, following page, top). The beach profile is narrow and relatively featureless (KNP-79, following page, bottom). Most gravel beaches of this type are classified as O.S.V.I. values 6-8, depending on sediment size and wave energy.

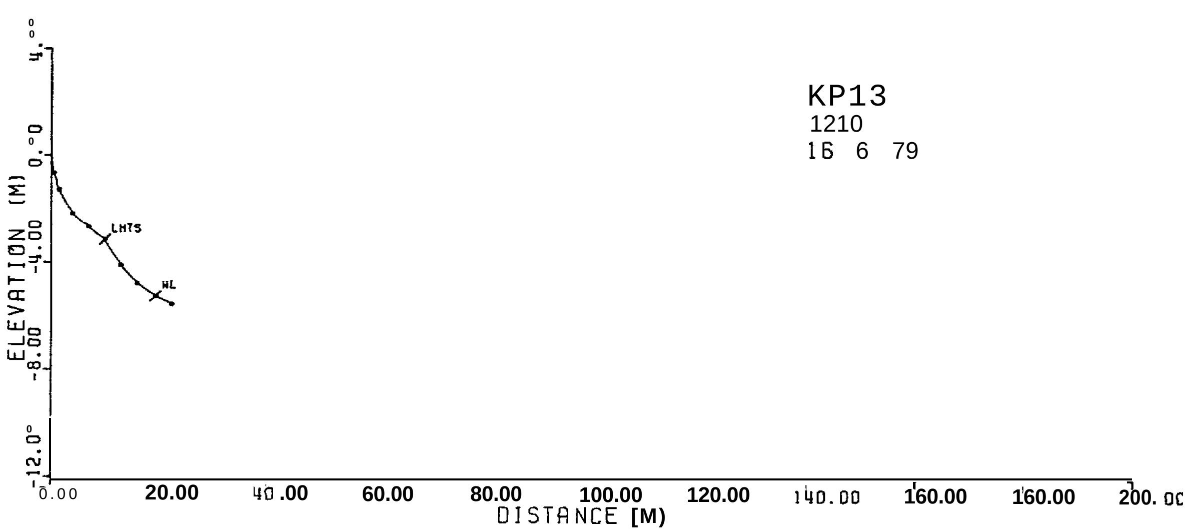

KP79
1330
1 7 7 9
ELEVATION (M)
4.00
0.00
-4.00
-8.00
2.00
LHTS
HL
'o. 00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
DISTANCE [MI



KN

mm


ROCK
ROCK
VERTICAL CLIFFS
YELLOW BROWN ALGAE
ANGULAR GRAVEL
PROFILE
REDDISH ALGAE
CALM


KP13
1210
16 6 79
ELEVATION (M)
DISTANCE [M]
LHTS
WL

from eroding bedrock; consequently, the material is immature and composed of relatively coarse sand and medium gravels.

Pocket beaches are relatively vulnerable to oil spills. The sediment composing these beaches is permeable, allowing oil to penetrate into the substrate. Assigned O.S.V.I. values are 4, 6, and 7.

Examples are survey stations KNP-5, 7, 13, 15 and 19.

Bayhead beaches. - These beaches are commonly found at the heads of many of the shoreline embayments. They are arcuate-shaped features that are relatively wide (30 to 50 meters) and long (Fig. 12). Sediments are mostly sand and gravel. Bayhead beaches are moderately vulnerable to oil spills, again, due to their relatively high permeability, allowing oil to penetrate the substrate. Assigned O.S.V.I. values are 4, 6, or 7.

Examples are survey stations KNP-41, 56, 59 and 64.

Spits. - Two types of spits are occasionally found in the study area. Cuspate spits (Fig. 13) are found in the numerous passageways between islands. Recurved spits are rare, but are typically found at the entrance to lagoons (Fig. 14). Both cuspate and recurved spit beaches are composed of sand and gravel. O.S.V.I. values are 4, 6 or 7.

Examples of the cuspate spits are survey stations KNP-2, 17, 25b, and 100.

Examples of recurved spits are survey stations KNP28, 36 and 43.

Uplifted beaches. - Uplifted beaches are common in the eastern portion of the study area, especially around Montague Island. These beaches often have large depositional berms, now above the reach of wave activity, infilled lagoons, cutoff inlets and wide flat areas between the uplifted berm and the active beach system (Fig. 15). O.S.V.I. values depend on the presently active beach system fronting the uplifted beaches, but normally are 4, 6 or 7.

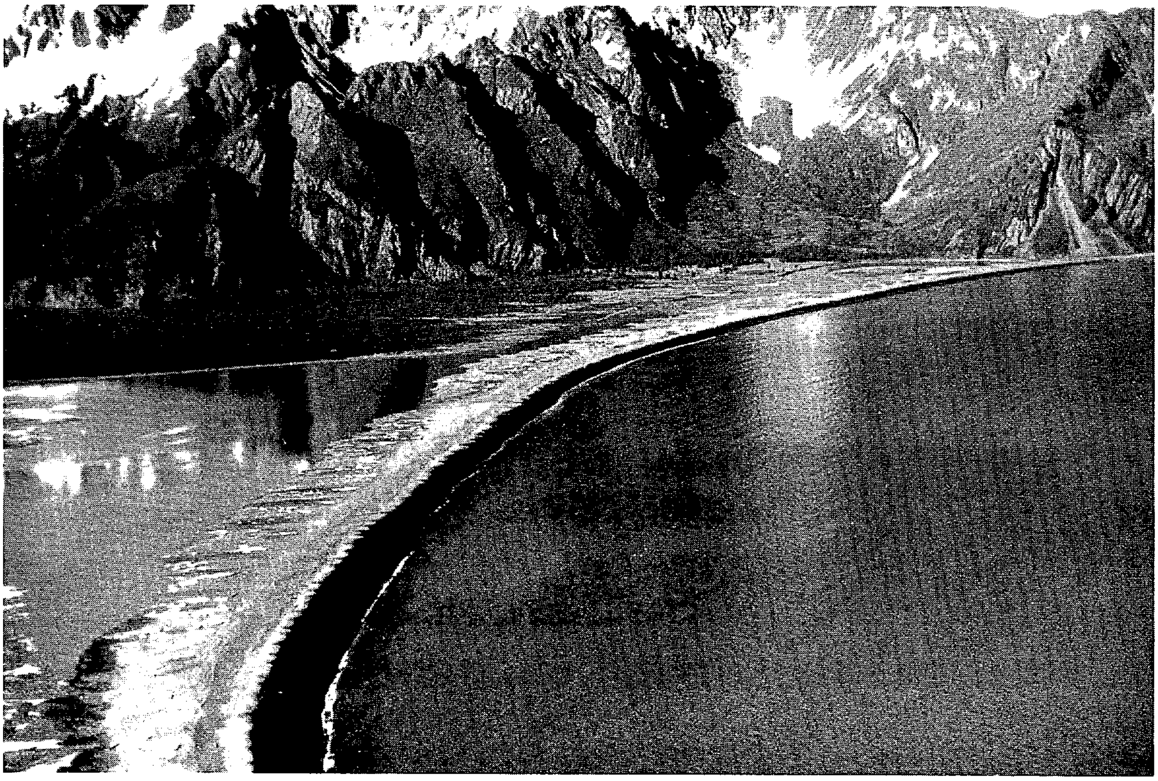
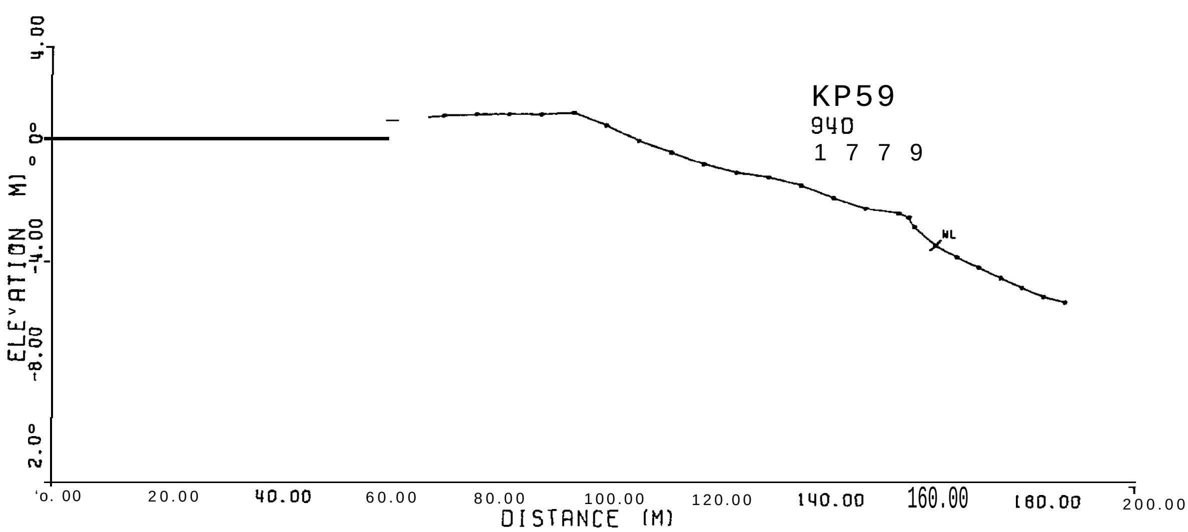


Figure 12. The bayhead beach shown above is typical of those found at the heads of the larger embayments in the study area. They are generally narrow, arcuate in shape and backed by open lagoons. Beach sediments are usually sand and gravel. The strongly convex upward nature of the beach profile is shown in the profile from station KNP-59 (below).



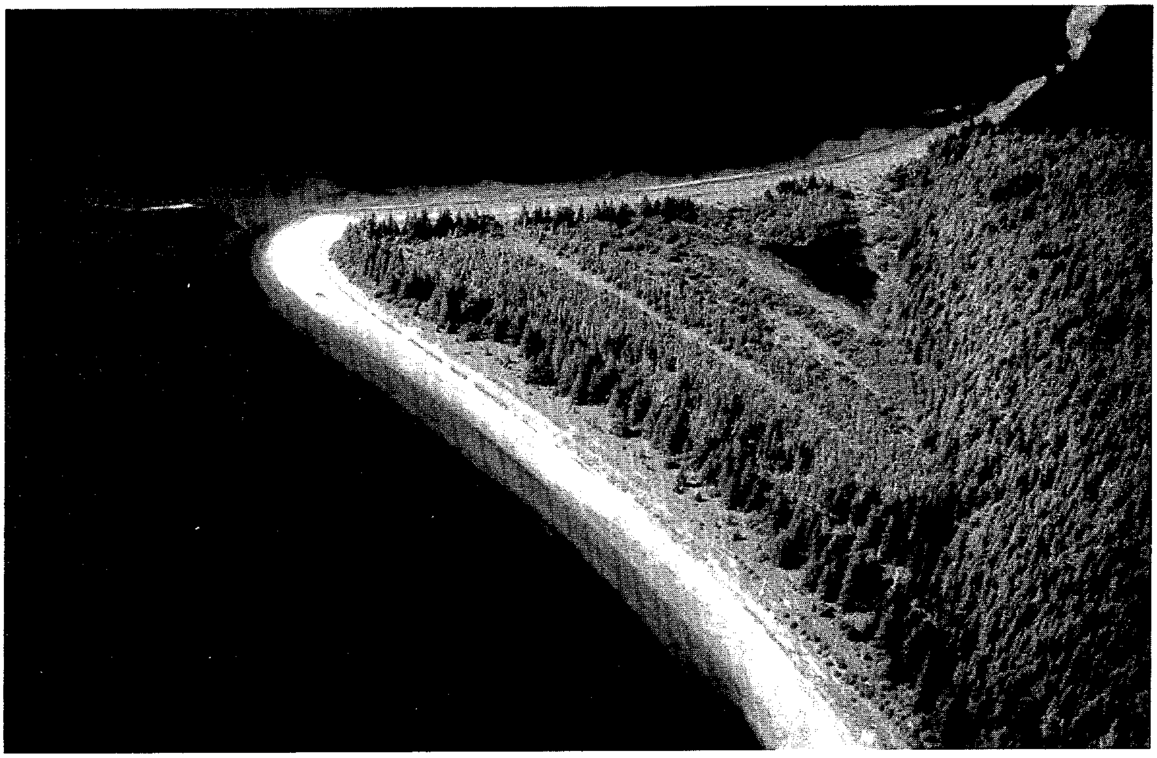
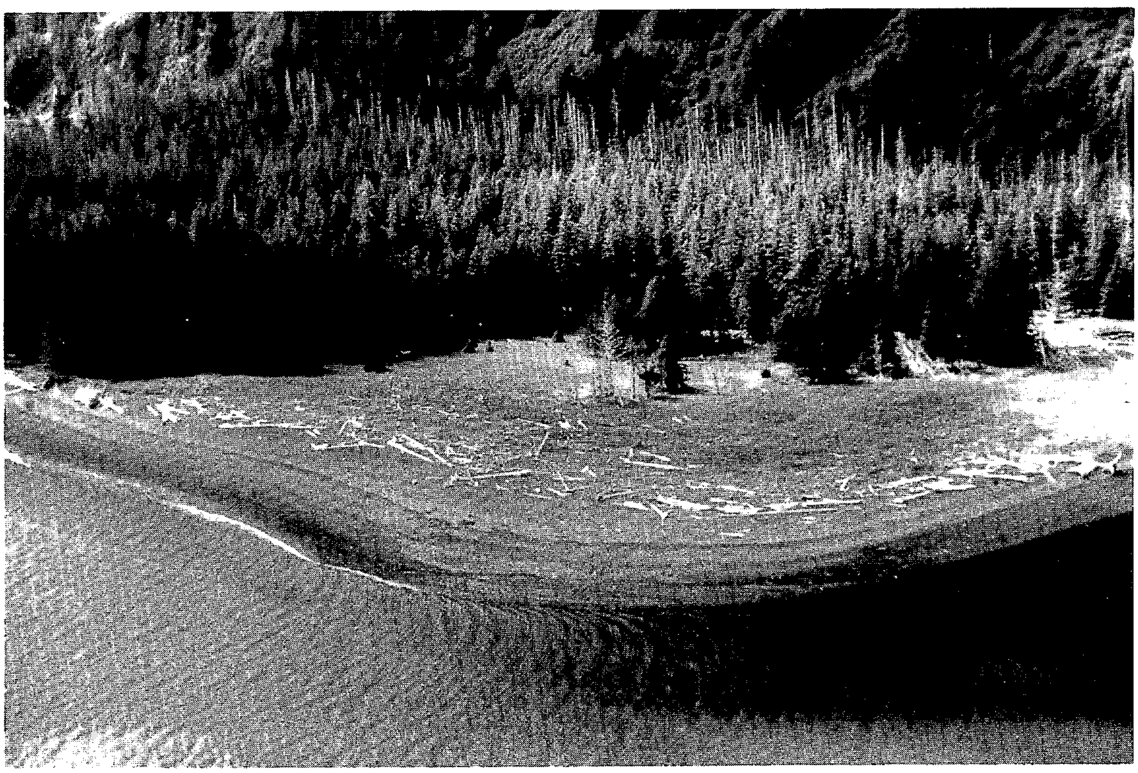
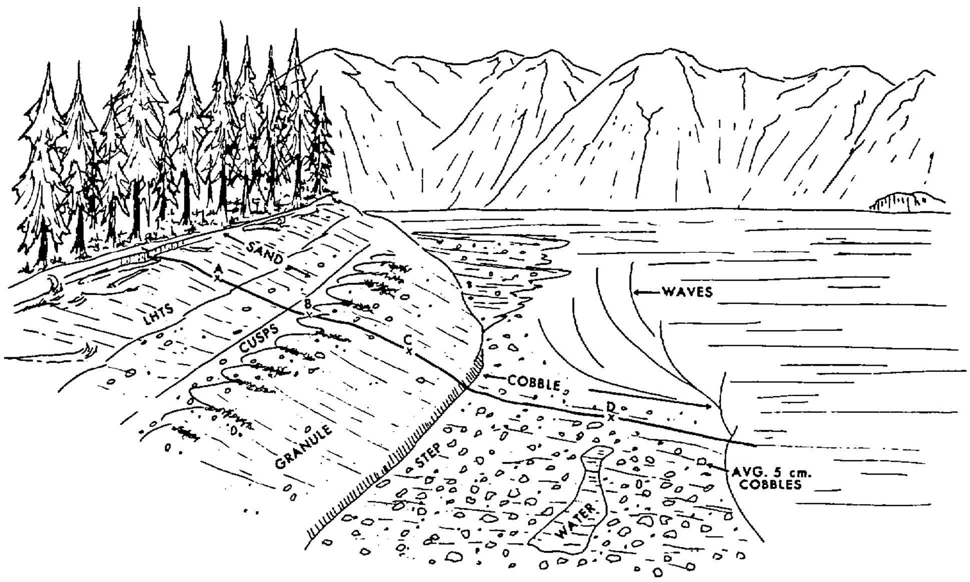


Figure 13. Profile station KNP-100 (above) and KNP-17 (below) are both prime examples of cuspate spits. These depositional features are typically found in the narrow restricted passageways between islands. The sketch and profile of station KNP-17 (following page) show the steep sand and gravel beachface and flat, cobble low-tide terrace typical of cuspate spits.




SAND
A
B
C
LHTS
CUSPS
GRANULE
STEP
COBBLE
WAVES
D
AVG. 5 cm. COBBLES
WATER

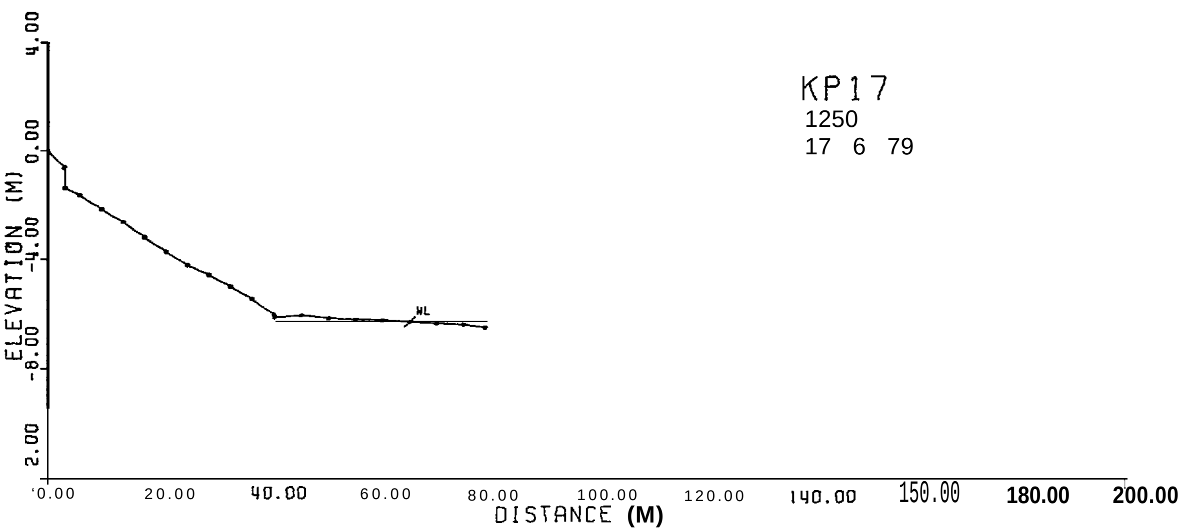

KP17
1250
17 6 79
WL
ELEVATION (M)
4.00
0.00
-4.00
-8.00
2.00
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
150.00
180.00
200.00
DISTANCE (M)

Figure 14. Recurved spit located at profile station KNP-28. These features are often found at the entrance to small open lagoons. Beach sediments are composed of sand and gravel. Note the broad, flat, cobble low-tide terrace at the recurved end of the spit. These terraces are often covered with abundant intertidal life. O.S.V.I. values range from 4-7 for recurved spit beaches.

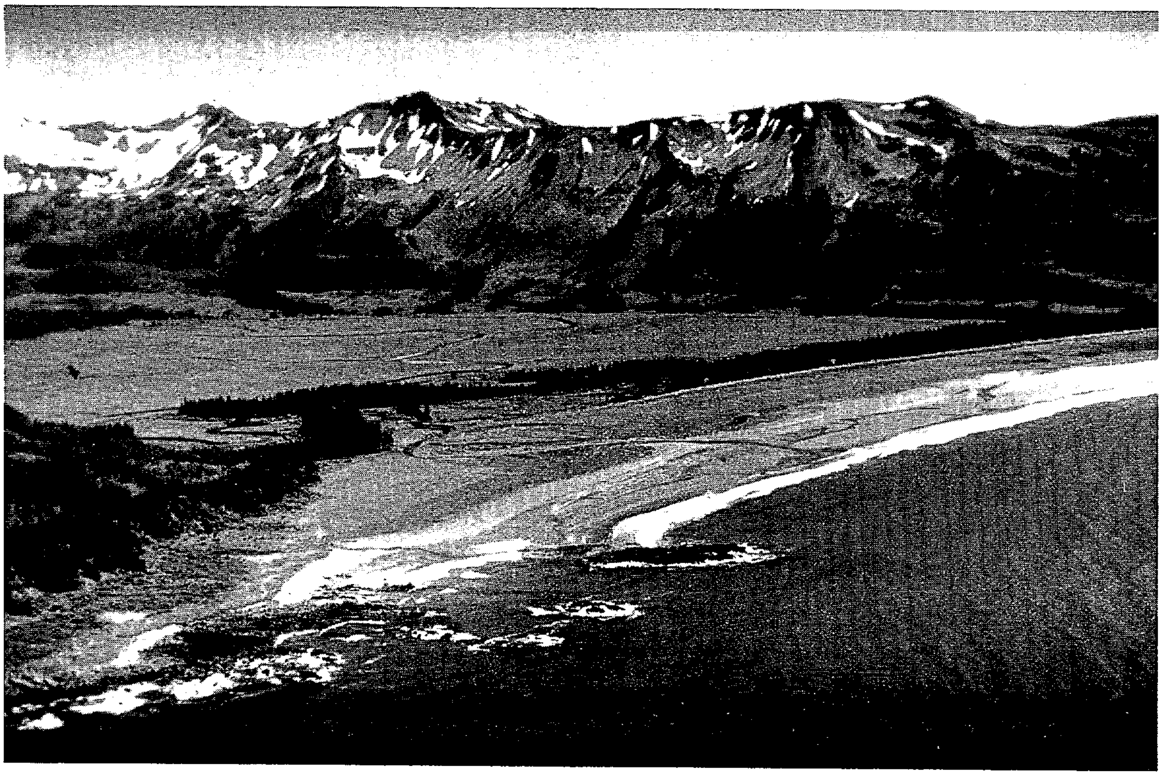
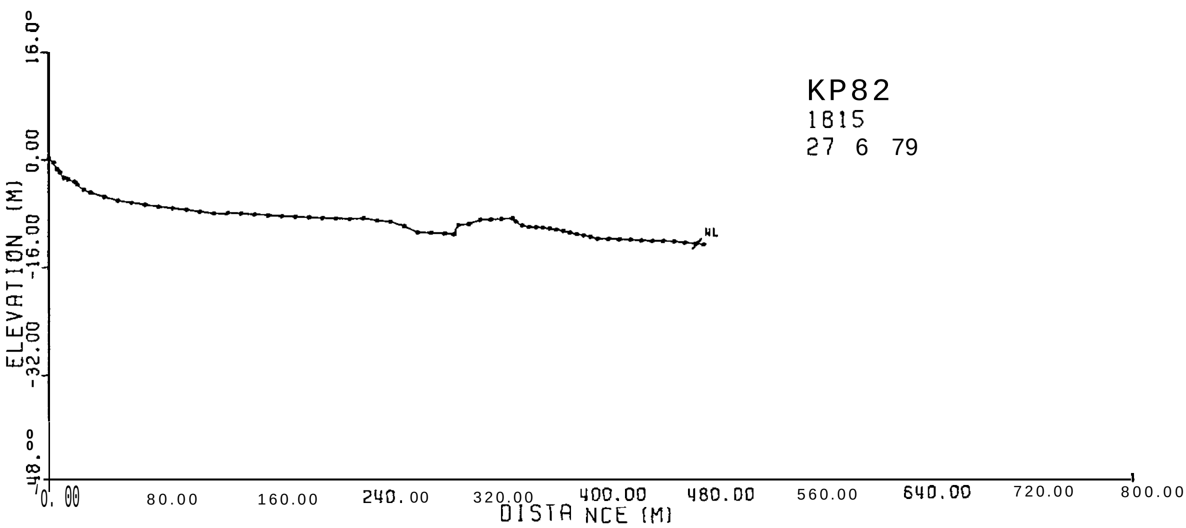


Figure 15. Profile station KNP-82 located at San Juan Bay on Montague Island. The present day beach was produced by uplift from the 1964 Good Friday Earthquake. The low tree line running parallel to the beach is the site of the pre-uplift depositional berm. Other features produced by the sudden emergence of this area include infilled lagoons and cutoff inlets (above and following page, top). A profile of station KNP-82 was run from the pre-uplifted berm to the present day beach, a distance of roughly 480 m (following page, bottom).



KP82
1815
27 6 79
ELEVATION (M)
16.00
0.00
-16.00
-32.00
-48.00
WL
0.00
80.00
160.00
240.00
320.00
400.00
480.00
560.00
640.00
720.00
800.00
DISTANCE (M)

Examples are survey stations KNP-82, 86, 87, 91, 93, 94, 95, 96, 97, 98 and 99.

River Mouth Delta-Tidal Flat and Salt Marsh Systems

River mouth delta-tidal flat systems are primarily found in relatively protected environments where small rivers intersect the coast. Due to the continual influx of sediments from the rivers, wide intertidal areas are formed (Fig. 16). They are dominantly composed of sand and fine gravel. Intertidal life is abundant. The delta-tidal flat systems are occasionally backed by fringing marshes. Approximately 81 km (4%) of the study area is composed of these features.

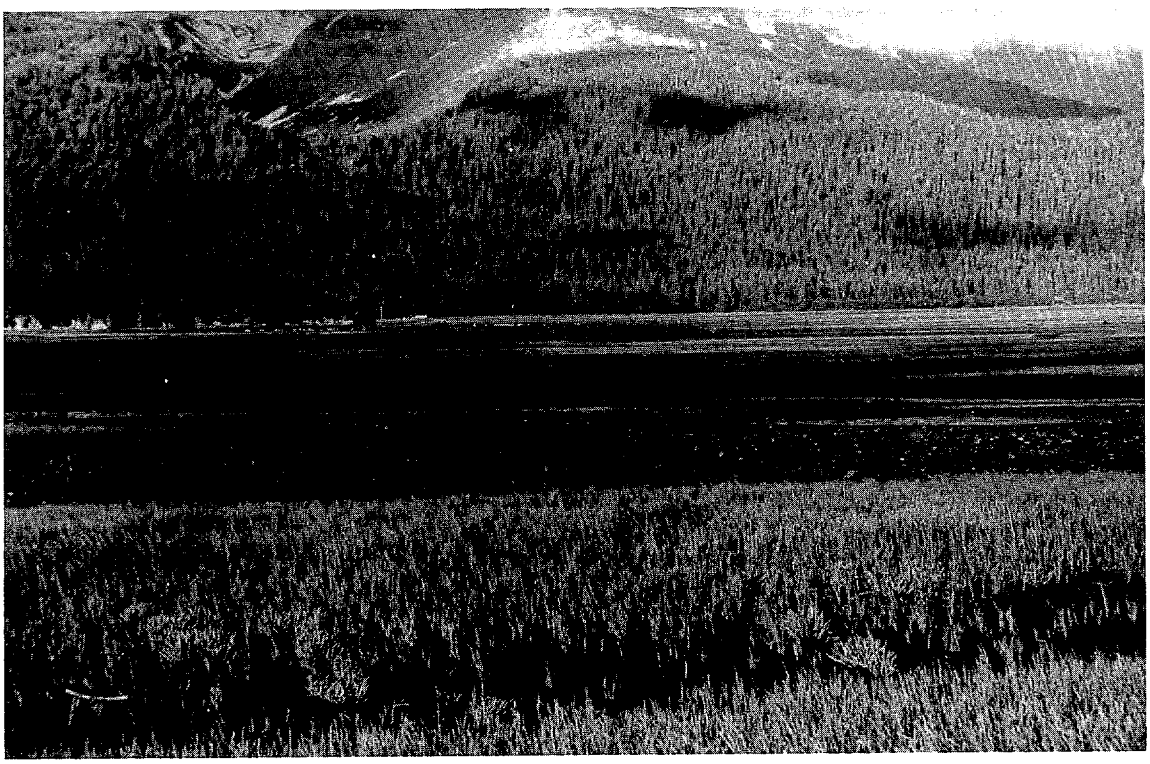
Examples are survey stations KNP-6, 11, 22, 27, 34, 50, 66 and 76.

Tidal flats and salt marshes are also found independent of river mouth deltas and comprise 101 km (5%) of the shoreline. These features are found in protected or embayed areas that have very little wave energy (Fig. 17). Consequently, the sediments are often fine-grained. Again, intertidal life is abundant.

Examples are the northernmost embayment in Port Bainbridge and the Port Chambers and Stockdale Harbor areas on the northwest side of Montague Island.

Both the delta-tidal flat and salt marsh systems are highly vulnerable to oil spills. Intertidal life can be severely damaged and, due to the protected nature of these environments, oil may remain for extremely long periods of time. These areas should be protected if at all possible. Assigned O.S.V.I. values are 9 or 10. In some instances, if the sediment size of the tidal flats is fine (silts and clays) and the wave or tidal energy is relatively high, the environment is less vulnerable to oil spills. Low permeability of the sediments prevents oil from penetrating the substrate allowing waves and tidal currents to naturally clean the flats.

Figure 16. River mouth delta-tidal flat systems are shown here at profile stations KNP-22 (above) and KNP-50 (below). Tidal flats are dominantly composed of sand and fine gravel and have wide, intertidal areas with abundant biota. O.S.V.I. values are 9 or 10.



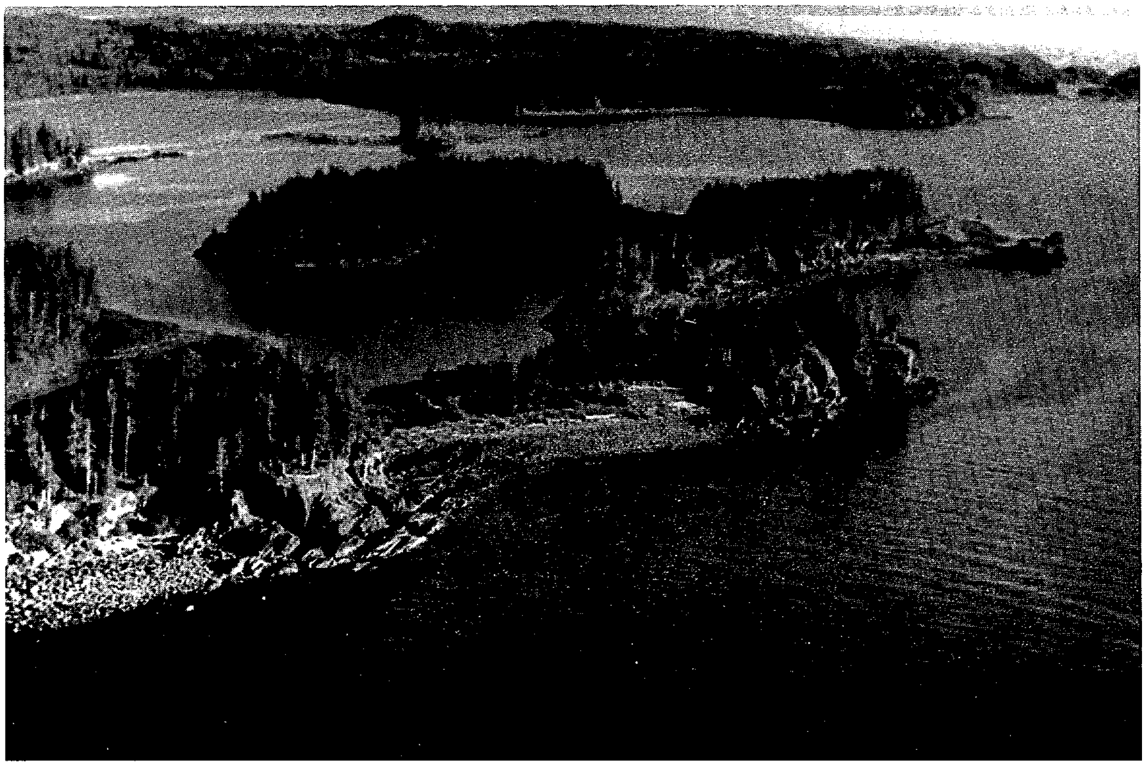
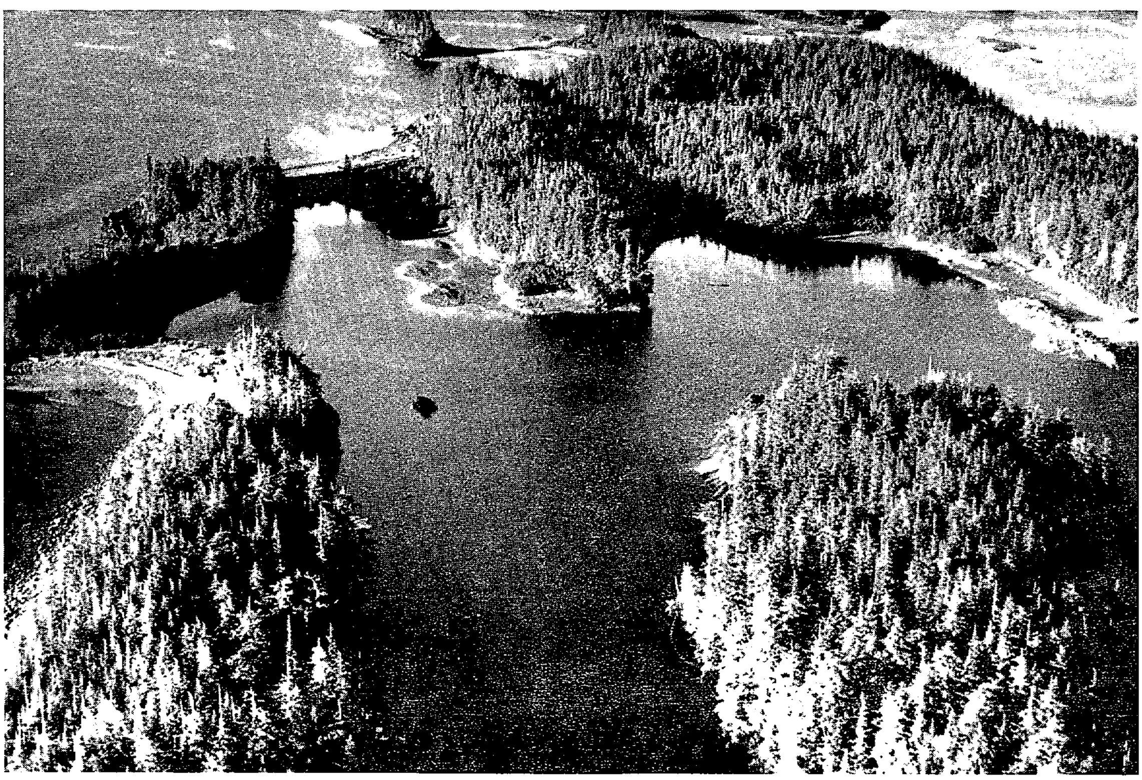


Figure 17. Embayed tidal flats (above and below), located on northwestern Montague Island. These features are found independent of river mouth deltas in protected low-wave energy environments. Sediments are fine-grained and intertidal life is abundant. O.S.V.I. values are 9 or 10.



In this case, the assigned O.S.V.I. value is 5.

OIL SPILL VULNERABILITY

Introduction

The major purpose of this study has been to supply baseline data regarding shoreline geomorphology and to indicate how that morphology may interact with potential oil spills. Of primary importance is the ranking of coastal environments with regard to the residence time of spilled contaminants. Thus, the primary product of our research is a set of 31 standard U.S.G.S. Quadrangle base maps at a 1:63,360 scale. These 31 topo sheets cover all of the outer Kenai Peninsula and Montague Island. Each map classifies the shoreline into 1 of 10 subclasses, described in this section. The maps are reproduced at page size and are shown in Appendix I. The original maps are submitted as an enclosure.

Our group has been studying oil spills and doing baseline analyses of various coastal areas for about 5 years. There is currently available a large number of publications dealing with specific spills (Blount, 1978; Blount and Gundlach, 1977; Gundlach and Hayes, 1977; Gundlach, Fischer and Stein, 1977; Gundlach, Ruby and Blount, 1977; Gundlach et al., 1977; Hayes and Gundlach, 1975; Hayes et al., 1976; Ruby et al., 1977) as well as many dealing specifically with our coastal work in parts of Alaska (Gundlach et al., 1977; Hayes, Michel and Brown, 1977; Ruby and Hayes, 1978, Hayes et al., 1976; Nummedal and Stephen, 1976; Nummedal, Stephen and Ruby, 1977; Nummedal and Ruby, 1979; and a number of Annual and Progress Reports to OCSEAP). These reports detail the controls that beach morphology, grain size and incoming energy can have on oil spill behavior and longevity. Several of the reports address the potential impacts of spills on various Alaskan marine assemblages. These earlier results will not be repeated in this report. They strongly support the concept that physical-degradation of spilled oil is directly related to the marine energy in the spill environment. There is an abundance of literature dealing with case studies of the numerous major and minor oil spills that "have taken place in the coastal waters of the lower 48 states and around the world. Predictive models for oil spill dispersal, spreading, bio-degradation and physical degradation have been developed from these studies. The sub-arctic areas, however, have been to a large extent omitted due to the difficulties inherent in any study of these environments and a general lack of actual oil spills in these environments from which to base detailed case studies. The Arrow oil spill in Chedabucto Bay, Nova Scotia, probably comes closest to a comparative model for the sub-Arctic. However, the clean-up effort and later studies (Owens, 1971; Owens and Drapeau, 1973; Owens, 1973; Drapeau, 1974; Owens and Rashid, 1976) made very little reference to the special problems encountered as a result of the colder environment (i.e., oil on ice and snow; ice-oil interaction with beach sediments; oil dispersal in heavily iced environments, etc.). Our investigation of the Buzzards Bay oil spill (Ruby et al., 1977) and the Ethyl H. spill in the frozen Hudson River have given new insight into the effects of oil spills in ice-choked waters.

Evaporation losses and biodegradation are slower in colder environments. Biodegradation can be reduced as much as 90% in water of 0°C when compared to water of 25°C (Robertson et al. 1972). Isakson et al (1975) states that burning may be the only feasible method of cleaning oil spills in iced areas; however, this may represent a trade of one type of pollution for another. During the Buzzards Bay spill clean-up, burning was an effective method for cleaning oil which was not accessible from the shore. Only a small amount of particulate matter resulting from the fires was noticed.

Oil Spill Vulnerability Index

This scale has been devised on the basis of actual spill analysis and a careful study of the literature. It is based primarily on the residence time of oil in each sub-environment, which is generally a function of the intensity of the marine processes, sediment grain size and transport trends. The biologic sensitivity has also been utilized to modify that ratings of various environments.

Coastal environments are listed and discussed below in order of increasing vulnerability to oil spills.

1. Straight rocky headlands:

Most areas of this type are exposed to maximum wave energy. Waves reflect off of the rocky scarps with great force, readily dispersing the oil. In fact, waves reflecting off the scarps at high tide tend to generate a surficial return flow that keeps the oil off the rocks (observed at the Urquiola site in Spain and the Amoco Cadiz spill in France). Even if oiled, natural cleaning will only require a few days or weeks. No human intervention is necessary. They represent the largest" single class within the study area, 28.2%.

2. Wave-cut platforms:

These areas are also swept clean by wave action. All of the wave-cut platforms at the Metula site were cleaned of oil after one year. The rate of removal of the oil is a function of wave climate and the irregularity of the platform. In general, no clean-up measures are needed for wave-cut platforms. However, there are large biologic populations in these areas. Most of this classification, 9.3% of tlie study area, occurs on Montague Island in highly exposed, *recently* uplifted areas.

3. **Flat, fine-grained sandy beaches:**

Beaches of this type are generally flat and hard packed. Oil that is emplaced on such beaches will not penetrate more than a few centimeters at most. Usually the oil will be deposited on the surface of the sand where it can be removed by elevated scrapers or other road grading machinery.

Furthermore, these types of beaches change slowly, so sand deposition and resultant burial of oil will take place at a slow rate. If left to natural processes, these beaches will be cleaned within several months. This type of beach is very rare in the study area, representing only 0.8% of the shoreline.

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

On these beaches, the depth of penetration would be greater than for the fine-grained beaches (though still only a few centimeters), but rates of burial of the oil would be greatly increased. Based on our earlier studies, it is possible for oil to be buried as much as 50-100 cm within a period of a few days on beaches of this class. In this situation, removal of the oil becomes a serious problem, since removal of the oiled sediments will often result in large scale erosion as the beach changes into a new equilibrium state. This was a common problem encountered during the clean-up of the Arrow spill in Chedabucto Bay, Nova Scotia (Owens and Rashid, 1976). Another problem is that burial of the oil preserves it for release at a later date when the beach erodes as part of the natural beach cycle, thus causing longer term pollution of the environment. This class represents only 1.5 % of the study area.

5. Impermeable exposed tidal flats:

One of the major surprises in the study of the Metula site was the discovery that oil had not remained on the mud flats. At the Urquiola site, oil was observed as it became refloated with rising tides on the mud flats. Penetration of the oil is prevented by the extremely fine sediment size, saturated with water. Therefore, if an oiled tidal flat is subject to winds and currents, the oil will tend to be removed, although not at the rapid rate encountered on exposed beaches. Mechanized cleanup is considered impossible. These are often areas of high biologic importance. These areas are very rare in the study area due to a lack of fine sediment. They represent only 0.3% of the total study area.

6. Mixed sand and gravel beaches:

On beaches of this type, the oil may penetrate several centimeters, and rates of burial are quite high (a few days in Spain). Any attempt to remove the oiled sediment will result in considerable erosion. These beaches occur primarily as pocket beaches between headlands or where till or glacial deposits are being reworked by marine processes. The longevity of the oil at the Metula site, particularly on the low-tide terraces and berm top areas, attests to the high susceptibility of tnis type of beach to long-term oil spill damage. Natural cleaning may require many years. This type of beach is relatively common in the study area, representing 11.9%.

7. Gravel beaches:

Pure gravel beaches allow the oil to penetrate to considerable depth (up to 45 cm in Spain). Furthermore, rapid burial is also possible. A heavily-oiled gravel beach will be impossible to clean up without completely removing the gravel. Natural cleaning will be quite slow for this type of beach; the exact time required will depend on the intensity of the marine processes. Pure gravel beaches are quite common in the study area representing almost 18.0% of the shoreline. They occur mostly as pocket beaches and linear beaches fronting rock scarps. In some cases, they can be quite long.

8. Sheltered rocky headlands:

Our experience in Spain indicates that oil tends to stick to rough rocky surfaces. In the absence of abrasion by wave action, oil could remain on such areas for years, with only chemical and biological processes left to degrade it. These headlands usually have gravel beaches associated with them; therefore, for the purposes of this study, sheltered gravel beaches are classified with sheltered rocky headlands. They represent the second largest single class or 23.1% of the study area. Most of these areas are in the quiet water passages and channels between Evans, Elrington and Bainbridge Islands and in the fjords along the western Kenai Peninsula shoreline.

9. Protected tidal flats:

If oil reaches a quiet, protected tidal flat, it will remain there for long periods because natural cleaning progresses at an extremely slow rate. Because of the low intensity of marine process parameters, removal of the oil will have to be accomplished by natural chemical and biogenic processes. This will-take many years, dependent on the amount of oil deposited. Because of their high biologic populations, these environments are very sensitive to the toxic effects of oil. These areas are relatively rare in the study area occurring only at fjord heads and at river mouth estuaries. Protected tidal flats comprise 5.12% of the shoreline.

10. Protected salt marshes:

In sheltered salt marshes, oil from a spill may have long-term deleterious effects. We observed oil from the Metula on the salt marshes of East Estuary, in the south shore of the Strait of Magellan, that had shown essentially no change in 1½ years. We predict a life span of at least 10 years for that oil. These areas are extremely important biologically, supporting large communities of organisms. These areas are generally associated with the protected tidal flats (#9) and are also rare, representing only 1.89% of the study area.

Applications to the Kenai Peninsula and Montague Island

Using the vulnerability classification just described, it is possible to make a few generalizations regarding the Kenai area and its reaction to potential oil spills. In general, the area is quite "high risk". Nearly 60% of the shoreline falls in classes 6 - 10 (Table 2). These classes will have a spill residence time of a year or two to more than 10

TABLE 2. Oil Spill Vulnerability Index, Kenai Peninsula and Montague Island

Class Description	Kilometers of Shoreline	% Total Study Area
1. Straight rocky headlands	609.8	28.3
2. Wave-cut platforms	198,8	9.3
3. Flat, fine-grained sandy beaches	16.6	0.8
4. Steeper, medium-to-coarse grained sandy beaches	30,0	1.3
5. Impermeable exposed tidal flats	6.3	0.3
6. Mixed sand and gravel beaches	258.5	11.9
7. Pure gravel beaches	389.1	18.0
8. Sheltered rocky headlands	496.9	23.0
9. Protected tidal flats	110.7	5.2
10. Protected salt marshes	40.3	1.9
	2157.0	100,0

NOTE: In general, classes 1 and 2 are highly erosional in nature. Classes 5, 9 and 10 are depositional. Classes 3, 4, 6, 7 and 8 can be either erosional or depositional, but in this area they tend to be more erosional.

years. The remaining 40% of the shorelines fall into classes 1 - 5, which are considerably lower risk areas where spilled oil would generally be expected to be cleaned by natural processes within a year.

Unfortunately, the study area is very complex and the higher risk areas do not lend themselves well to being protected during a spill. In many instances, a low-risk rock scarp will lie just seaward of a large embayment with high-risk pure gravel beaches. The fact that the environments change so frequently and rapidly along the shoreline makes the entire shoreline a fairly high-risk area. The indented (fjord) character of the coast will act as "oil traps" for floating oil. Oil will tend to be moved deeper into the fjords rather than to be flushed out. In general, this will result in an oiling of increasingly sensitive environments, since higher risk, lower energy classes are located deeper in fjords and embayments.

Since the Oil Spill Vulnerability Index is based partly on the residence time of potential oil spills within each of the subenvironments, the following guidelines are given:

OSVI	Spill Residence Time
1 + 2	A few days to a few weeks
3 + 4	A month to six months
5 + 6	Six to 24 months
7 + 8	A year or two to as much as 8 years
9 + 10	Up to ten years

These figures are highly dependent on the wave energy during the spill and partly dependent on the temperature. They can vary and are meant to be estimates only. They give a relative indication of the residence time from one environment to another.

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APPENDIX I

OIL SPILL VULNERABILITY

This section is prefaced by a table showing the percent shoreline in each Oil Spill Vulnerability Index (O.S.V.I.) class for each topographic sheet (1:63,360 scale) in the study area. The total shoreline length in kilometers for each map is given in the right-hand column of the table. Following this are photographic reductions of all 31 topographic sheets, showing the number-coded O.S.V.I. class for every section of coastline within the study area. The O.S.V.I. number code is outlined in the text of this report.

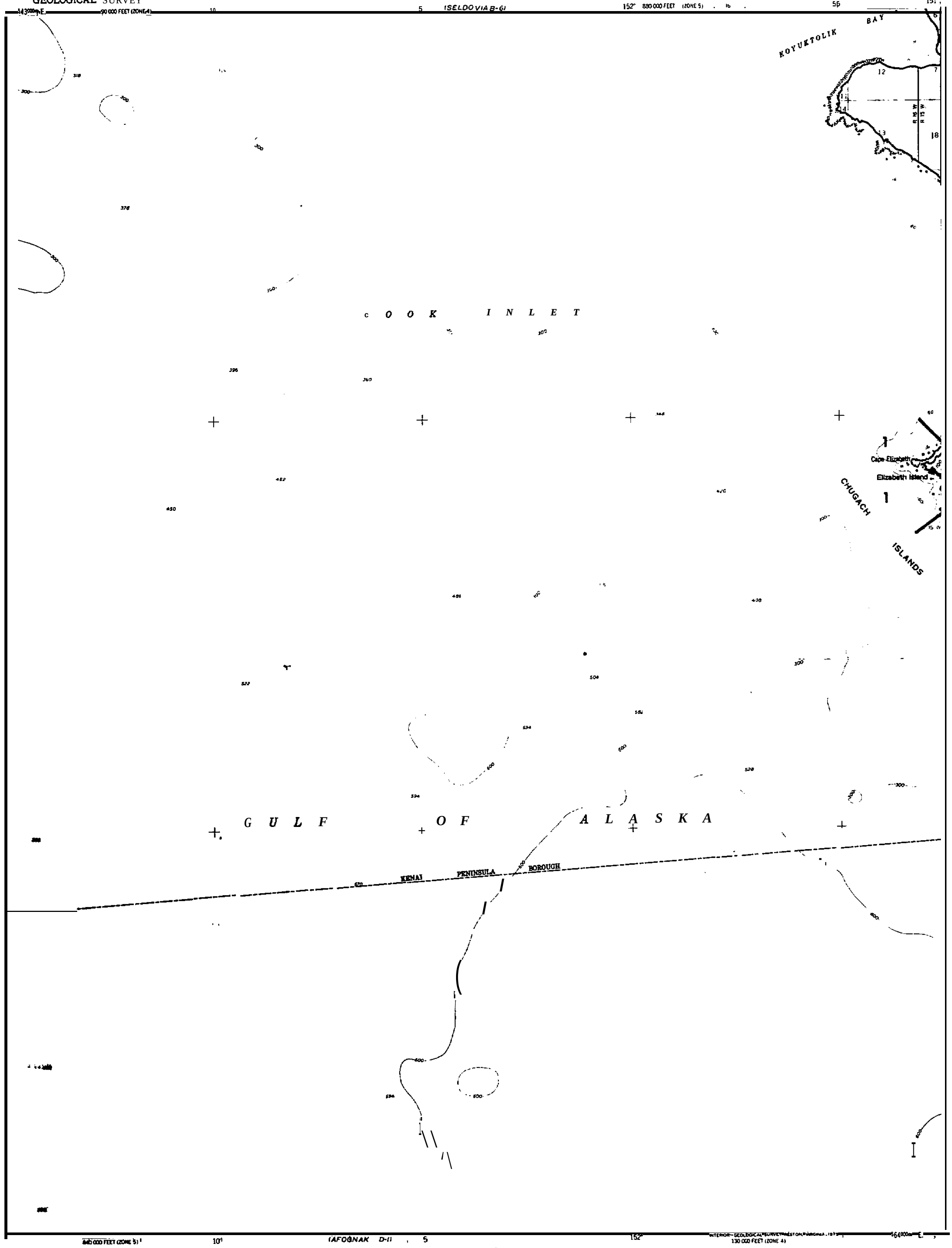
% Shoreline in Each Oil Spill Vulnerability Index Class (for each 1:63,360 topographic sheet).

Map	O.S.V.I. Class										Shoreline length in km
	1	2	3	4	5	6	7	8	9	10	
Seldovia A-6	100%										1.9
Seldovia A-5	36	3%		14%		27%	2%	10%	7%	2%	
Seldovia A-4	47	8		18		19	1	8			64.4
Seldovia B-4	2			6		14		41	25	12	53.1
Seldovia B-3	31			2		18	6	35	6	2	81.9
Seldovia A-3	65					23	5	5		2	26.9
Seldovia B-2	40				1%	9	3	42	6		178.2
Seldovia C-2	4					8	12	55	12	8	76.3
Seldovia C-2	26					25	12	32	5	1	150.6
Seldovia B–1	62							38			58.1
Bly. Sd. C-8	19					25	8	47	2		81.9
Seldovia D-1							36	64			13.8
Bly. Sd. D-8	14					2	33	41	9		108.8
Bly. Sd. D-7	68					4	12	15			144.4
Bly.Ds. C-7	80						1	20			53.4
Seward A-7	19					14	23	15	19	11	46.3
Bly. Sd. D-6	74		4%	3		4	11	4			46.3
Seward A-6	32					16	21	7	16	7	35.0
Bly. Sd. D-5	58					23	11		5	4	35.6
Seward A-5	27					2	36	9	13	13	14.1
Bly. Sd. D-4	47					11	38	5			53.1
Seward A-4	27	1	1			13	23	29	5	2	139.1
Seward A-3	17	3				12	34	31	2		201.3
Bly. Sd. D-3	3	45	6		2	10	26	4	4	2	82.5
Bly. Sd. D-1 and D-2	7	52	9		5	6	20		2		80.0
Seward A-1		58				6	24		11	1	63.1
Cordova A-7 and A-8		100									2.5
Cordova B-8		87				4	9				14.4
Seward B-1		28				11	47		7	7	100.6
Seward A-2		40	5			2	53				38.8
Seward B-2		37				21	37		.4	1	30.3

TOTAL 2159.2

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SELDOVIA (A-6) QUADRANGLE
ALASKA
1:63 360 SERIES (TOPOGRAPHIC)



...ped, edited, and published by the Geological Survey
...rol by NOS/NOAA
...graphy by photogrammetric methods from aerial photographs
... 1951. Map not field checked
...ted hydrographic data compiled from USC&GS Charts
..., 8532, and 8554 (1:200,000 scale). This information
...t intended for navigational purposes

Universal Transverse Mercator projection, 1927 North American datum
10,000-foot grids based on Alaska coordinate system, zones 5 and 4
1000-metre Universal Transverse Mercator grid ticks,
zone 5, shown in blue

Land lines represent unsurveyed and unmarked locations
predetermined by the Bureau of Land Management
Folio S-16, Seward Meridian

TRUE NORTH
MAGNETIC NORTH
24°
APPROXIMATE MEAN
DECLINATION, 1951

SCALE 1:63 360
1 ½ 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 .5 0 1 2 3 4 5 KILOMETRES

CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 12 FEET

FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ALASKA
QUADRANGLE LOCATION

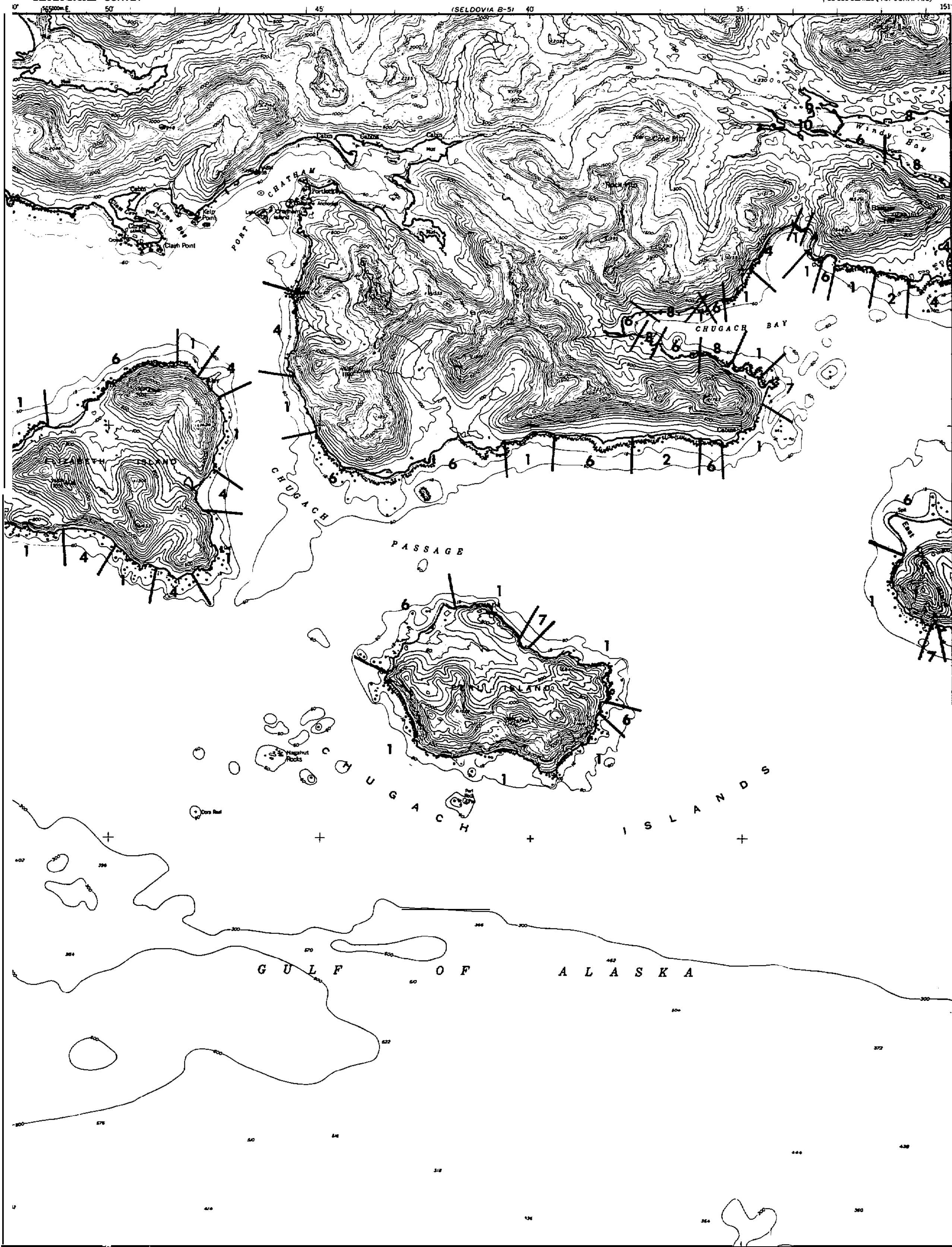
ROAD CLASSIFICATION
No roads in this area

SELDOVIA (A-6), ALASKA
N5900—W15152.5/15X22.5

1951
1973

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SELDOVIA (A-5) QUADRANGLE
ALASKA-THIRD JUDICIAL DIVISION
63 360 SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey
Control by USC&GS and USCE
Hydrography compiled from USC&GS charts 8531, 8532, 8554 (1:200,000 scale), and 8558
Topography from aerial photographs by multiplex methods 1953
Aerial photographs taken 1951
Universal Transverse Mercator projection, zone 5
1927 North American datum
Unchecked elevations are shown in brown
1000-meter Universal Transverse Mercator grid ticks, zone 5, shown in blue

TRUE NORTH
MAGNETIC NORTH
24°
APPROXIMATE MEAN DECLINATION, 1953

SCALE 1 63360

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT HALF-INTERVAL CONTOURS
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 12 FEET

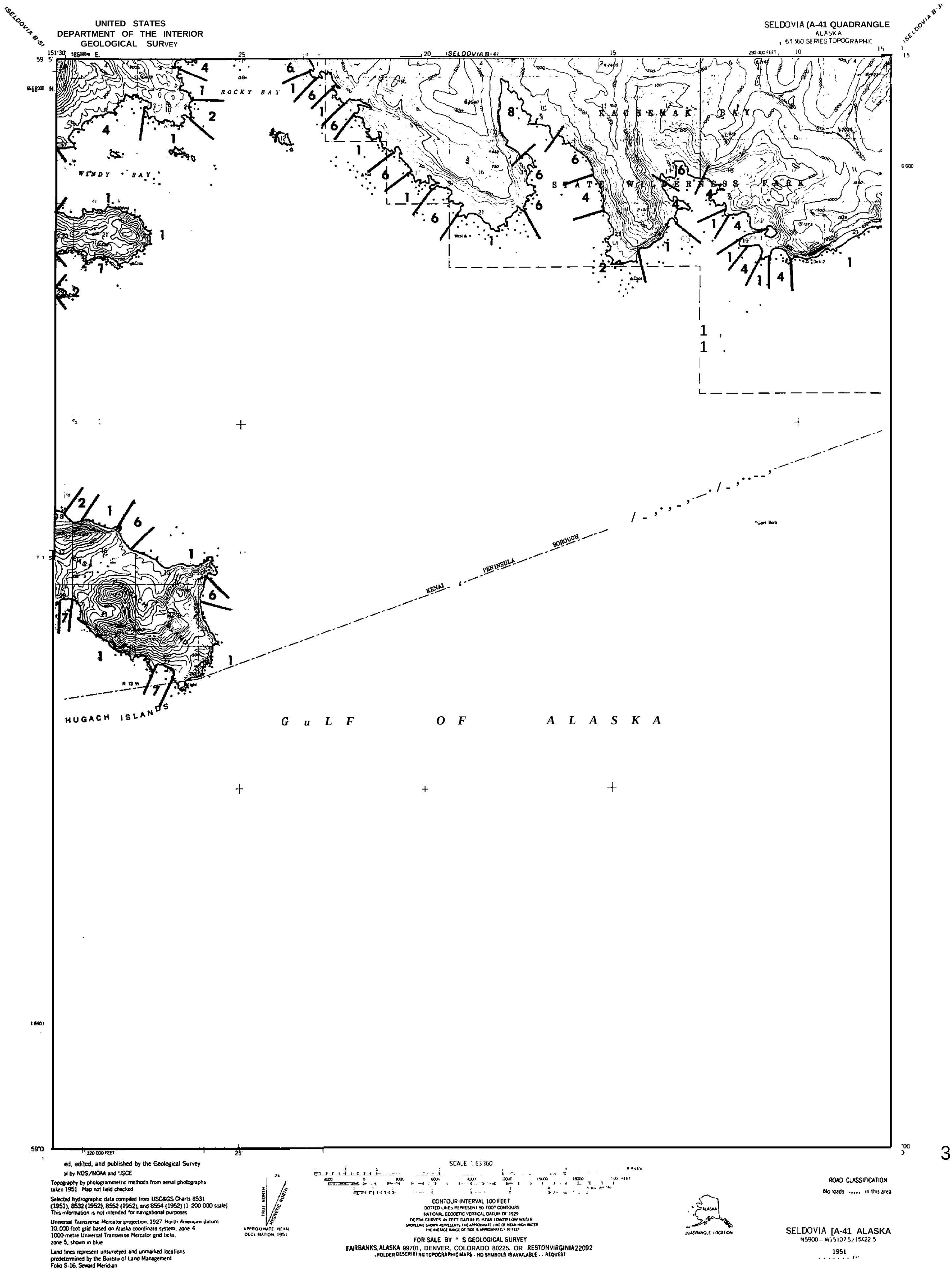
ALASKA
QUADRANGLE LOCATION

ROAD CLASSIFICATION

ALL WEATHER ROADS		DRY WEATHER ROADS	
Hard-surface	None	Improved dirt	None
Other	None	Unimproved dirt	None
		Trails	

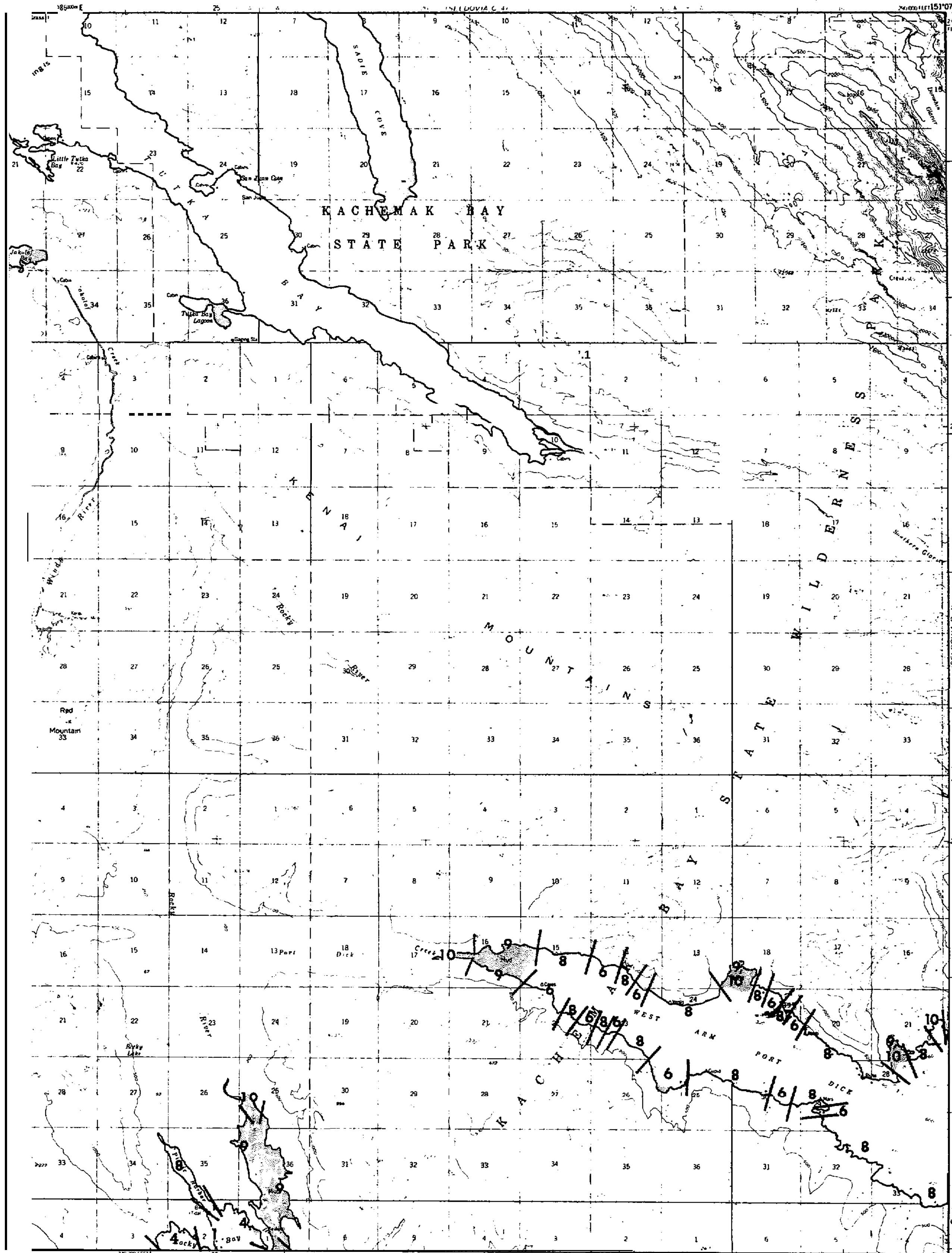
SELDOVIA (A-5), ALASKA
N5900—W15130/15X22.5
1953

FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA FEDERAL CENTER, DENVER, COLORADO WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SELDOVIA (A-4) QUADRANGLE
ALASKA
(SELDOVIA B-5)
(SELDOVIA B-4)
(SELDOVIA B-3)
ROCKY BAY
WINDY BAY
KACHEMAK BAY
STATE WILDERNESS PARK
KENAI PENINSULA BOROUGH
HUGACH ISLANDS
GULF OF ALASKA
SCALE 1:63 360
CONTOUR INTERVAL 100 FEET
FOR SALE BY U S GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR RESTON VIRGINIA 22092
ROAD CLASSIFICATION
No roads in this area
QUADRANGLE LOCATION
APPROXIMATE MEAN DECLINATION, 1951
SELDOVIA (A-4) ALASKA
1951

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SELDOVIA (B-4) QUADRANGLE
ALASKA, KENAI PENINSULA BOROUGH
1:63 360 SERIES (TOPOGRAPHIC)



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USC&GS and USCE

Topography by photogrammetric methods from aerial photographs taken 1951. Map not field checked

Selected hydrographic data compiled from USC&GS Charts 8531, 8552 and 8554 (1:200 000 scale)
This information is not intended for navigational purposes

Universal Transverse Mercator projection. 1927 North American datum
10 000-foot grid based on Alaska coordinate system, zone 4

Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folio S 16, Seward Meridian

TRUE NORTH
MAGNETIC NORTH
24°
APPROXIMATE MEAN DECLINATION 1951

SCALE 1:63 360

CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOWER LOW WATER
THE AVERAGE RANGE OF TIDE IS 16 FEET IN TUTKA BAY AND 10 FEET IN PORT DICK

FOR SALE BY U S GEOLOGICAL SURVEY
FAIRBANKS ALASKA 99701, DENVER COLORADO 80225 OR RESTON VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION
Light duty
Unimproved dirt

QUADRANGLE LOCATION

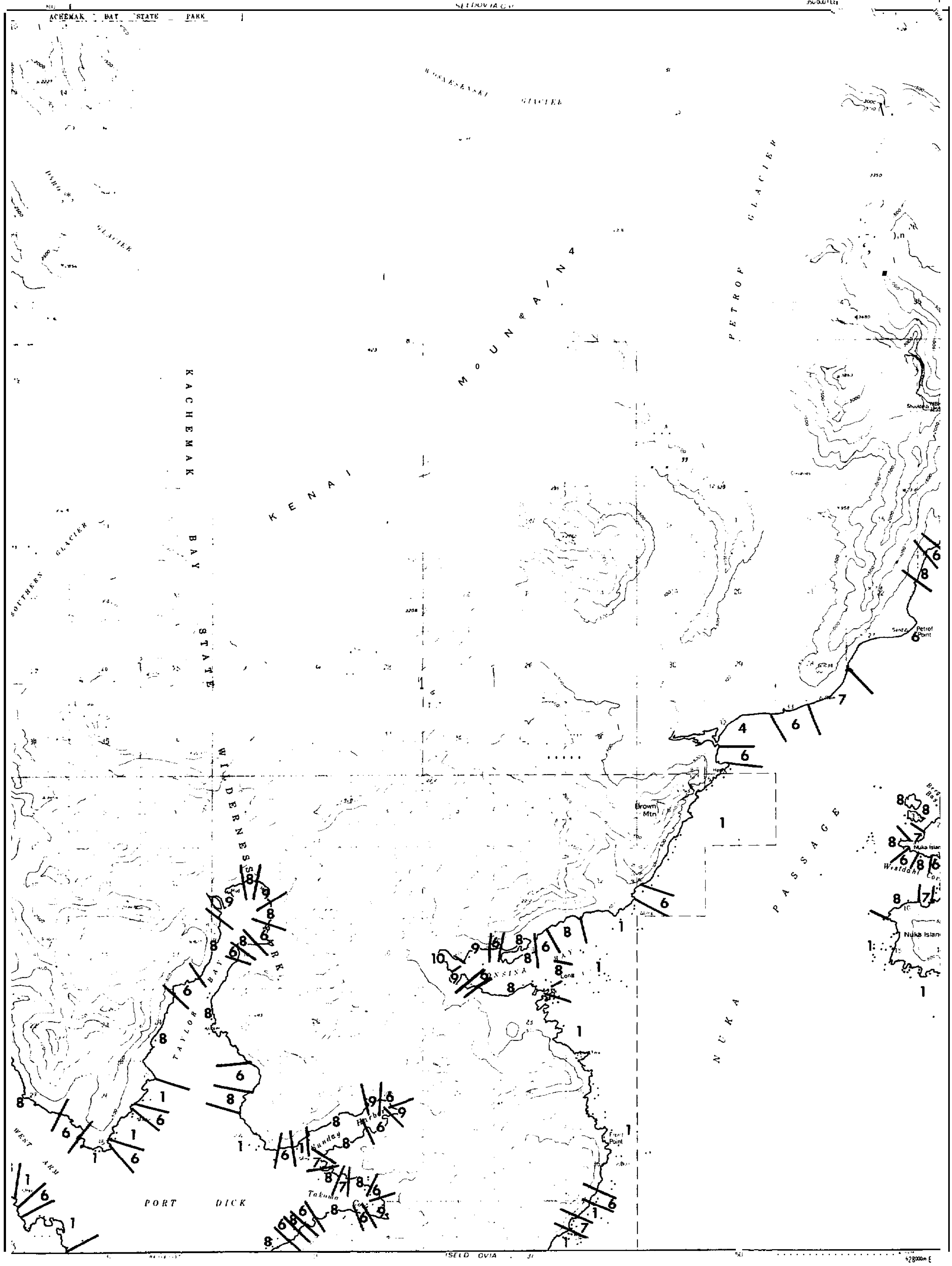
SELDOVIA (B-4), ALASKA

1951
MINOR REVISIONS 1976

4

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SELDOVIA (B-3) QUADRANGLE
ALASKA KENAI PENINSULA BOROUGH



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FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

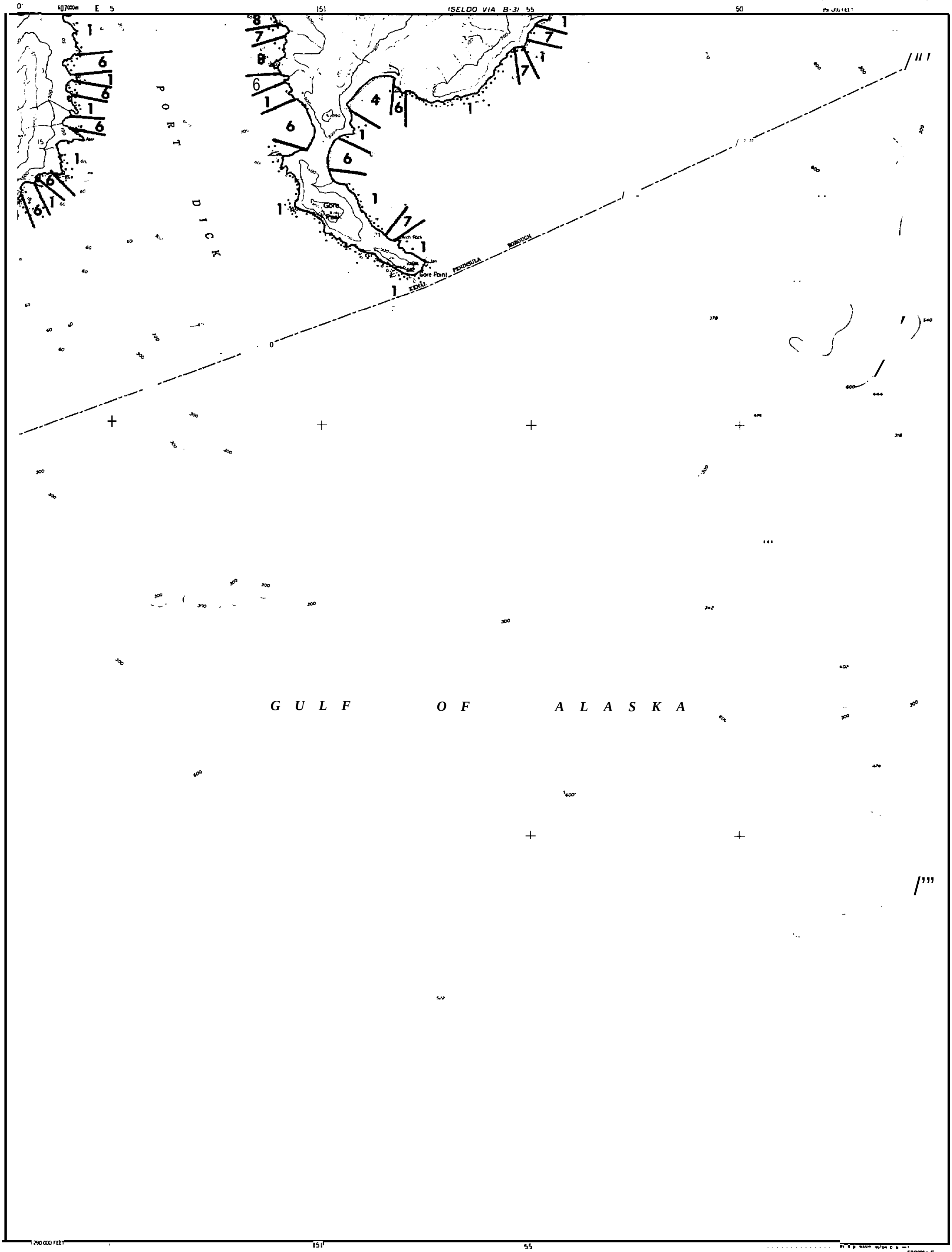
ROAD CLASSIFICATION

SELDOVIA (B-3) ALASKA

1951

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SELDOVIA (A-3) QUADRANGLE
ALASKA



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Control by USC&GS and USCE

Topography by photogrammetric methods from aerial photographs taken 1951. Field annotated 1951. Map not field checked

Selected hydrographic data compiled from USC&GS Charts 8530, 8531, (1951), 8552 (1951), and 8564 (1952) (1:200 000 scale)
This information is not intended for navigational purposes

Universal Transverse Mercator projection. 1927 North American datum
10,000 foot grid based on Alaska coordinate system, zone 4
1000 meter Universal Transverse Mercator grid ticks, zone 5, shown in blue

Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folio S 16, Seward Meridian

CONTOUR INTERVAL 100 FEET

FOR SALE BY U S GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225 OR WASHINGTON D C 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

ROAD CLASSIFICATION

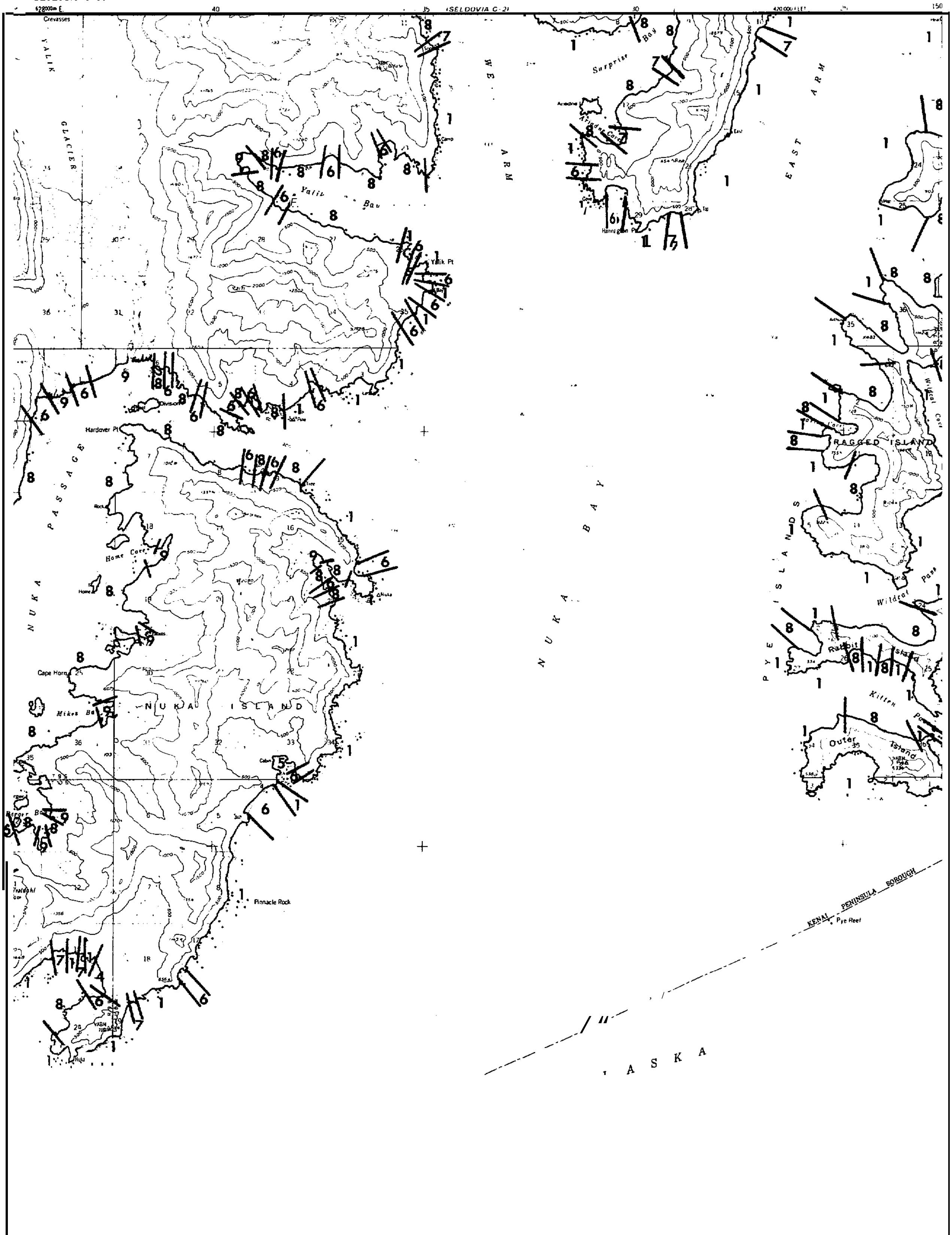
No roads or trails in this area

SELDOVIA (A-3), ALASKA
W15045/15X22.5

1951

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SELDOVIA (B-2) QUADRANGLE
ALASKA



...ed, edited, and published by the Geological Survey
Control by USC&GS and USCE
Topography by photogrammetric methods from aerial photographs taken 1951. Map not field checked
Selected hydrographic data compiled from USC&GS Charts 8530 and 8552 (1:200 000 scale). This information is not intended for navigational purposes
Universal Transverse Mercator projection. 1927 North American datum. 10,000-foot grid based on Alaska coordinate system, zone 4
Land lines represent unsurveyed and unmarked local predetermined by the Bureau of Land Management
Lake elevations are unchecked

CONTOUR INTERVAL 100 FEET

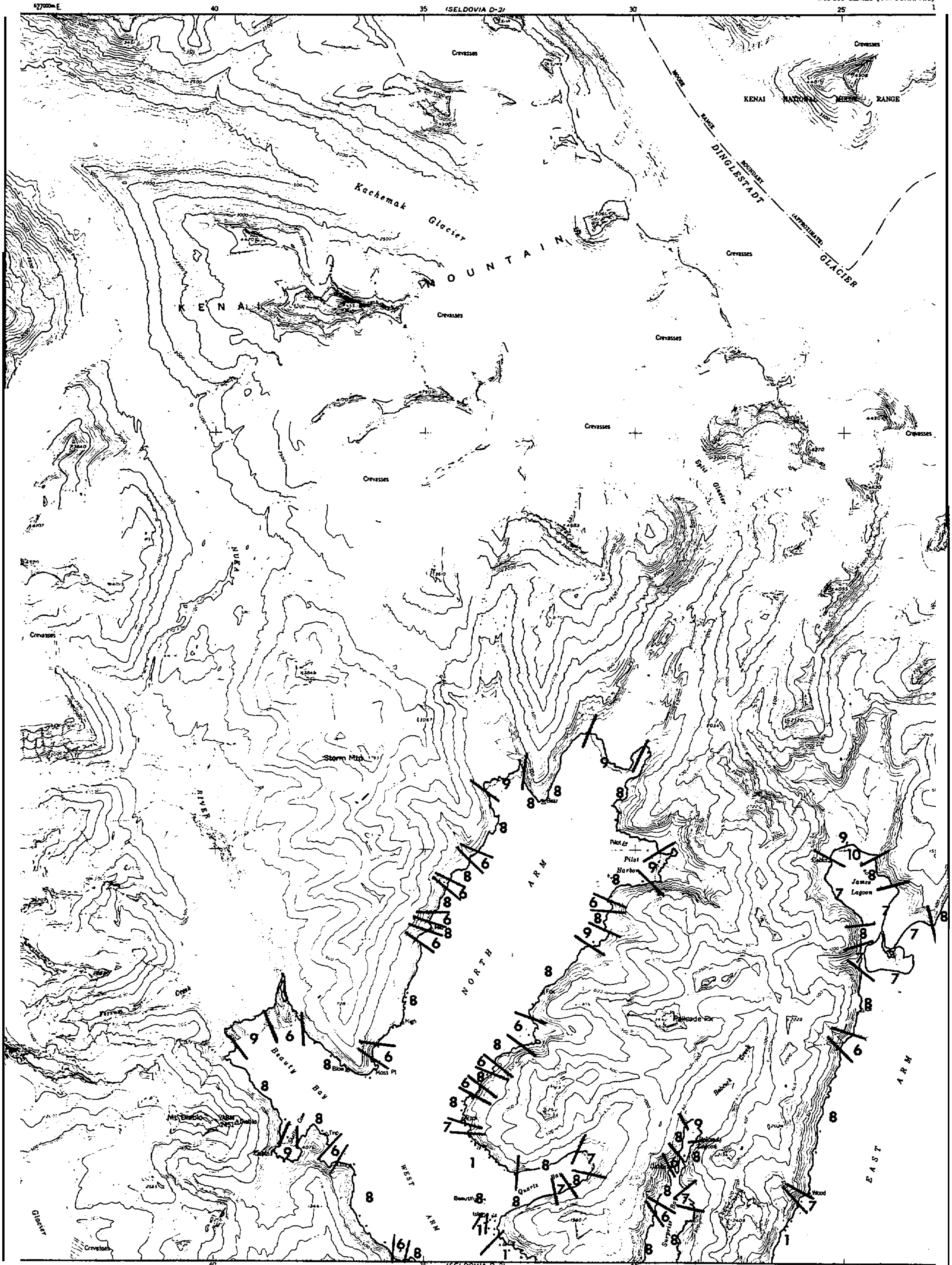
FOR SALE BY U S GEOLOGICAL SURVEY
FAIRBANKS ALASKA 99701 DENVER COLORADO 80225 OR WASHINGTON D C 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION
No roads or trails in this area

SELDOVIA (B-2) ALASKA
1951

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SELDOVIA (C-2) QUADRANGLE
ALASKA-THIRD JUDICIAL DIVISION
1:63 360 SERIES (TOPOGRAPHIC)



8

Mapped, edited and published by the Geological Survey
by USC&GS and USCE
aphy compiled from USC&GS charts 8530
52 (1:200,000 Scale)
Topography from aerial photographs by multiplex methods 1953
Aerial photographs taken 1951
Universal Transverse Mercator projection zone 5
1927 North American datum
Unchecked elevations are shown in brown
1000-meter Universal Transverse Mercator grid ticks zone 5, shown in blue

SCALE 1:63 360

APPROXIMATE MEAN DECLINATION, 1953

CONTOUR INTERVAL 100 FEET

ROAD CLASSIFICATION

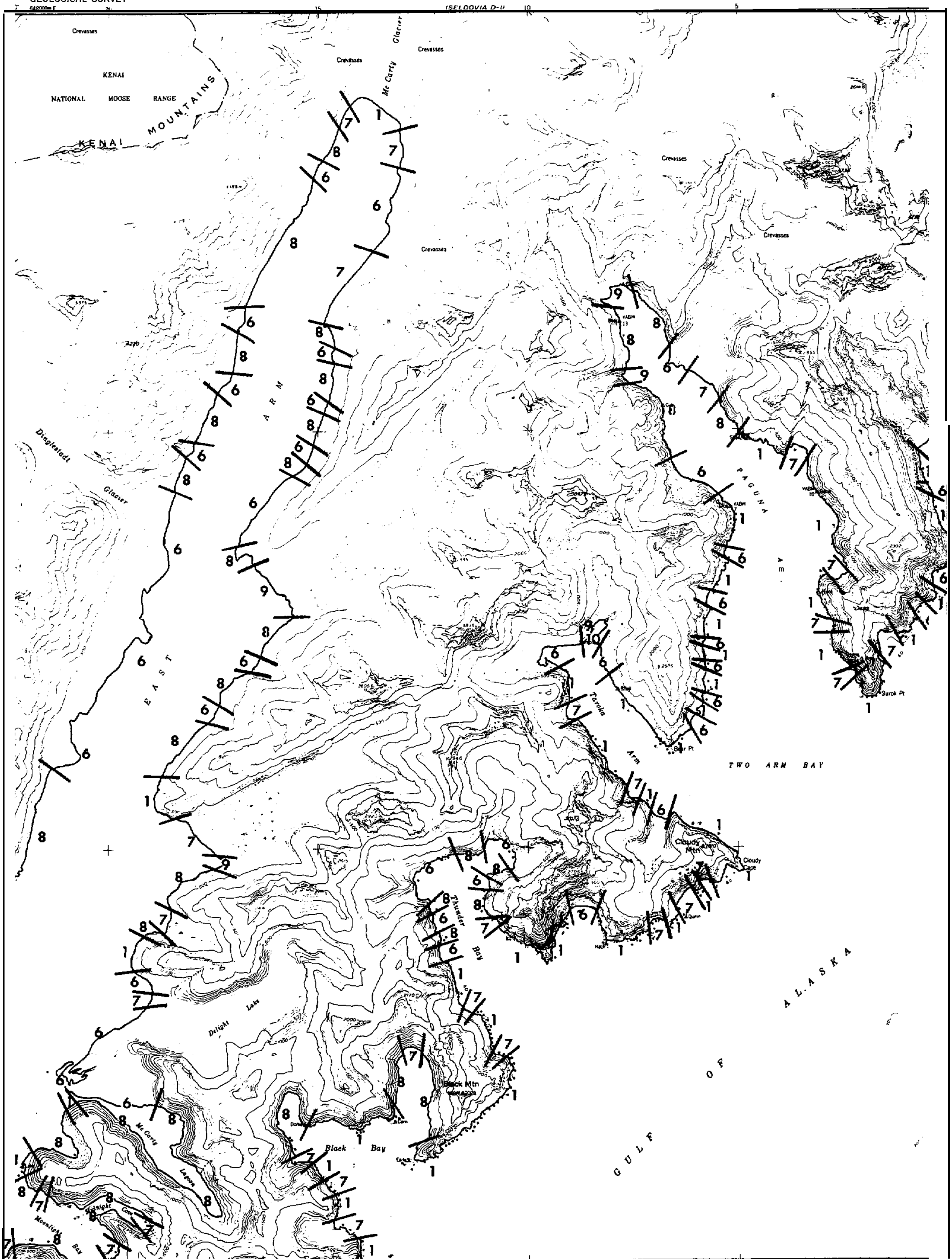
QUADRANGLE LOCATION

FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA ... COLORADO ... WASHINGTON 25, D. C.

SELDOVIA (C-2), ALASKA
N5930—W15022.5/15X22.5
1953

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SELDOVIA (C-1) QUADRANGLE
ALASKA-THIRD JUDICIAL DIVISION
1:63 360 SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey
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Hydrography compiled from USC&GS charts 8529, 8530, and 8552 (1:200,000 scale)
Topography from aerial photographs by multiplex methods 1953
Aerial photographs taken 1950
Universal Transverse Mercator projection, zone 5
1927 North American datum
Unchecked elevations are shown in brown and blue
1000-meter Universal Transverse Mercator grid ticks, zone 5, shown in blue

APPROXIMATE MEAN DECLINATION, 1953

SCALE 1:63 360

CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL

FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA DENVER 2, COLORADO WASHINGTON 25, D. C.
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INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.

ROAD CLASSIFICATION

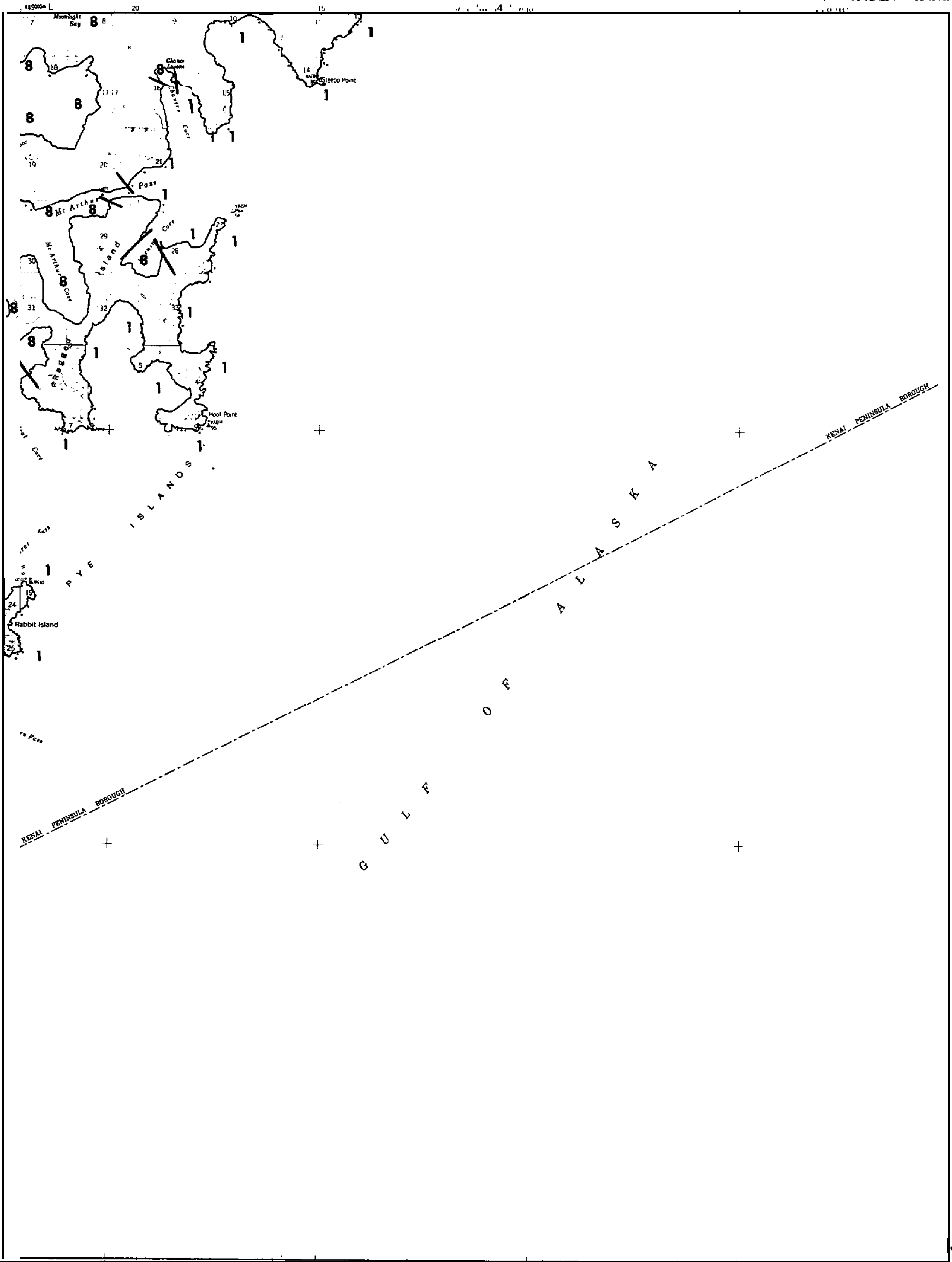
ALL WEATHER ROADS		DRY WEATHER ROADS	
Hard-surface	None	Improved dirt	None
Other	None	Unimproved dirt	None
Trails	None		

QUADRANGLE LOCATION

SELDOVIA (C-1), ALASKA
N5930—W15000/15X22.5
1953

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SELDOVIA (B-1) QUADRANGLE
ALASKA



10

I, edited, and published by the Geological Survey
by USC&GS and USCS

Topography by photogrammetric methods from aerial photographs taken 1951. field annotated 1953. Map not field checked

Selected hydrographic data compiled from USC&GS Charts 8530, 1951 (1:83,074 scale), 8552, 1952 (1:200,000 scale), and 8529, 1951 (1:81,847 scale). This information is not intended for navigational purposes

Universal Transverse Mercator projection. 1927 North American datum
10,000 foot grid based on Alaska coordinate system, zone 4
1000 meter Universal Transverse Mercator grid ticks, zone 5, shown in blue

Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folio S 16, Seward Meridian

SCALE 1:63 360

CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET DATUM IS MEAN LOWER LOW WATER

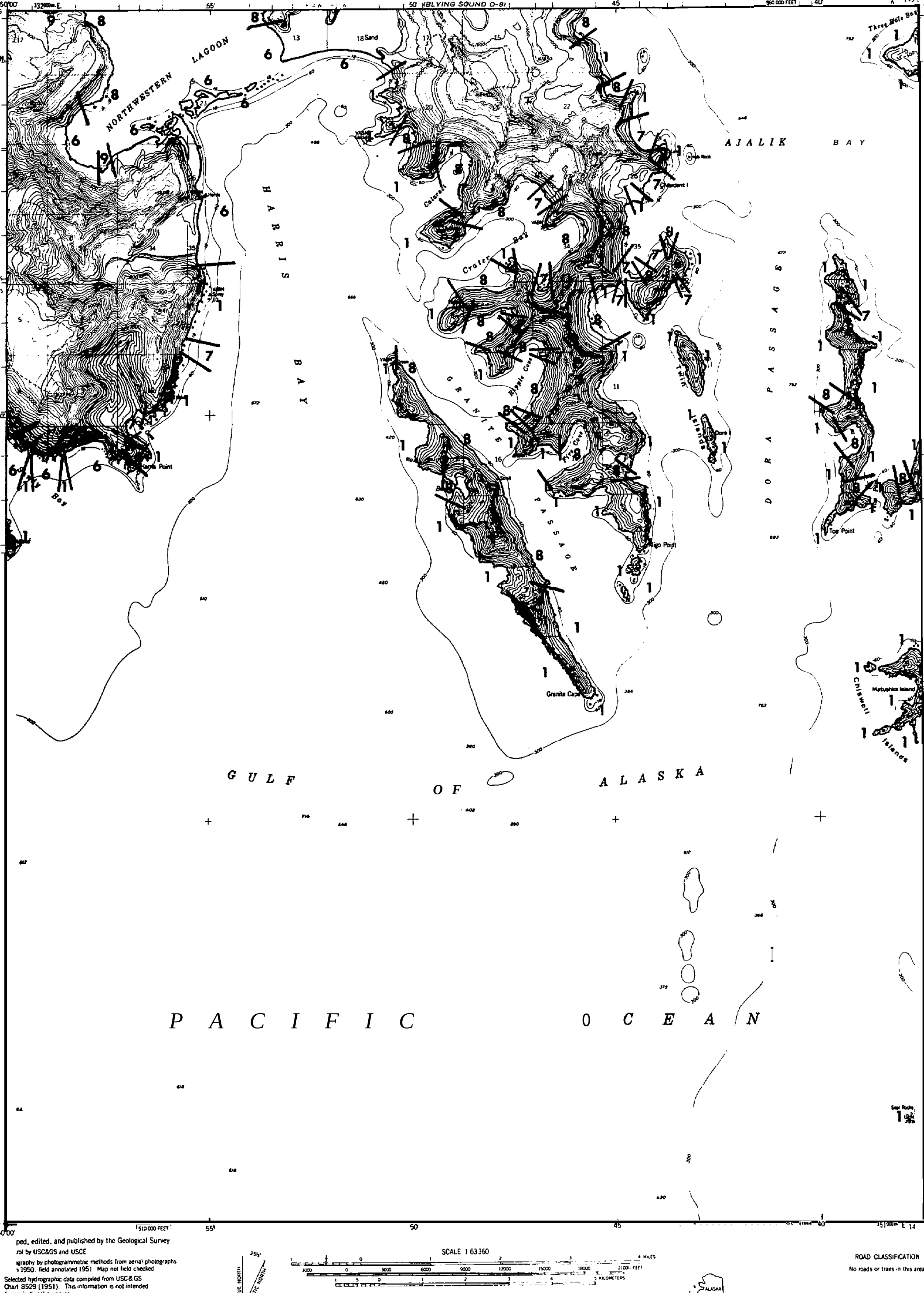
FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION
No roads or trails in this area

SELDOVIA (B-1), ALASKA
N5915—W15000/15X22.5
1953

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BLYING SOUND (C-8) QUADRANGLE
ALASKA
1:63 360 SERIES (TOPOGRAPHIC)



11

ped, edited, and published by the Geological Survey
rol by USC&GS and USCE
graphy by photogrammetric methods from aerial photographs
1950. field annotated 1951 Map not field checked

Selected hydrographic data compiled from USC&GS Chart 8529 (1951). This information is not intended for navigational purposes

Universal Transverse Mercator projection, 1927 North American datum
10,000-foot grid based on Alaska coordinate system, zone 4
1000-meter Universal Transverse Mercator grid ticks, zone 6, shown in blue

Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folio S-16, Seward Meridian

TRUE NORTH
MAGNETIC NORTH
25½°
APPROXIMATE MEAN DECLINATION, 1951

SCALE 1:63 360

CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 8 FEET

FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA DENVER 25, COLORADO WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

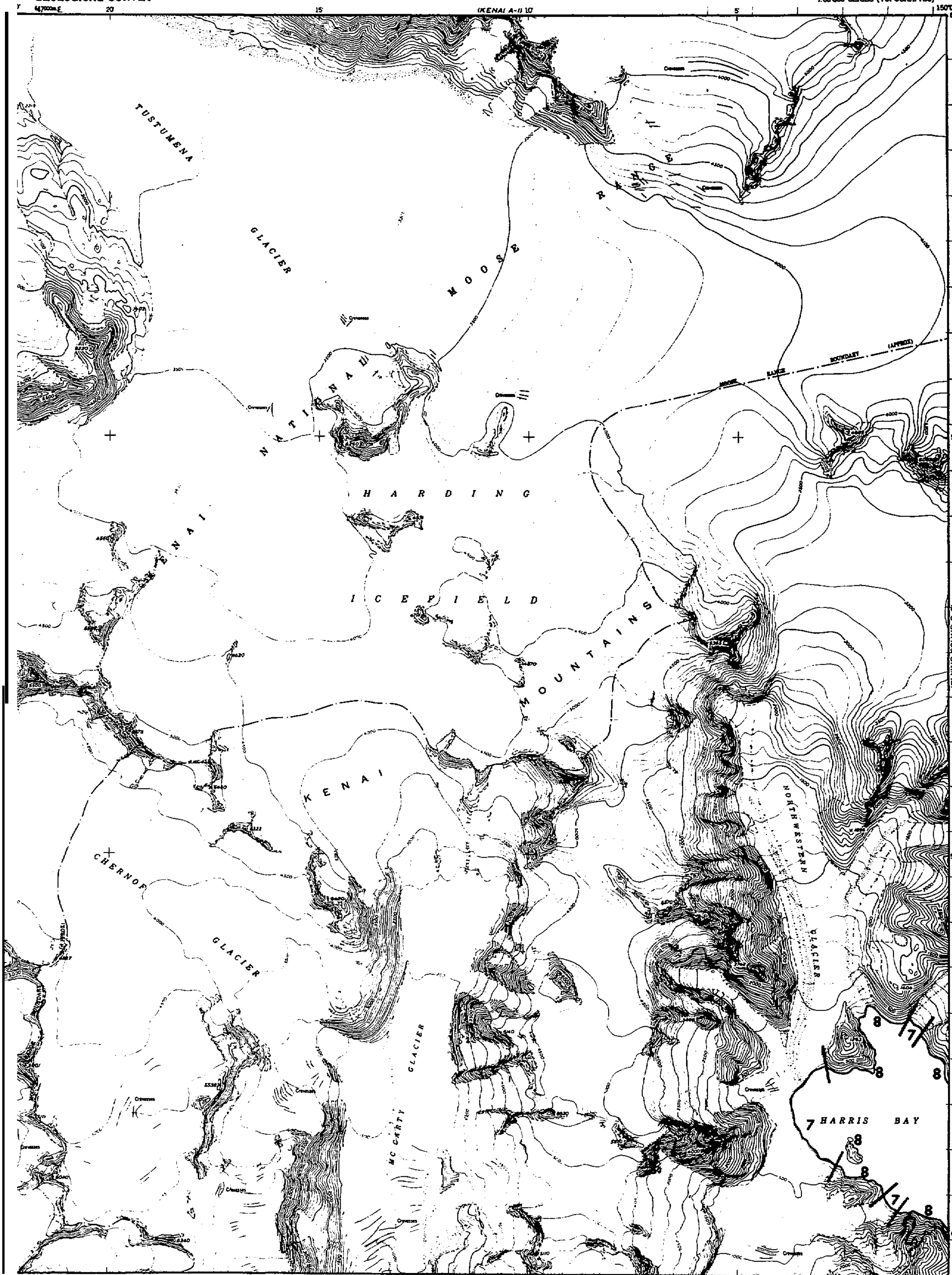
ALASKA
QUADRANGLE LOCATION

ROAD CLASSIFICATION
No roads or trails in this area

BLYING SOUND (C-8), ALASKA
N5930 – W14937.5/15X22.5
1951
MINOR REVISIONS 1963

UNITED STATES
:PARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SELDOVIA (D-1) QUADRANGLE
ALASKA-THIRD JUDICIAL DIVISION
1:63 360 SERIES (TOPOGRAPHIC)



ɔed, edited, and published by the Geological Survey
Control by USC&GS and USCE
Topography from aerial photographs by multiplex methods 1953
Aerial photographs taken 1950
Universal Transverse Mercator projection, zone 5
1927 North American datum
Unchecked elevations are shown in brown and blue
1000-meter Universal Transverse Mercator grid ticks, zone 5, shown in blue

APPROXIMATE MEAN DECLINATION, 1953

SCALE 1:63360

CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL

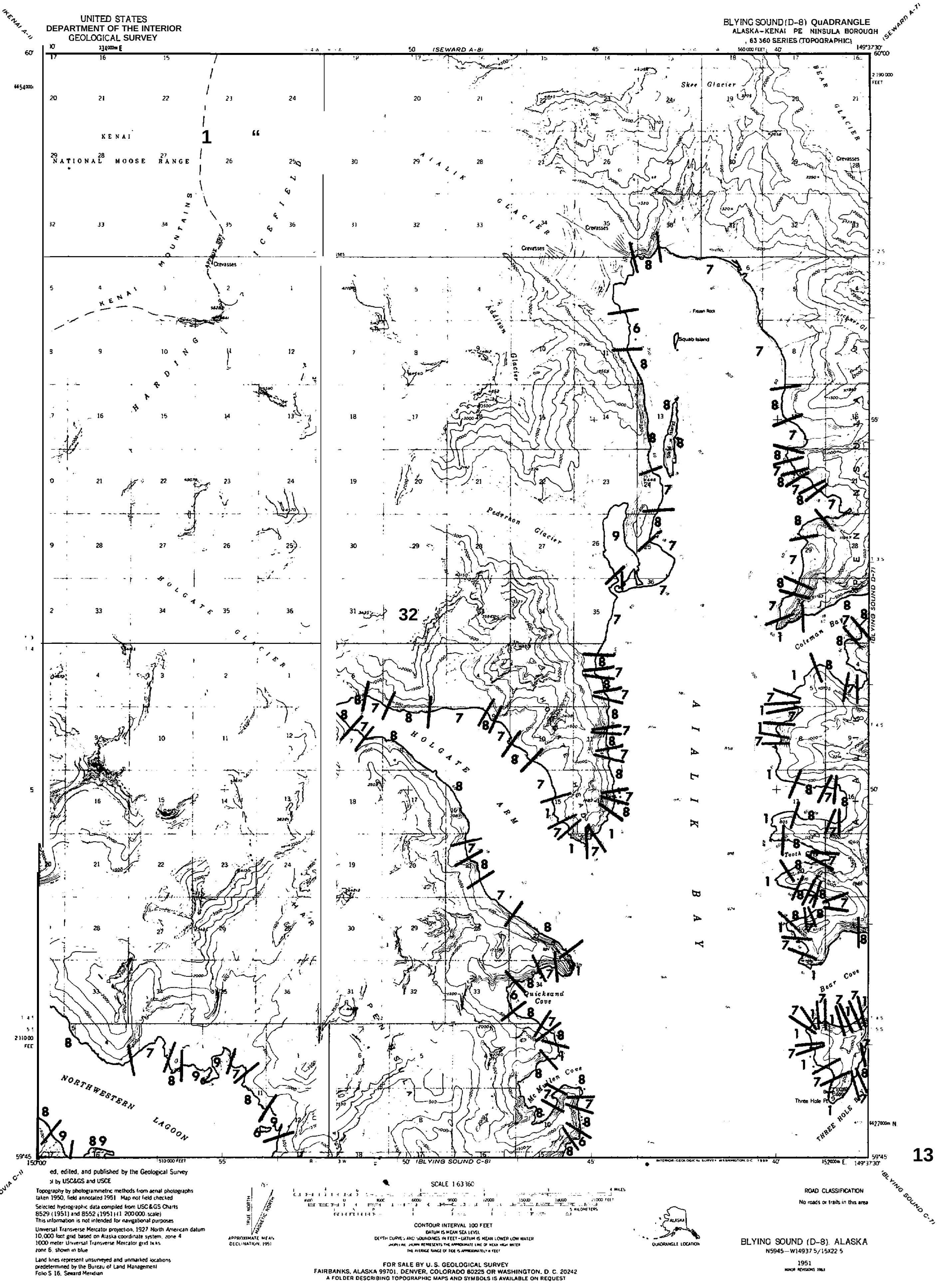
FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA DENVER 2, COLORADO WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

ROAD CLASSIFICATION

ALL WEATHER ROADS		DRY WEATHER ROADS	
Hard-surface	None	Improved dirt	None
Other	None	Unimproved dirt	None
		Trails	None

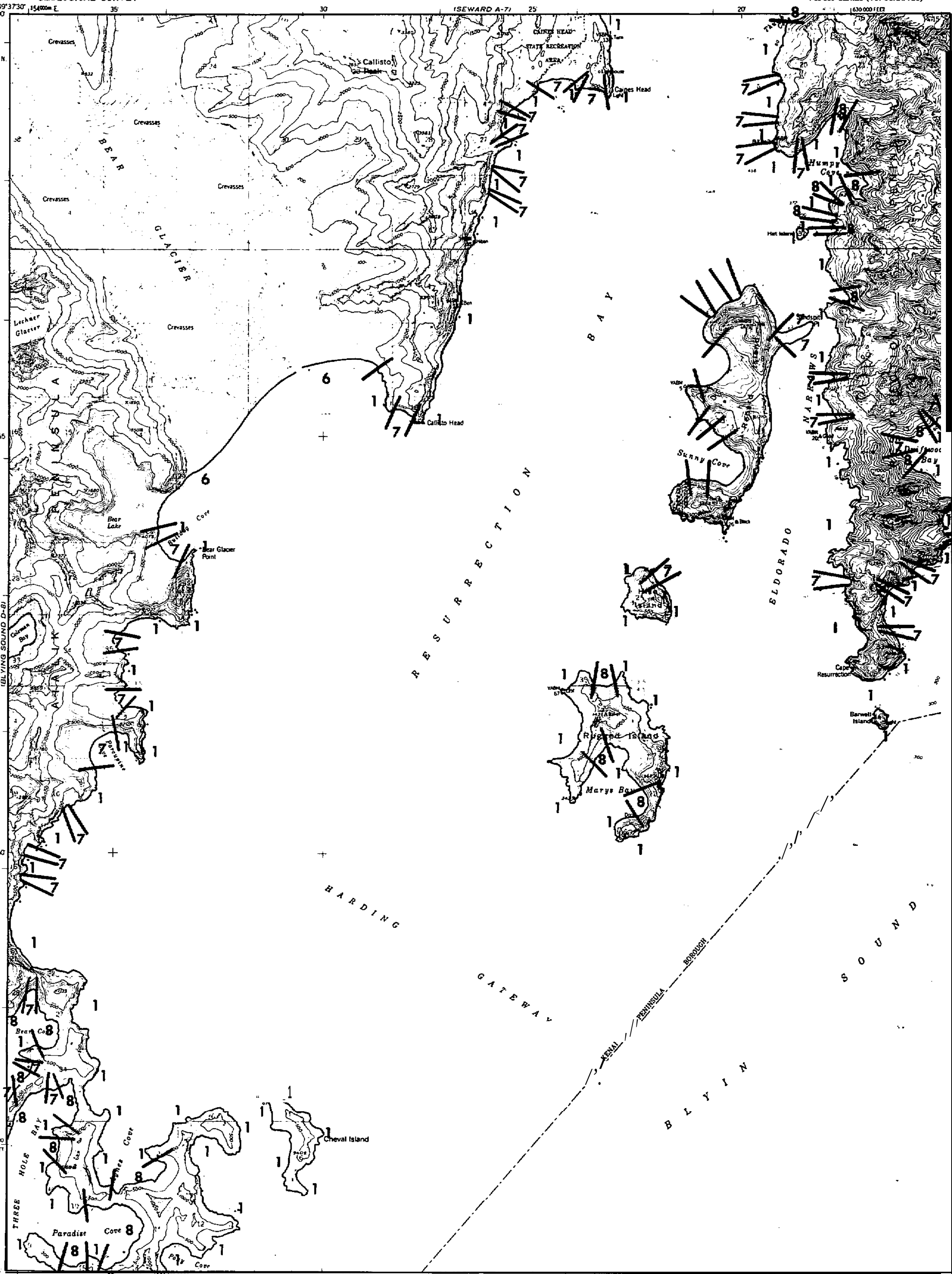
SELDOVIA (D-1), ALASKA
N5945—W15000/15X22.5
1953



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
BLYING SOUND (D-8) QUADRANGLE
ALASKA–KENAI PENINSULA BOROUGH
63 360 SERIES (TOPOGRAPHIC)
(SEWARD A-8)
KENAI NATIONAL MOOSE RANGE
KENAI MOUNTAINS
HARDING ICEFIELD
AIALIK GLACIER
Skee Glacier
BEAR GLACIER
Crevasses
Addison Glacier
Pederson Glacier
Squab Island
HOLGATE GLACIER
HOLGATE ARM
AIALIK BAY
AIALIK CAPE
Coleman Bay
Tooth
Bear Cove
Quicksand Cove
McMullen Cove
Three Hole Point
THREE HOLE BAY
NORTHWESTERN LAGOON
(BLYING SOUND C-8)
(BLYING SOUND D-7)
Edited and published by the Geological Survey
Control by USC&GS and USCE
Topography by photogrammetric methods from aerial photographs taken 1950, field annotated 1951. Map not field checked
Selected hydrographic data compiled from USC&GS Charts 8529 (1951) and 8552 (1951) (1:200 000 scale)
This information is not intended for navigational purposes
Universal Transverse Mercator projection, 1927 North American datum
10,000 foot grid based on Alaska coordinate system, zone 4
1000 meter Universal Transverse Mercator grid ticks zone 6, shown in blue
Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folio S 16, Seward Meridian
SCALE 1:63 360
CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL
FOR SALE BY U.S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225 OR WASHINGTON, D.C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
No roads or trails in this area
BLYING SOUND (D-8), ALASKA
N5945—W14937.5/15X22.5
1951

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BLYING SOUND (D-7) QUADRANGLE
ALASKA
1:63 360 SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USC&GS and USCE

Topography by photogrammetric methods from aerial photographs taken 1950, field annotated 1951. Map not field checked

Selected hydrographic data compiled from USC&GS Charts 8528 (1959), 8529 (1961), and 8552 (1958), (1:200 000 scale). This information is not intended for navigational purposes

Universal Transverse Mercator projection. 1927 North American datum. 10 000-foot grid based on Alaska coordinate system, zone 4. 1000-meter Universal Transverse Mercator grid ticks, zone 6, shown in blue

Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management. Folios S 15 and S 16, Seward Meridian

SCALE 1:63 360

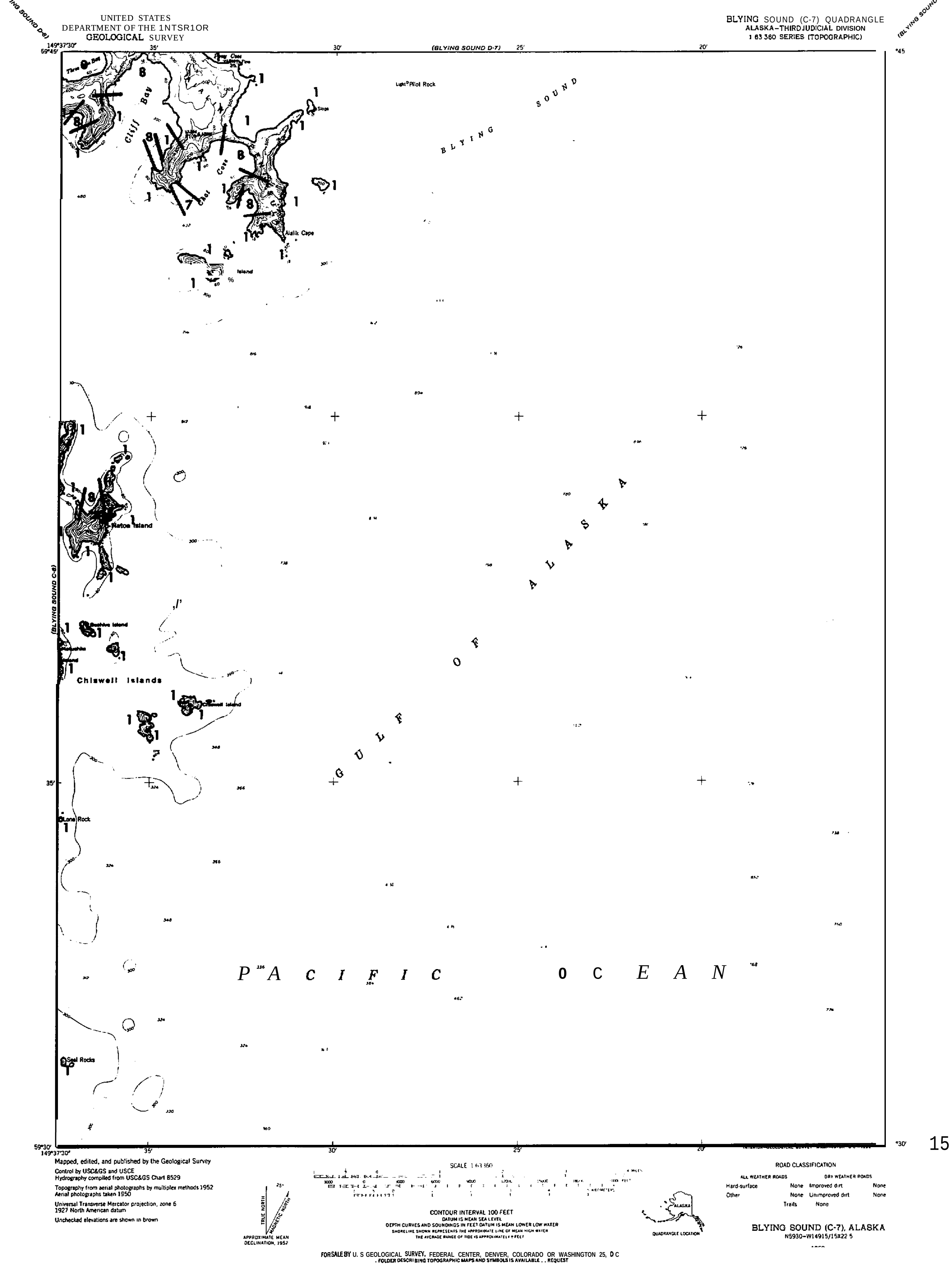
CONTOUR INTERVAL 100 FEET

FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR WASHINGTON, D.C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION
Unimproved dirt

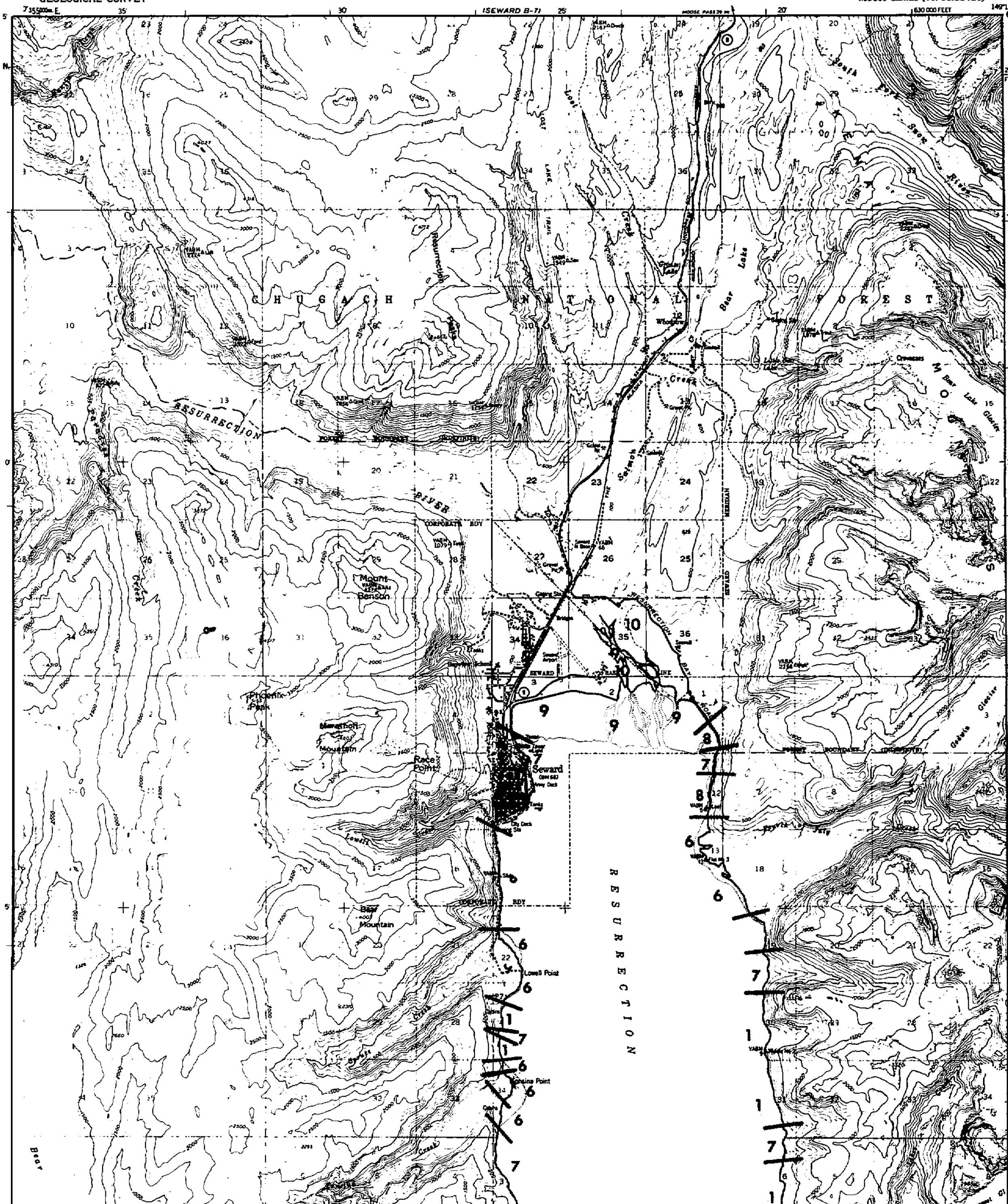
QUADRANGLE LOCATION

BLYING SOUND (D-7), ALASKA
N5945—W14915/15X22.5
1951
MINOR REVISIONS 1972


UNITED STATES
DEPARTMENT OF THE 1NTSR1OR
GEOLOGICAL SURVEY
BLYING SOUND (C-7) QUADRANGLE
ALASKA–THIRD JUDICIAL DIVISION
1 63 360 SERIES (TOPOGRAPHIC)
(BLYING SOUND D-7)
(BLYING SOUND C-8)
Pilot Rock
BLYING SOUND
Aialik Cape
Chiswell Islands
Natoa Island
Lone Rock
Seal Rocks
GULF OF ALASKA
PACIFIC OCEAN
Mapped, edited, and published by the Geological Survey
Control by USC&GS and USCE
Hydrography compiled from USC&GS Chart 8529
Topography from aerial photographs by multiplex methods 1952
Aerial photographs taken 1950
Universal Transverse Mercator projection, zone 6
1927 North American datum
Unchecked elevations are shown in brown
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1952
SCALE 1:63 360
CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
ALASKA
QUADRANGLE LOCATION
ROAD CLASSIFICATION
ALL WEATHER ROADS
DRY WEATHER ROADS
Hard-surface None
Improved dirt None
Other None
Unimproved dirt None
Trails None
BLYING SOUND (C-7), ALASKA
N5930–W14915/15X22 5
FOR SALE BY U. S GEOLOGICAL SURVEY, FEDERAL CENTER, DENVER, COLORADO OR WASHINGTON 25, D C
FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE . . REQUEST

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SEWARD (A-7) QUADRANGLE
ALASKA-KENAI PENINSULA BOROUGH
1:63 360 SERIES (TOPOGRAPHIC)



…ped, edited, and published by the Geological Survey
…rol by USGS and USCE

Topography by photogrammetric methods from aerial photographs taken 1950. Map not field checked

Selected hydrographic data compiled from USC&GS Charts 8552 (1951) (scale1:200 000), and 8529 (1951) (scale1:81 847). This information is not intended for navigational purposes

Universal Transverse Mercator projection, 1927 North American datum
10,000-foot grid based on Alaska coordinate system, zone 4
1000-metre Universal Transverse Mercator grid ticks, zone 6, shown in blue

Gray land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folios S-14, S-15, and S-16, Seward Meridian

Swamps, as portrayed, indicate only the wetter areas, usually of low relief, as interpreted from aerial photographs

Lake elevations are unchecked

APPROXIMATE MEAN DECLINATION, 1950

SCALE 1:63 360

CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 8 FEET

FOR SALE BY U.S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

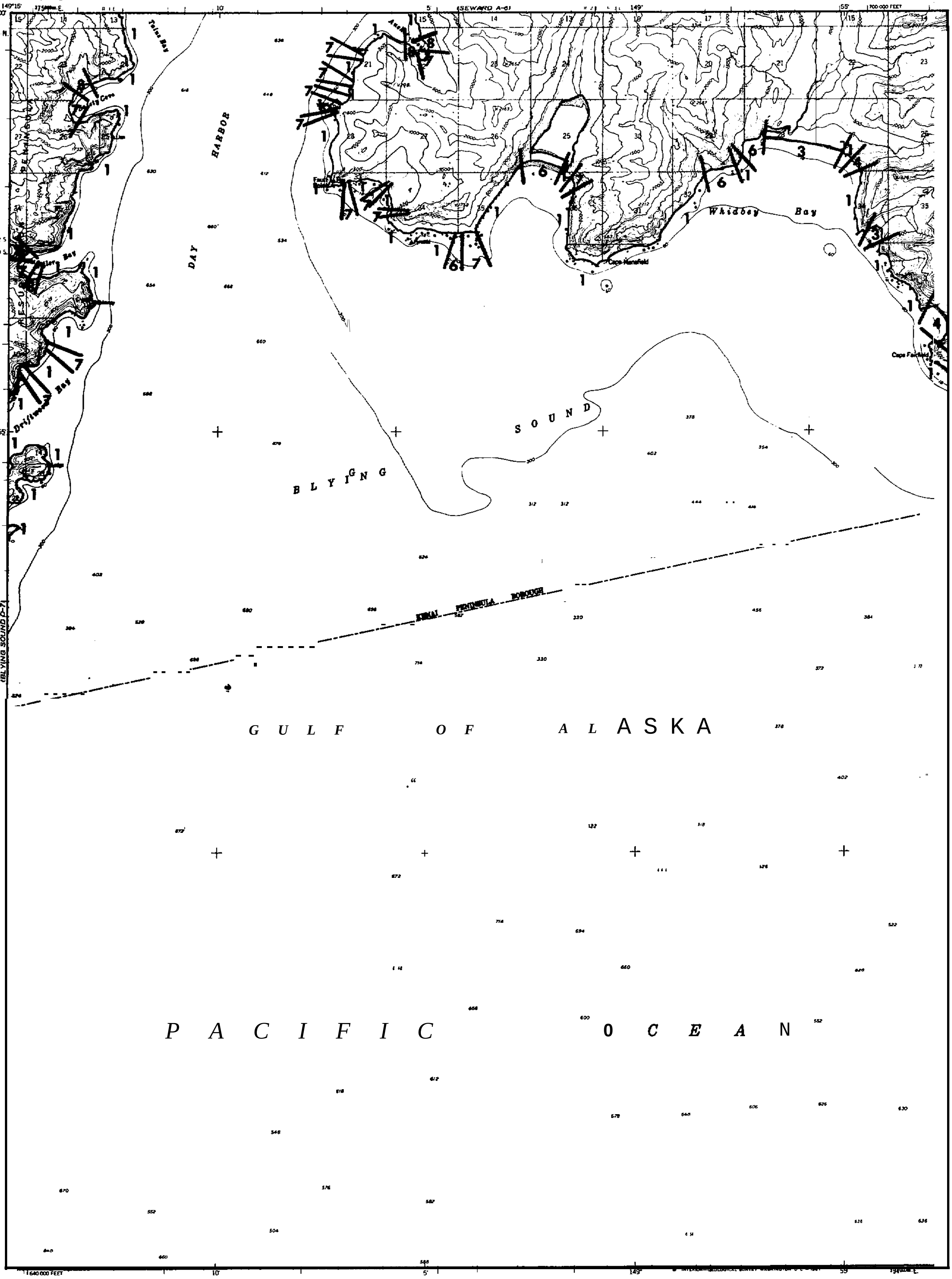
QUADRANGLE LOCATION

ROAD CLASSIFICATION
Medium-duty — Light-duty —
Unimproved dirt ....
State Route

SEWARD (A-7), ALASKA
N6000—W14915/15X22.5
1950
MINOR REVISIONS 1975

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BLYING SOUND (D-6) QUADRANGLE
ALASKA
1:63 360 SERIES (TOPOGRAPHIC)



ped, edited, and published by the Geological Survey

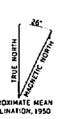
Control by USCE and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1950. Map not field checked

Selected hydrographic data compiled from USC&GS Charts 8528 and 8552 (1:200 000 scale). This information is not intended for navigational purposes

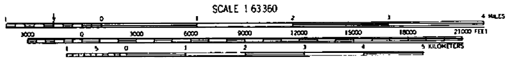
Universal Transverse Mercator projection, 1927 North American datum
10,000-foot grid based on Alaska coordinate system, zone 4
1000-meter Universal Transverse Mercator grid ticks, zone 6, shown in blue

Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folio S-15, Seward Meridian



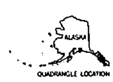
APPROXIMATE MEAN DECLINATION, 1950

SCALE 1:63 360



CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 8 FEET

FOR SALE BY " S GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701 DENVER, COLORADO 80225, OR WASHINGTON, O C 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS " AVAILABLE ON REQUEST



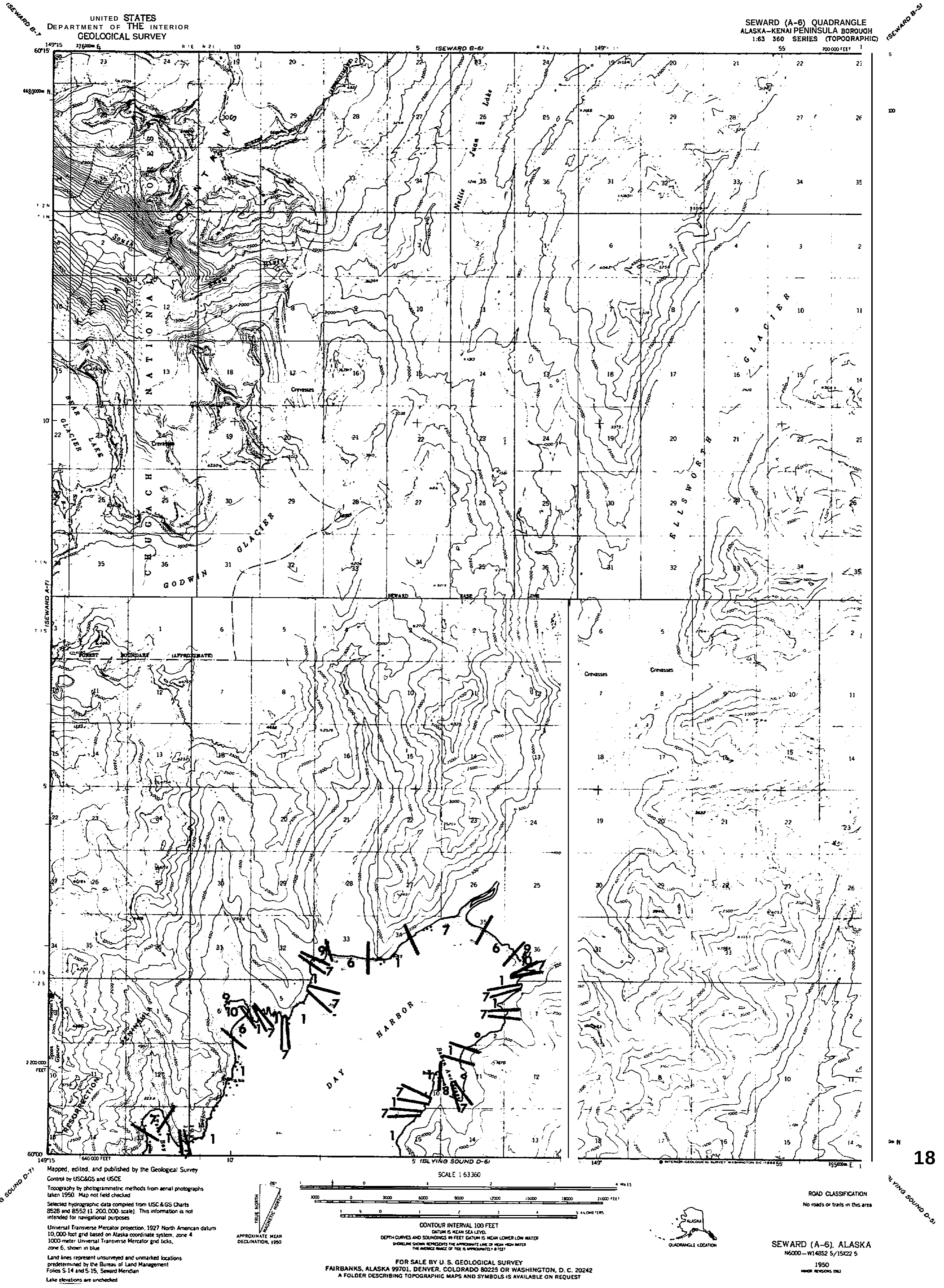
QUADRANGLE LOCATION

ROAD CLASSIFICATION

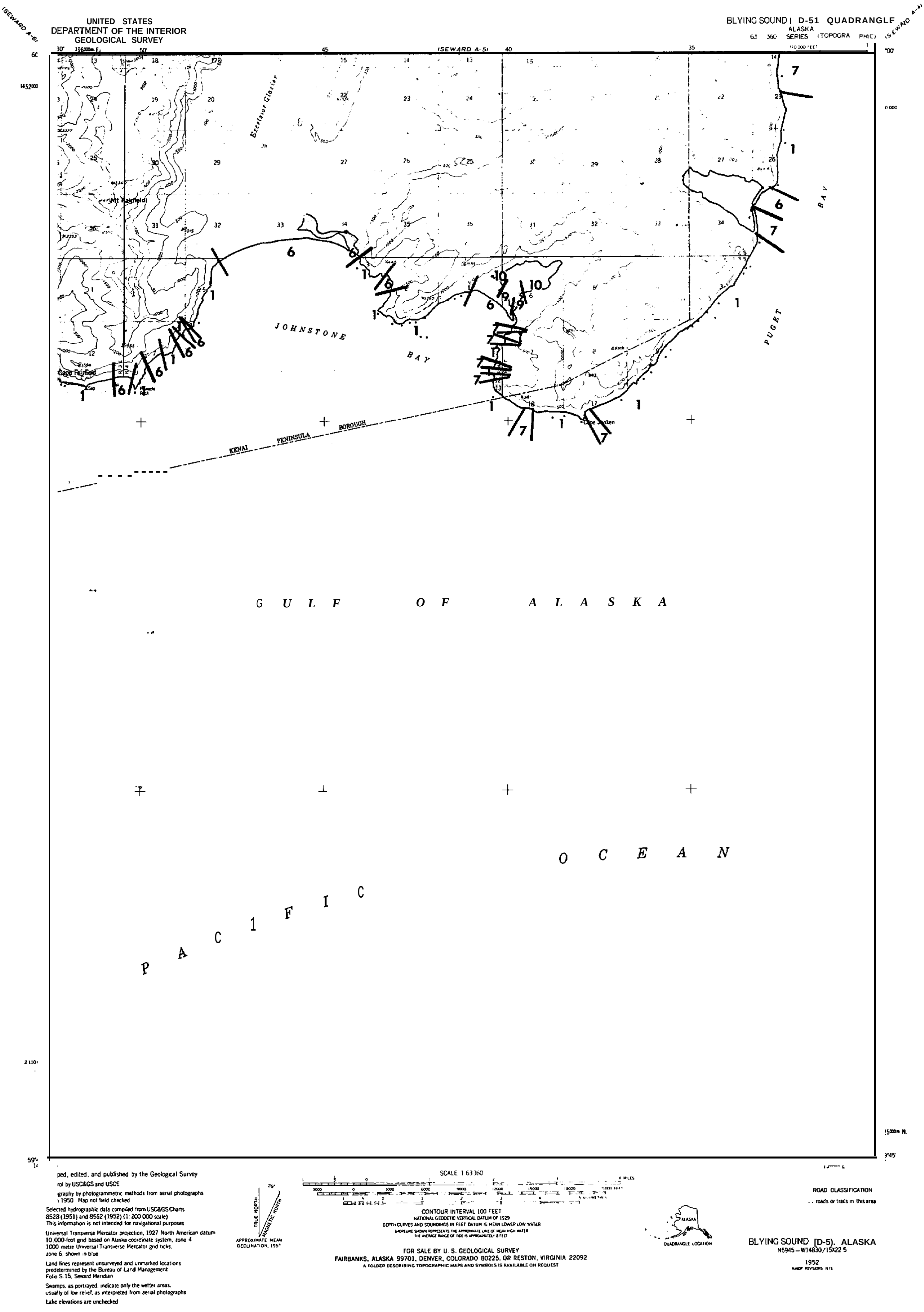
No roads or trails in this area

BLYING SOUND (D-6), ALASKA
N5945—W14852 5/15X22 5

1950
MINOR REVISIONS 1967

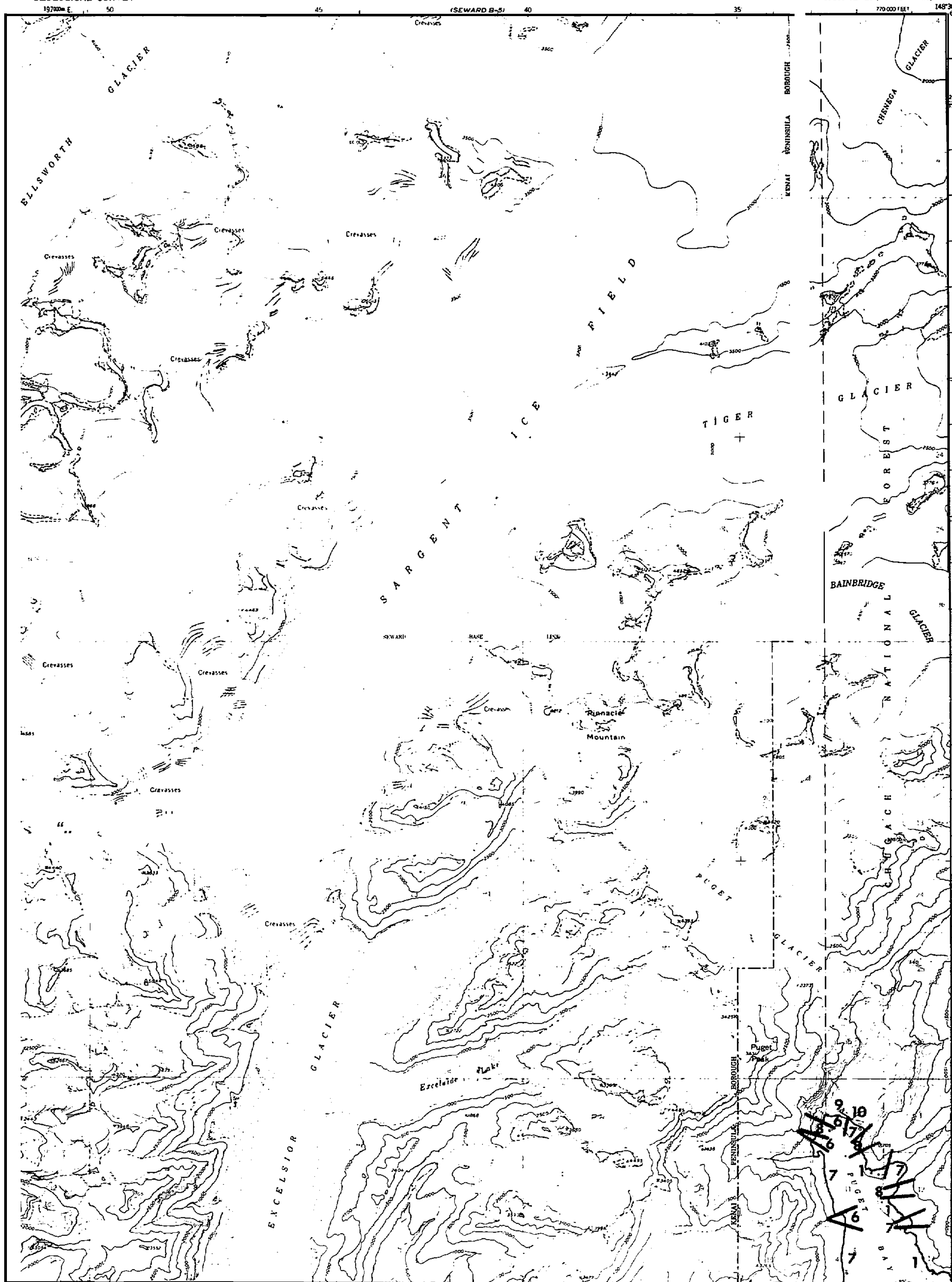

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SEWARD (A-6) QUADRANGLE
ALASKA–KENAI PENINSULA BOROUGH
1:63 360 SERIES (TOPOGRAPHIC)
(SEWARD B-6)
Nellie Juan Lake
CHUGACH NATIONAL FOREST
GODWIN GLACIER
ELLSWORTH GLACIER
BEAR GLACIER
Crevasses
SEWARD BASE LINE
FOREST BOUNDARY (APPROXIMATE)
DAY HARBOR
RESURRECTION
(SEWARD A-7)
(BLYING SOUND D-6)
Mapped, edited, and published by the Geological Survey
Control by USC&GS and USCE
Topography by photogrammetric methods from aerial photographs taken 1950. Map not field checked
Selected hydrographic data compiled from USC&GS Charts 8528 and 8552 (1:200,000 scale). This information is not intended for navigational purposes
Universal Transverse Mercator projection. 1927 North American datum
10,000-foot grid based on Alaska coordinate system, zone 4
1000-meter Universal Transverse Mercator grid ticks, zone 6, shown in blue
Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folios S-14 and S-15, Seward Meridian
Lake elevations are unchecked
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1950
SCALE 1:63360
CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL
FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225 OR WASHINGTON, D. C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ALASKA
QUADRANGLE LOCATION
ROAD CLASSIFICATION
No roads or trails in this area
SEWARD (A-6), ALASKA
1950

18


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
BLYING SOUND (D-5) QUADRANGLE
ALASKA
SERIES (TOPOGRAPHIC)
(SEWARD A-6)
(SEWARD A-5)
(SEWARD A-4)
Excelsior Glacier
Mt Fairfield
Cape Fairfield
JOHNSTONE BAY
PUGET BAY
KENAI PENINSULA BOROUGH
Cape Junken
GULF OF ALASKA
PACIFIC OCEAN
SCALE 1:63 360
CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 8 FEET
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1951
ped, edited, and published by the Geological Survey
rol by USC&GS and USCE
graphy by photogrammetric methods from aerial photographs
1950 Map not field checked
Selected hydrographic data compiled from USC&GS Charts 8528 (1951) and 8552 (1952) (1:200 000 scale)
This information is not intended for navigational purposes
Universal Transverse Mercator projection, 1927 North American datum
10 000-foot grid based on Alaska coordinate system, zone 4
1000-metre Universal Transverse Mercator grid ticks, zone 6, shown in blue
Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folio S-15, Seward Meridian
Swamps, as portrayed, indicate only the wetter areas, usually of low relief, as interpreted from aerial photographs
Lake elevations are unchecked
FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ALASKA
QUADRANGLE LOCATION
ROAD CLASSIFICATION
roads or trails in this area
BLYING SOUND (D-5), ALASKA
N5945—W14830/15X22.5
1952
MINOR REVISIONS 1973

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SEWARD (A-5) QUADRANGLE
ALASKA
1:63 360 SERIES (TOPOGRAPHIC)



(SEWARD B-6)

(SEWARD B-4)

(BLYING SOUND D-6)

(BLYING SOUND D-4)

Mapped, edited, and published by the Geological Survey

Control by USC&GS and USCE

Topography by photogrammetric methods from aerial photographs taken 1950, field annotated 1951. Map not field checked

Selected hydrographic data compiled from USC&GS Chart 8528 (1950) (1:81 436 scale). This information is not intended for navigational purposes

Universal Transverse Mercator projection, 1927 North American datum
10,000 foot grid based on Alaska coordinate system, zone 4
1000 meter Universal Transverse Mercator grid ticks, zone 6, shown in blue

Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folios S 14 and S 15, Seward Meridian

Swamps, as portrayed, indicate only the wetter areas, usually of low relief, as interpreted from aerial photographs

SCALE 1:63 360

CONTOUR INTERVAL 100 FEET

FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR WASHINGTON, D.C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

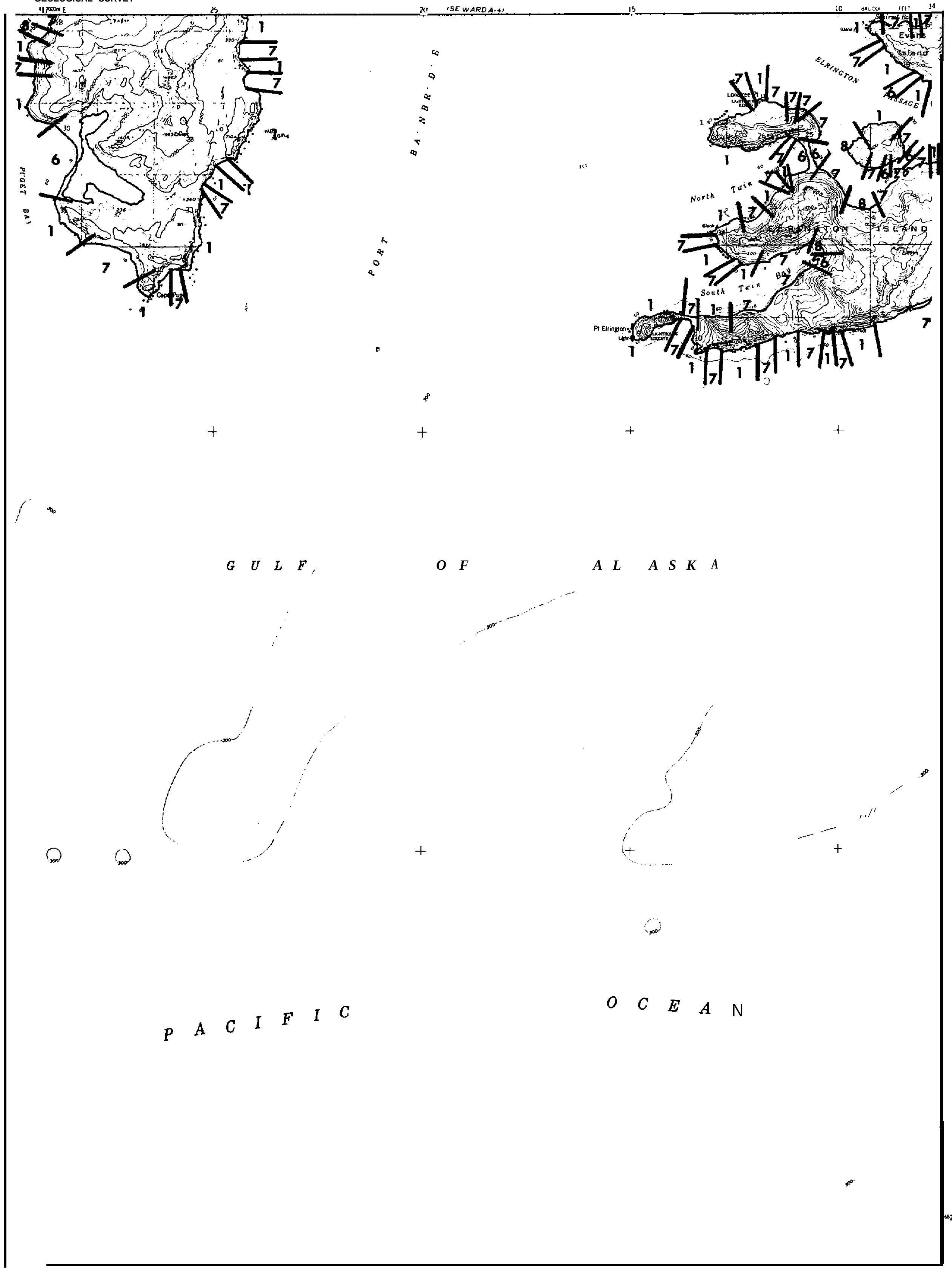
ROAD CLASSIFICATION
No roads or trails in this area

SEWARD [A-5] ALASKA
N6000—W14830/15X22.5

1951

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BLYING SOUND [D-4] QUADRANGLE
ALASKA
63 360 SERIES (TOPOGRAPHIC)



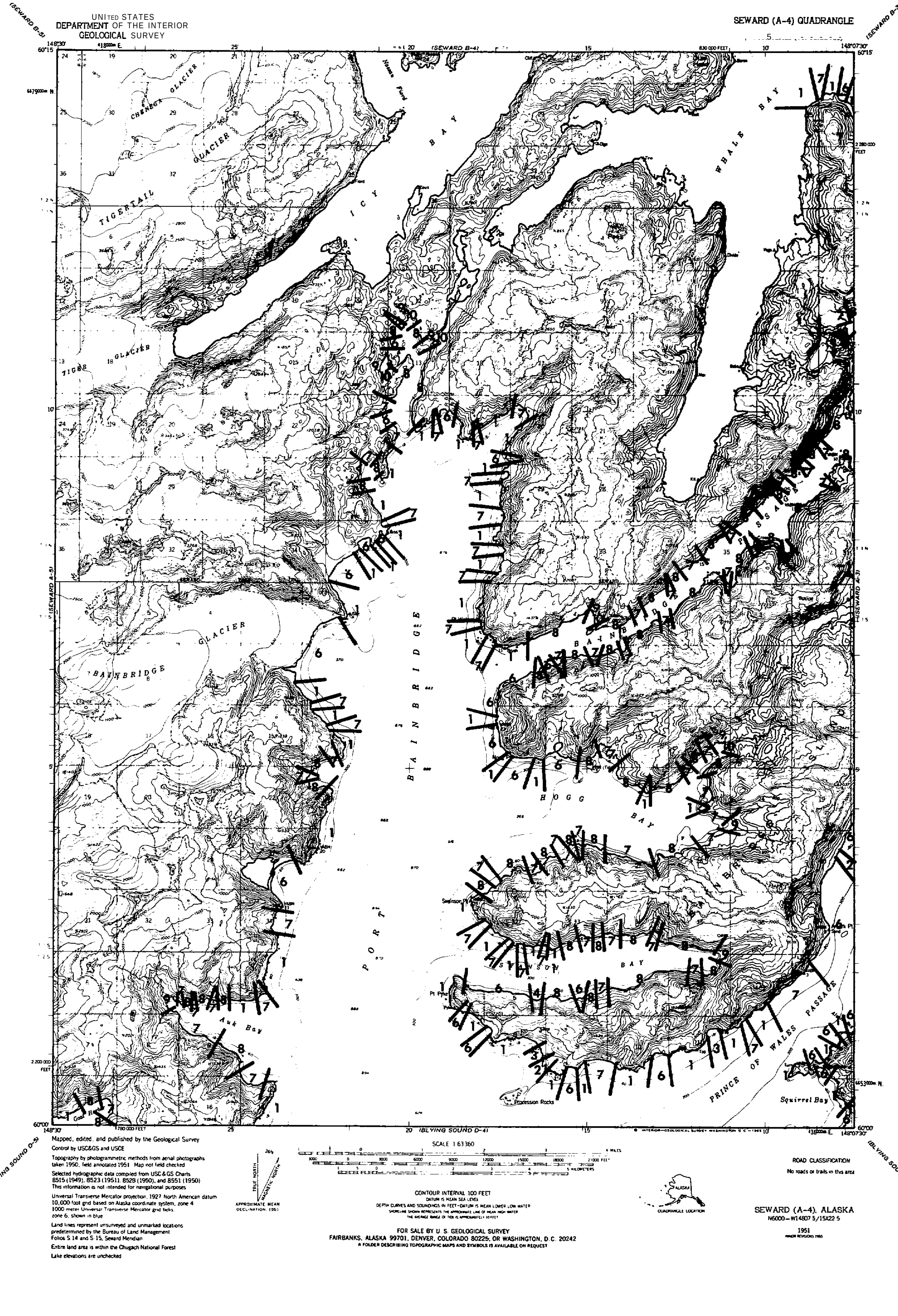
Mapped, edited, and published by the Geological Survey
Control by USC&GS and USCE
Topography by photogrammetric methods from aerial photographs taken 1950. Map not field checked
Selected hydrographic data compiled from USC&GS Charts 8515, 8523, 8528, and 8551 (1:200 000 scale). This information is not intended for navigational purposes
Universal Transverse Mercator projection. 1927 North American datum
10 000 foot grid based on Alaska coordinate system, zone 4
1000 meter Universal Transverse Mercator grid ticks, zone 6, shown in blue
Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folio S 15, Seward Meridian
Entire land area is within the Chugach National Forest

CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES IN FEET DATUM IS MEAN LOWER LOW WATER

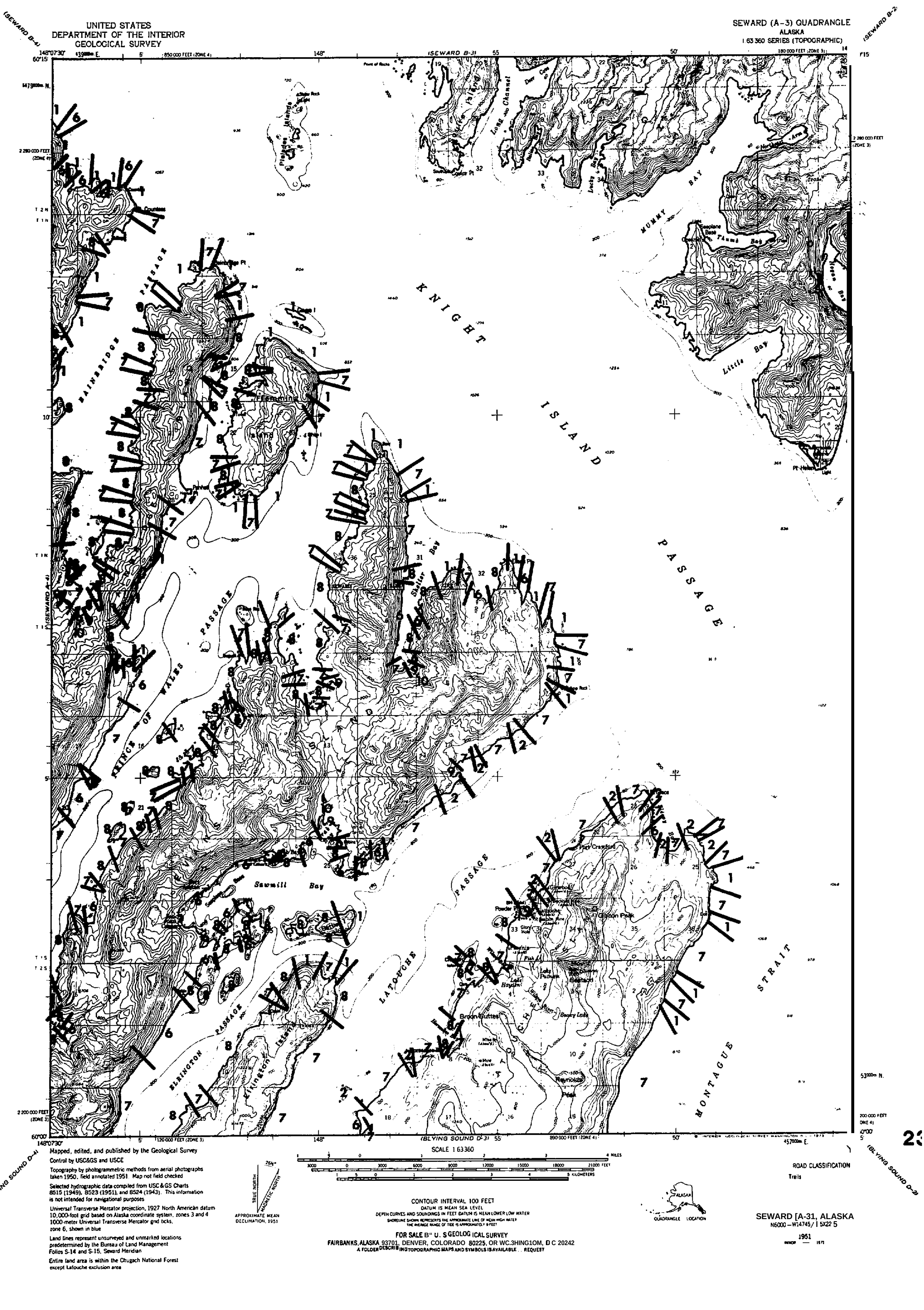
FOR SALE BY U S GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR WASHINGTON, D C 20242
FOLDER DESCRIBING TOPOGRAPHIC MAPS ... IS AVAILABLE ... REQUEST

ROAD CLASSIFICATION
No roads or trails in this area

BLYING SOUND (D-4) ALASKA
N5945 – W14807.5/15X22.5
1950

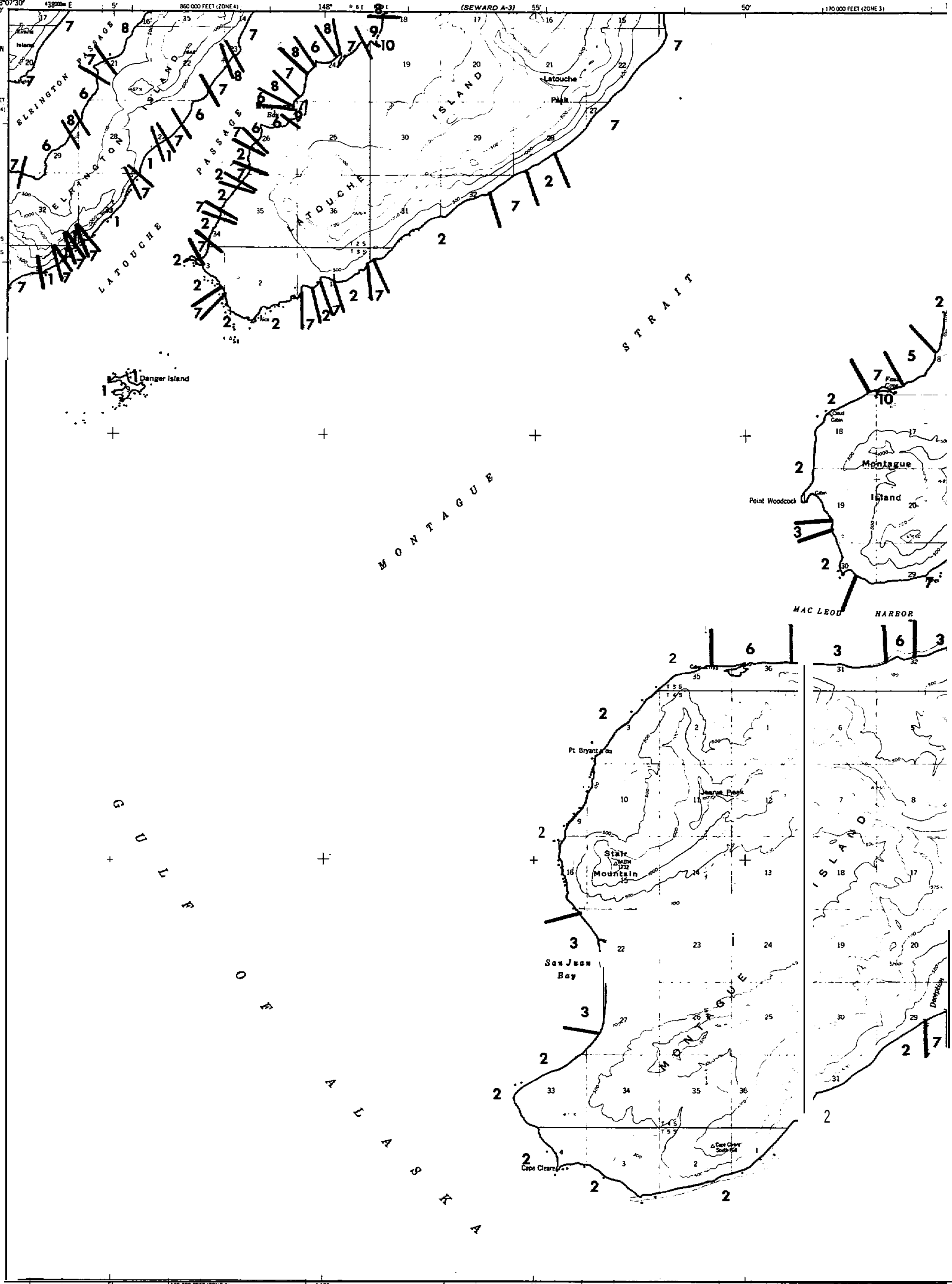

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SEWARD (A-4) QUADRANGLE
(SEWARD B-4)
(SEWARD A-5)
(SEWARD A-3)
(BLYING SOUND D-4)
ICY BAY
WHALE BAY
CHENEGA GLACIER
TIGERTAIL GLACIER
TIGER GLACIER
BAINBRIDGE GLACIER
PORT BAINBRIDGE
HOGG BAY
BAINBRIDGE PASSAGE
PRINCE OF WALES PASSAGE
Auk Bay
Squirrel Bay
Procession Rocks
SCALE 1:63360
CONTOUR INTERVAL 100 FEET
ROAD CLASSIFICATION
No roads or trails in this area
FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR WASHINGTON, D.C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
SEWARD (A-4), ALASKA
1951

22


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SEWARD (A-3) QUADRANGLE
ALASKA
1:63 360 SERIES (TOPOGRAPHIC)
KNIGHT ISLAND PASSAGE
MONTAGUE STRAIT
PRINCE OF WALES PASSAGE
BAINBRIDGE PASSAGE
LATOUCHE PASSAGE
ELRINGTON PASSAGE
Sawmill Bay
Little Bay
Thumb Bay
Port Crawford
Powder Pt
Pt Helen
Reynolds Peak
Mapped, edited, and published by the Geological Survey
Control by USC&GS and USCE
Topography by photogrammetric methods from aerial photographs taken 1950. field annotated 1951. Map not field checked
Selected hydrographic data compiled from USC&GS Charts 8515 (1949), 8523 (1951), and 8524 (1943). This information is not intended for navigational purposes
Universal Transverse Mercator projection, 1927 North American datum
10,000-foot grid based on Alaska coordinate system, zones 3 and 4
1000-meter Universal Transverse Mercator grid ticks, zone 6, shown in blue
Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folios S-14 and S-15, Seward Meridian
Entire land area is within the Chugach National Forest except Latouche exclusion area
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1951
SCALE 1:63 360
CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET DATUM IS MEAN LOWER LOW WATER
FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR WASHINGTON, D C 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ROAD CLASSIFICATION
Trails
QUADRANGLE LOCATION
SEWARD (A-3), ALASKA
1951
23

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

LYING SOUND (D-3) QUADRANGLE
ALASKA
1:63 360 SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USC&GS and USCE

Topography by photogrammetric methods from aerial photographs taken 1950, field annotated 1953. Map not field checked

Selected hydrographic data compiled from USC&GS Charts 8515 (1949) and 8523 (1951). This information is not intended for navigational purposes

Universal Transverse Mercator projection. 1927 North American datum. 10,000-foot grid based on Alaska coordinate system, zones 3 and 4. 1000-meter Universal Transverse Mercator grid ticks, zone 6, shown in blue

Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management. Folio S 15, Seward Meridian

Entire land area is within the Chugach National Forest

APPROXIMATE MEAN DECLINATION, 1953

SCALE 1:63 360

CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 9 FEET

FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

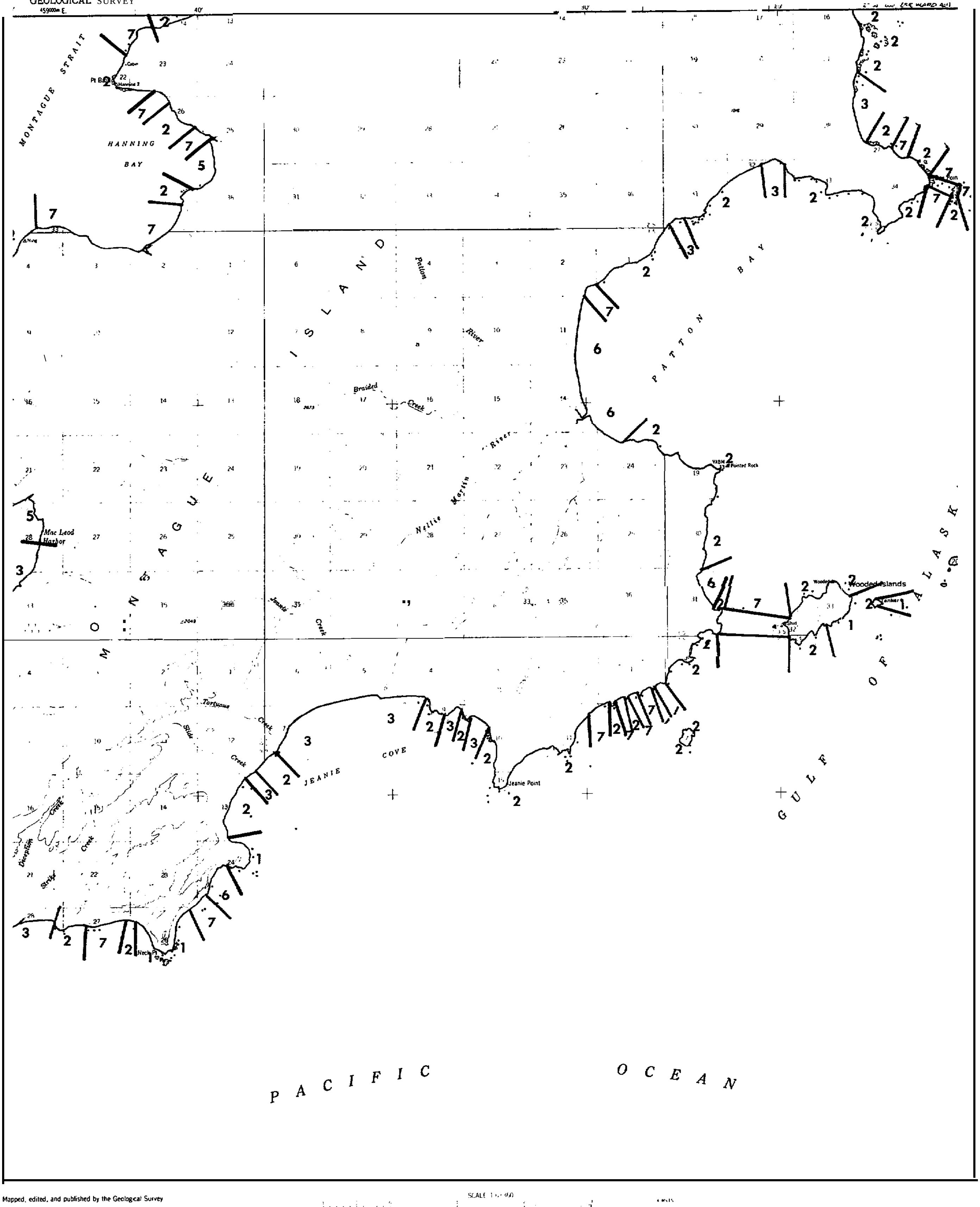
ROAD CLASSIFICATION
No roads or trails in this area

QUADRANGLE LOCATION

LYING SOUND (D-3), ALASKA
N5945—W14745/15X22.5
1953

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

BLYING SOUND (D-1 AND D-2) QUADRANGLE
ALASKA
1 63360 SERIES (TOPOGRAPHIC)



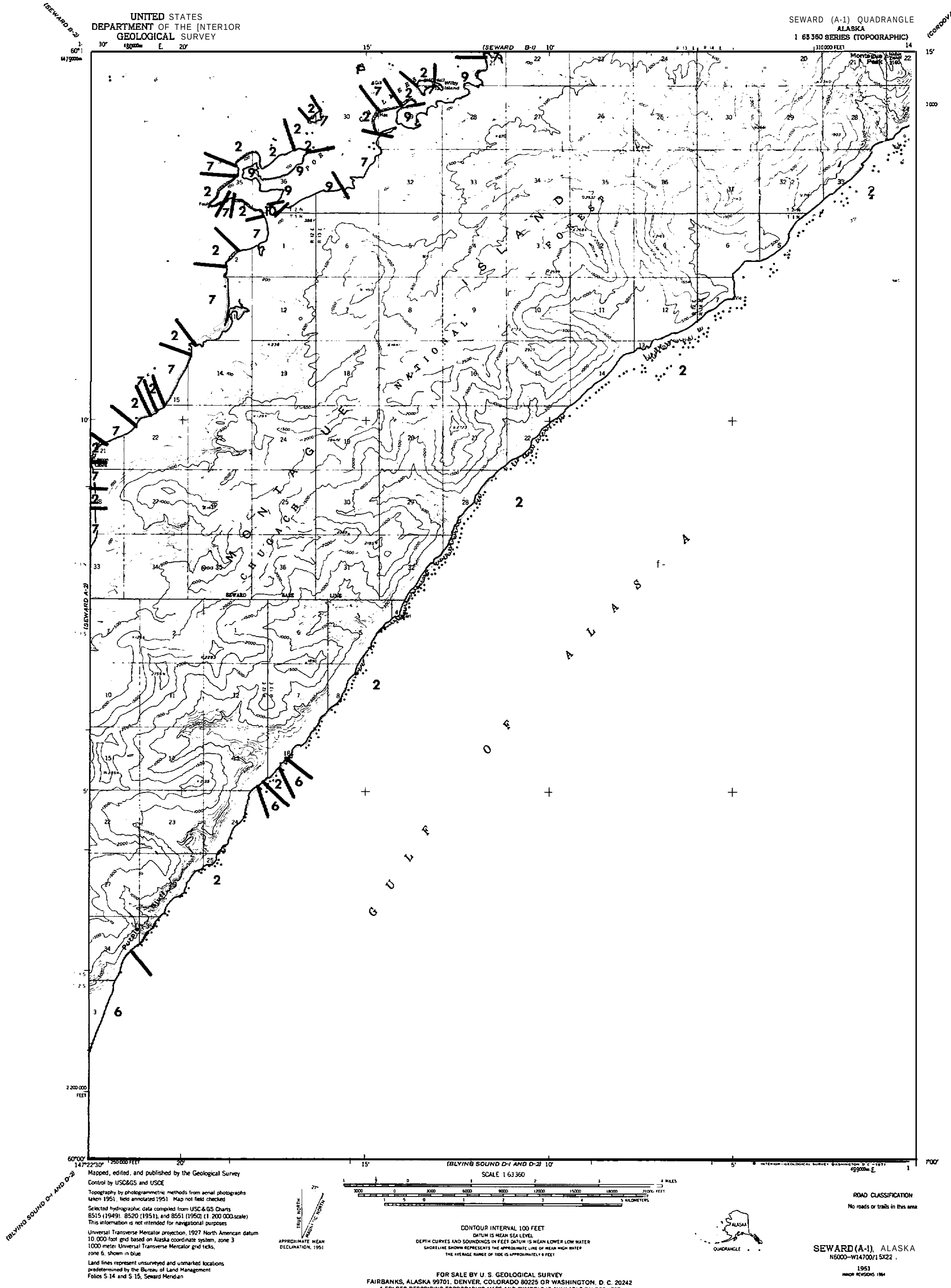
Mapped, edited, and published by the Geological Survey
Control by USC&GS and USCE
Topography by photogrammetric methods from aerial photographs taken 1951 and 1952, field annotated 1951. Map not field checked
Selected hydrographic data compiled from USC&GS Chart 8515 (1949). This information is not intended for navigational purposes
Universal Transverse Mercator projection, 1927 North American datum
10,000 foot grid based on Alaska coordinate system, zone 3
1000 meter Universal Transverse Mercator grid ticks, zone 6, shown in blue
Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folio S 15, Seward Meridian
Entire &cd,!" is within the Chugach National Forest

CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES IN FEET DATUM IS MEAN LOWER LOW WATER

FOR SALE BY U S GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225 OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION
No roads or trails in this area

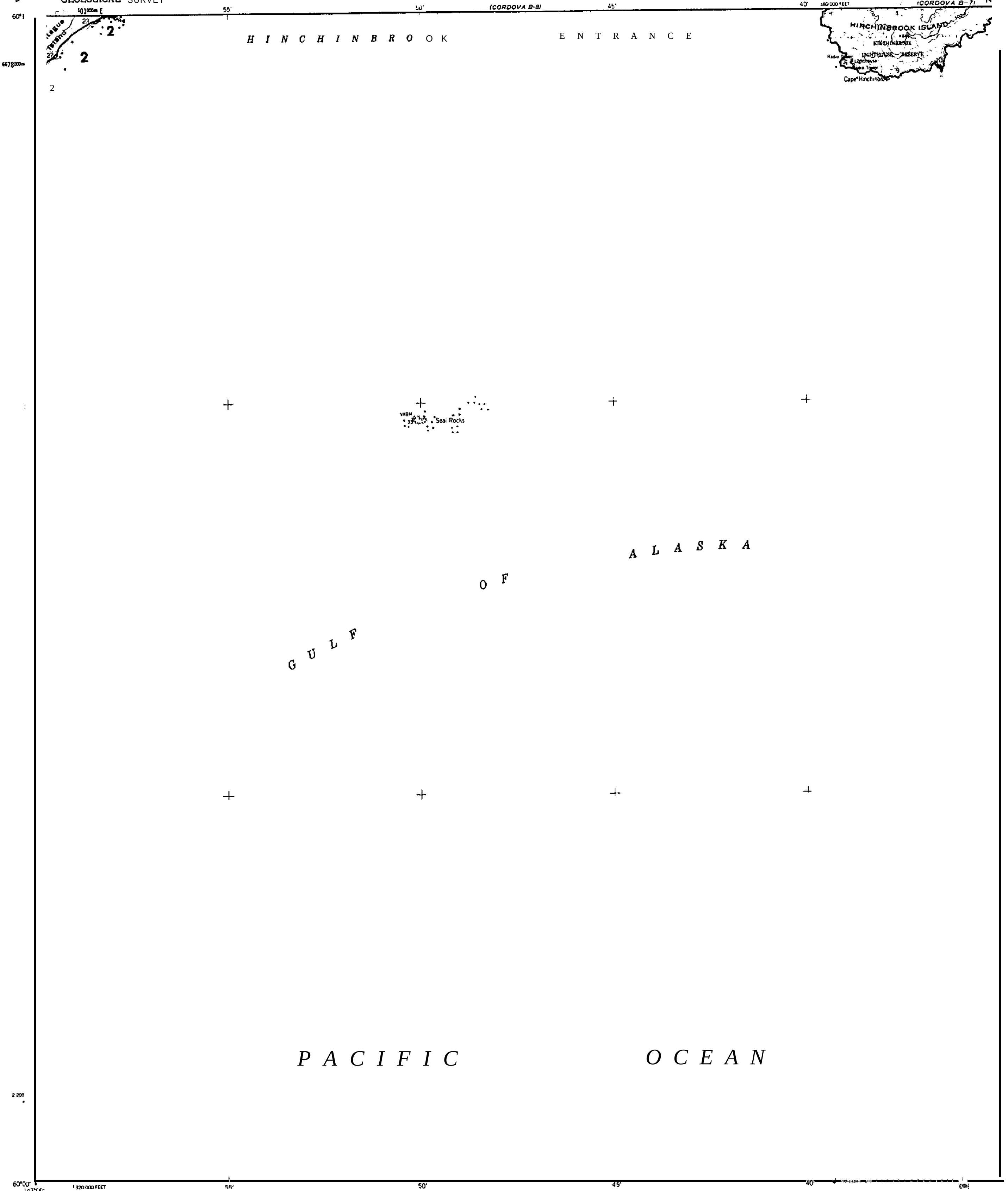
BLYING SOUND (D-1 AND C-21, ALASKA
N5945-W14720/15X25
1951



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SEWARD (A-1) QUADRANGLE
ALASKA
1:63 360 SERIES (TOPOGRAPHIC)
(SEWARD B-2)
(SEWARD B-1)
(CORDOVA B-8)
(SEWARD A-2)
(BLYING SOUND D-1 AND D-2)
Montague Peak
Willby Island
PORT
MONTAGUE ISLAND
CHUGACH NATIONAL FOREST
SEWARD BASE LINE
GULF OF ALASKA
Mapped, edited, and published by the Geological Survey
Control by USC&GS and USCE
Topography by photogrammetric methods from aerial photographs taken 1951. Field annotated 1951. Map not field checked
Selected hydrographic data compiled from USC&GS Charts 8515 (1949), 8520 (1951), and 8551 (1950) (1:200 000 scale). This information is not intended for navigational purposes
Universal Transverse Mercator projection. 1927 North American datum
10,000-foot grid based on Alaska coordinate system, zone 3
1000-meter Universal Transverse Mercator grid ticks, zone 6, shown in blue
Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folios S-14 and S-15, Seward Meridian
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1951
SCALE 1:63 360
4 MILES
5 KILOMETERS
CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 6 FEET
FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225 OR WASHINGTON, D. C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
ALASKA
QUADRANGLE
ROAD CLASSIFICATION
No roads or trails in this area
SEWARD (A-1), ALASKA
N6000—W14700/15X22
1951
MINOR REVISIONS 1964

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CORDOVA (A-7 AND A-8) QUADRANGLE
ALASKA
63 360 SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1950 and 1951 Map not field checked

Selected hydrographic data compiled from USC&GS Charts 8520 (1951), and 8551 (1:200,000 scale) (1950)
This information is not intended for navigational purposes

Universal Transverse Mercator projection, 1927 North American datum
10,000-foot grid based on Alaska coordinate system, zone 3
1000-meter Universal Transverse Mercator grid ticks, zone 6, shown in blue

Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folios S-14, Seward Meridian and CR-5, Copper River Meridian

APPROXIMATE MEAN DECLINATION, 1951

SCALE 1:63360

CONTOUR INTERVAL 100 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN ...
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY ... FEET

FOR SALE BY U.S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

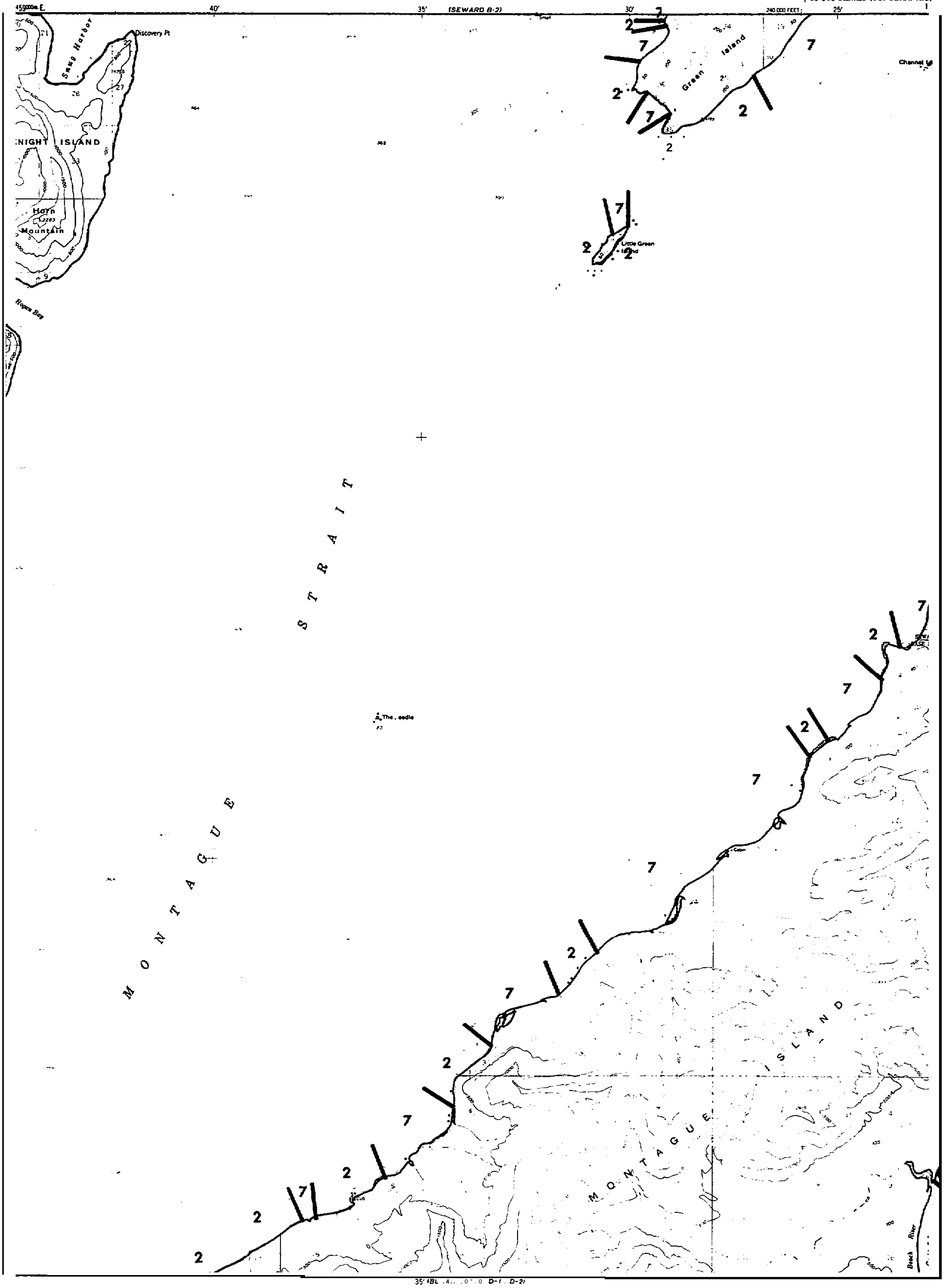
QUADRANGLE LOCATION

ROAD CLASSIFICATION

CORDOVA (A-7 AND A-8), ALASKA
N6000-W14635/15X25
1951

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SEWARD (A-2) QUADRANGLE
ALASKA
1:63 360 SERIES (TOPOGRAPHIC)



30

ied, edited, and published by the Geological Survey
Control by USC&GS and USCE
Topography by photogrammetric methods from aerial photographs taken 1951. Map not field checked
Selected hydrographic data compiled from USC&GS Charts 8515 and 8551 (1:200,000 scale). This information is not intended for navigational purposes
Universal Transverse Mercator projection, 1927 North American datum
10,000 foot grid based on Alaska coordinate system, zone 3
1000 metre Universal Transverse Mercator grid ticks, zone 6, shown in blue
Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folios S-14 and S-15, Seward Meridian
Entire land area is within the Chugach National Forest

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1951

SCALE 1:63 360

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT 50 FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY FEET

FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS ALASKA 99701 DENVER COLORADO 80225 OR RESTON VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION
No roads or trails in this area

SEWARD (A-2), ALASKA
N6000—W14722.5/15X22.5
1951
MINOR REVISIONS 1983

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SEWARD (B-1) QUADRANGL
ALASKA
, 6356.3 SERIES (TOPOGRAPHIC)

ed, edited, and published by the Geological Survey
l by USC&GS and USCE

Topography by photogrammetric methods from aerial photographs taken 1950-1951, field annotated 1951. Map not field checked

Selected hydrographic data compiled from USC&GS Charts 8515, 8517, and 8551 (1:200,000 scale). This information is not intended for navigational purposes

Universal Transverse Mercator projection, 1927 North American datum
10,000-foot grid based on Alaska coordinate system, zone 3
1000 meter Universal Transverse Mercator grid ticks, zone 6, shown in blue

Land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folio S 14, Seward Meridian

Entire land area is within the Chugach National Forest

Lake elevations are unchecked

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1951

SCALE 1:63360

CONTOUR INTERVAL 100 FEET
DOTTED LINES REPRESENT 50 FOOT CONTOURS
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET. DATUM IS MEAN LOWER LOW WATER

FOR SALE BY U. S. GEOLOGICAL SURVEY
FAIRBANKS, ALASKA 99701, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

ROAD CLASSIFICATION
No roads or trails in this area

SEWARD (B-1), ALASKA
N6015—W14700/15X22.5
1951
MINOR REVISIONS 1963

APPENDIX II

SURVEY STATION LOCATIONS AND TASKS COMPLETED

This gives the exact locations (latitude and longitude) of all 100 survey stations monitored for this study. The tasks completed at each station (aerial reconnaissance, ground reconnaissance, beach profile, and sediment analysis) are indicated by asterisks.

SURVEY STATION LOCATION AND TASKS COMPLETED

Station Number	LOCATION		TASKS COMPLETED		
	Latitude	Longitude	Aerial Reconn.	Ground Reconn.	Beach profile and seal. analysis
KNP-1	59°8'50"N	151°51'50"W	*		
2	59°7'30"	151°42'17"	*	*	
3	59°6'48"	151°27'59"	*		
4	59°9'30"	151°43'10"	*	*	
5	59°11'52"	151°32'30"	*	*	
6	59°13'45"	151°33'5"	*	*	
7	59°14'9"	151°26118"	*	*	
8	59°15'10"	151°23'35"	*	*	
9	59°12'40"	151°18'29"	*		
10	59°12'29"	151°8'00"	*		
11	59°18'35"	151°18'25"	*		
12	59°17'30"	151°5'40"	*		
13	59°18'30"	151°1'50"	*		
14	59°13'5"	151°1'00"	*		
15	59°14'5"	150°58'05"	*	*	*
16	59°18'30"	150°55'20"	*		
17	59°22'22"	150°46'15"	*	*	*
18	59°25'43"	150°36'00"	*		
19	59°22'58"	150°42'00"	*	*	*
20	59°19'10"	150°39'50"	*		
21	59°31'09"	150°36'40"	*		
22	59°36'02"	150°30'50"	*	*	
23	59°30'11"	150°33'03"	*		
24	59°29'00"	150°27'30"	*	*	
25	59*35'49°	150°21'30"	*	*	
26	54°43'50"	150°13'27"	*		

Stat ion Number	Latitude	Longitude	Aerial Reconn.	Ground Reconn.	Beach profile and seal. analysis
KNP- 27	59°37′59″	150°15′40″	*	*	
28	59°32′10″	150°21′05″	*	*	
29	59°26′31″	150°23′30″	*		
30	59°20′35″	150°22′59″	*		
31	59°28′38″	150°17′20″	*		
32	59°31′51″	150°10′59″	*		
33	59°34′31″	150° 5′35″	*		
34	59°40′35″	150° 5′55″	*	*	*
35	59°38′24″	149°59′48″	*		
36	59°43′30″	149°55′32″	*	*	
37	59°50′13″	149°56′30″	*	*	*
38	59°41′20″	149°49′05″	*		
39	59°36′50″	149°46′10″	*		
40	39°39′15″	149°44′40″	*		
41	59°47′20′″	149°47′05″	*	*	*
42	59°49′39″	149°44′33″	*		
43	59°57′10″	149°41′30″	*	*	*
44	59°50′21″	149°41′00″	*		
45	59°45′55″	149°36′39″	*		
46	59°43′30″	149°31′40″	*		
47	59°46′17″	149°35′25″	*		
48	59°52′42″	149°33′05″	*		
49	59°58′18″	149°25′55″	*		
50	60°7′ 21″	149°24′10″	*	*	
51	60°0′ 33″	149°20′04″	*		
52	59°53′25″	149°51′30″	*		
53	59°55′18″	149°21′12″	*		
54	59°50′39″	149°24′08″	*		
55	59°58′29″	149°12′30″	*		
56	60°2′55″	149° 2′45″	*	*	*
57	59°57′22″	149° 4′22″	*	*	*
58	59°55′40″	148°52′34″	*		
59	59°57127″	148°46′00″	*	*	*

Station Number	Latitude	Longitude	Aerial Reconn.	Ground Reconn.	Beach profile and seal. analysis
KNP-60	59°55′51″	148°35′50″	*..		
61	60°01′18″	148°33′00″	*	*	*
62	59°57′30″	148°25′30″	*		
63	60°02’28”	148°23′41″	*	*	*
64	60°06’41”	148°22′40″	*	*	
65	60°10′29″	148°20′18″	*	*	*
66	60°07′07″	148°14′42″	*	*	
67	60°11′12″	148°06′58″	*		
68	60°07′18″	148°12′25″	*		
69	60°03′04″	148°18′20″	*		
70	60°01’59”	148°09′20″	*		
71	60°08’45”	148°04′02″	*	*	
72	60°06’50”	147°59′52″	*	*	
73	59°59’22”	148°08′40″	*		
74	59°55’57”	148°13′00″	*		
75	60°01′24″	148°00′00″	*		
76	59°58’01”	148°06′41″	*	*	
77	60°03’51”	148°00′40″	*	*	*
78	60°03’24”	147°53′45″	*	*	
79	60°01?41”	147°50′31″	*	*	*
80	59°56’48”	147°59′28″	*		
81	59°51’00”	147°53′35″	*	*	
82	59°48’34”	147°53′19″	*	*	*
83	59°46’15”	147°50′22″	*		
84	59°48′02″	147°45′41″	*		
85	59°50′28″	147°31′28″	*		*
86	59°54′42″	147°29′40″	*		
87	59°58′40″	147°23′00″	*		*
88	60°06′35″	147°15′20″	*		
89	60°13′46″	147°01′00″	*		
90	60°18′00″	146°54′45″	*		

Station Number	Latitude	Longitude	Aerial Reconn.	Ground Reconn.	Beach profile and seal. analysis
KNP-91	60°18′21″	147°03′08″	*	*	
92	60°20′25″	147°04′52″	*	*	*
93	60°20′01″	147°12′48″	*	*	*
94	60°14′38″	147°13′20″	*	*	
95	60°10′39″	147°19′50″	*	*	*
96	60°05′42″	147°26′00″	*		
97	60°01′14″	147°35′49″	*	*	*
98	59°57′01″	147°42′10″	*		
99	59°53′18″	147°44′00″	*	*	*
100	60°15′19″	147°23′25″	*	*	*

APPENDIX III

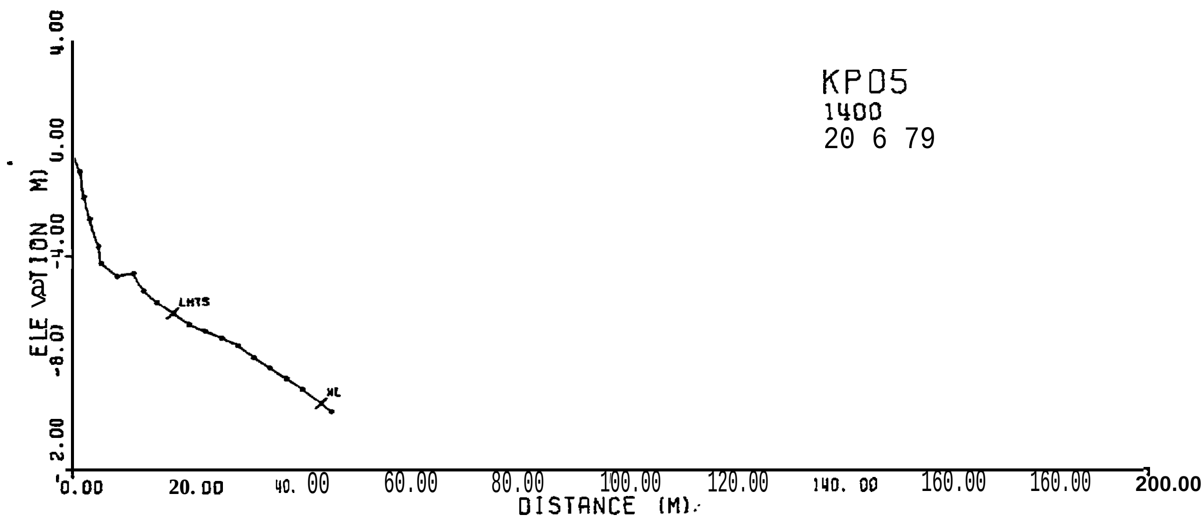
BEACH PROFILES

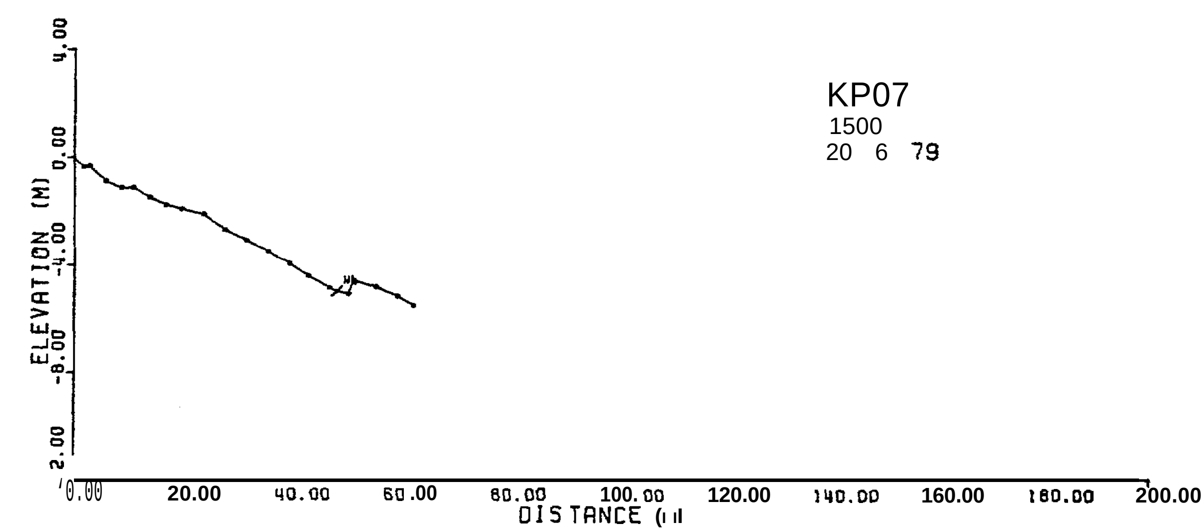
Computer plots of the 28 survey stations that were profiled for this report are given here. Profiles are at a 1:5 vertical exaggeration.

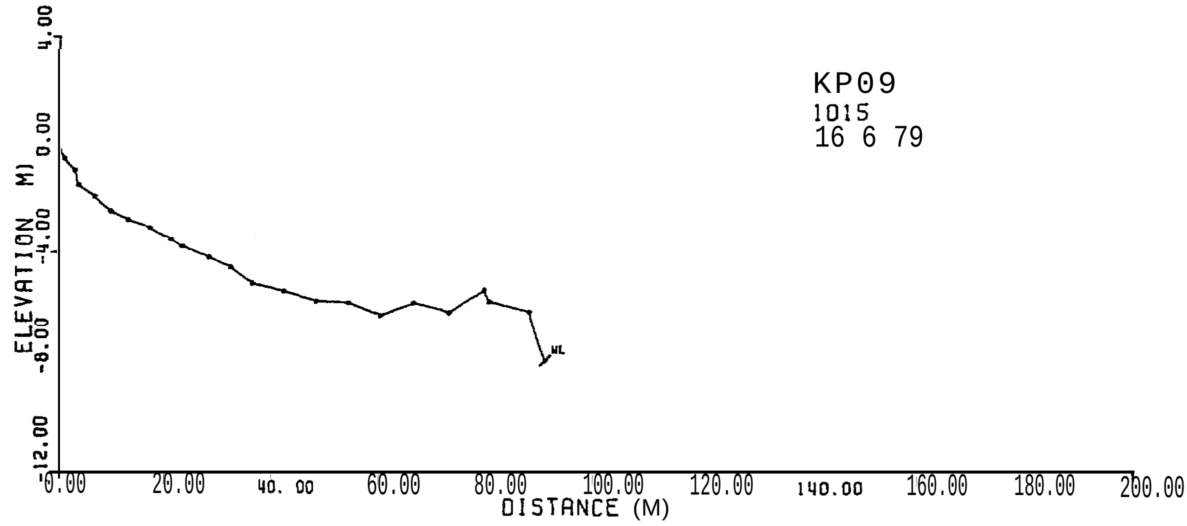
BEACH PROFILES

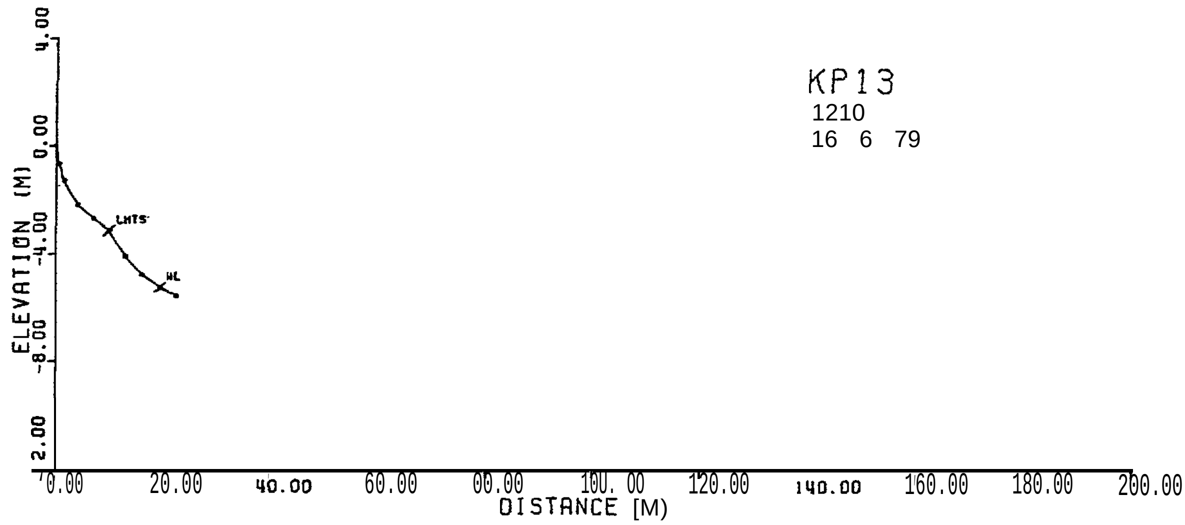
KENAI PENINSULA - MONTAGUE ISLAND

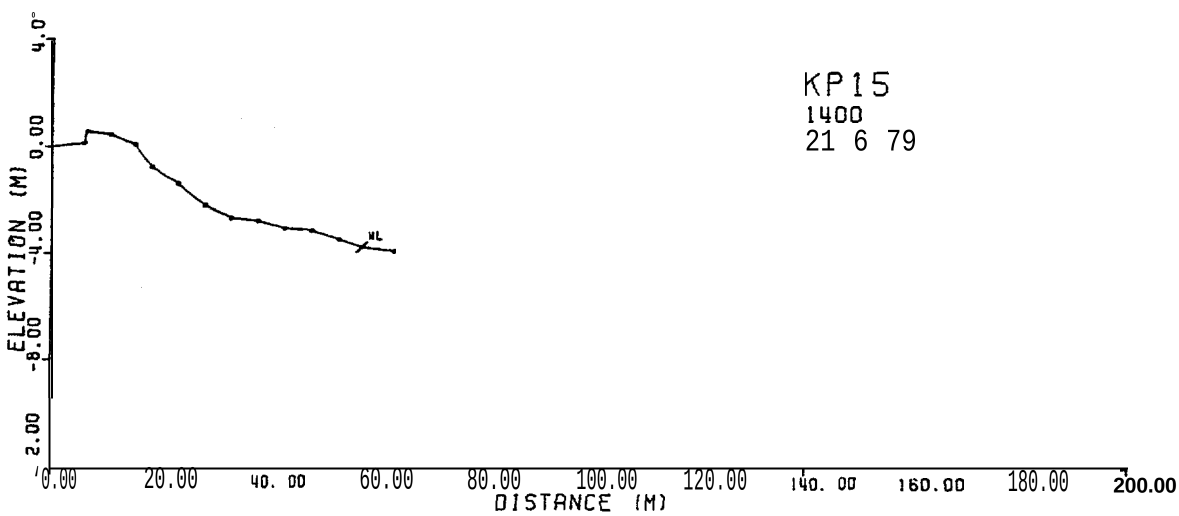
1979

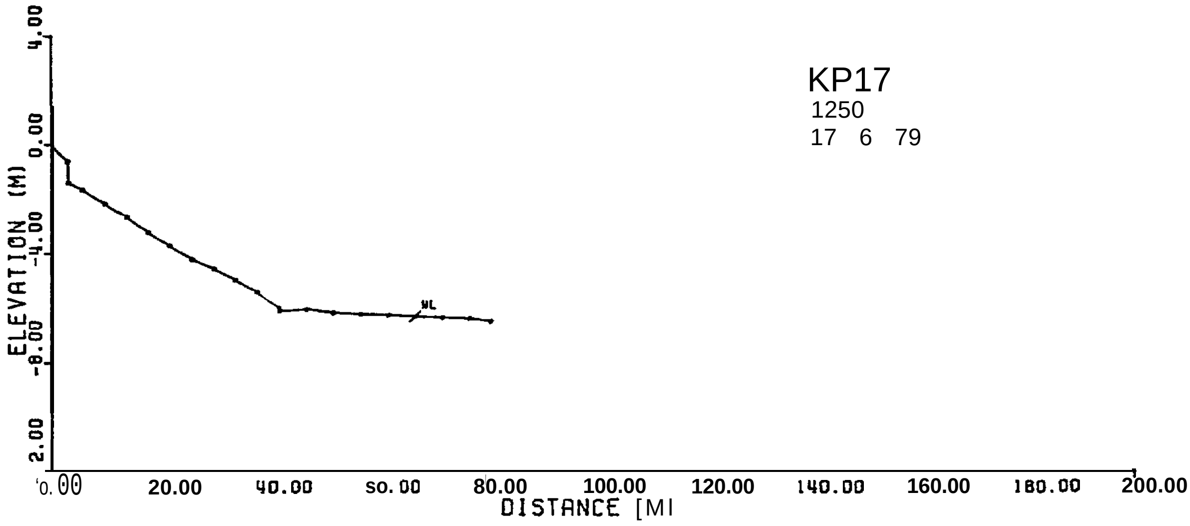


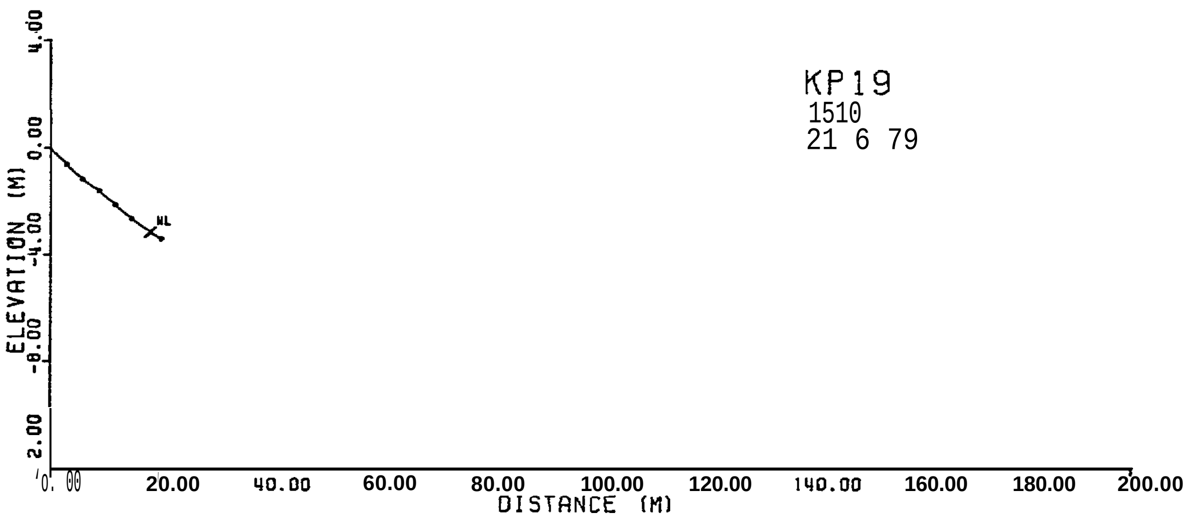


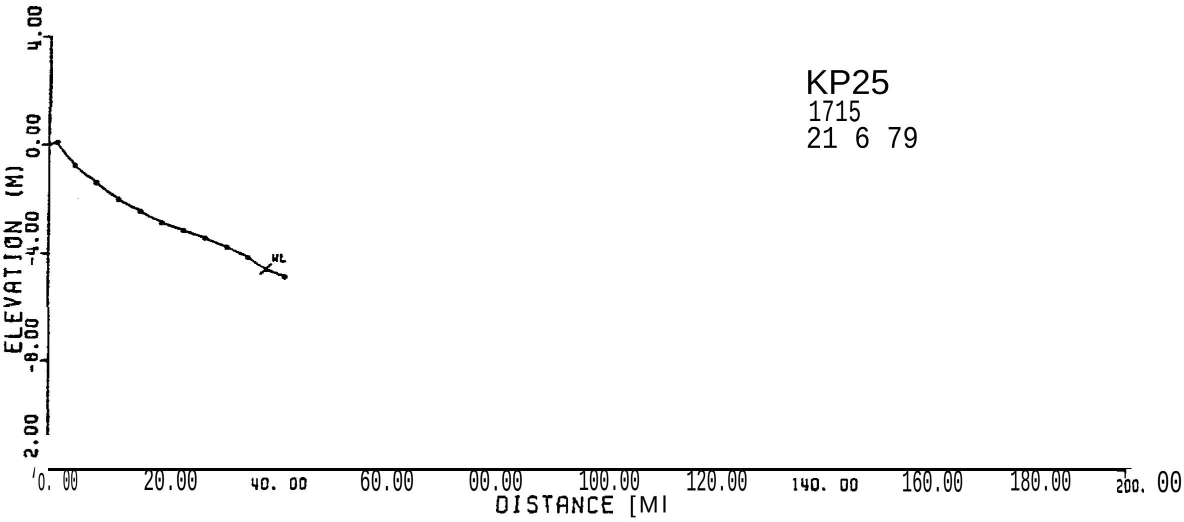

KP09
1015
16 6 79
ELEVATION (M)
DISTANCE (M)
WL

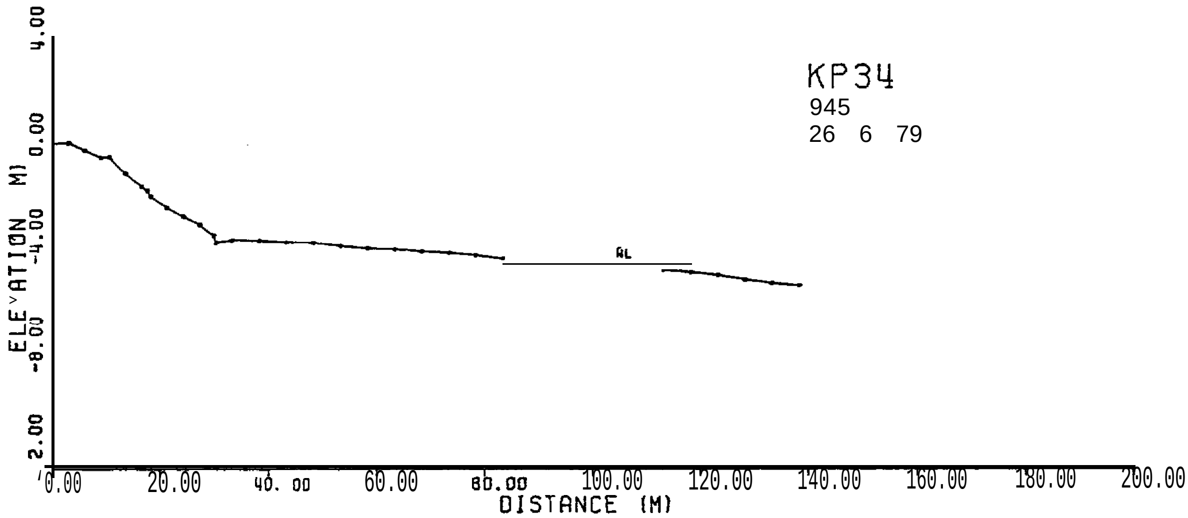

KP13
1210
16 6 79
ELEVATION (M)
DISTANCE (M)
LHTS
WL

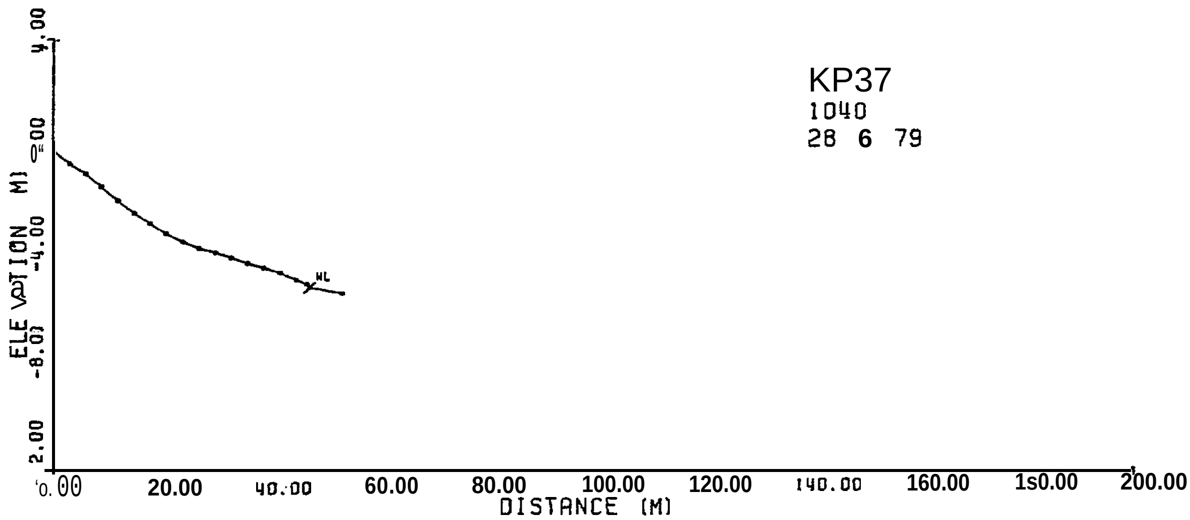

KP15
1400
21 6 79
ELEVATION (M)
DISTANCE (M)
WL


KP17
1250
17 6 79
ELEVATION (M)
DISTANCE [MI
WL


KP19
1510
21 6 79
ELEVATION (M)
DISTANCE (M)
WL


KP25
1715
21 6 79
ELEVATION (M)
DISTANCE [MI
WL


KP34
945
26 6 79
ELEVATION (M)
4.00
0.00
-4.00
-8.00
2.00
WL
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
DISTANCE (M)


KP37
1040
28 6 79
ELEVATION (M)
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0.00
-4.00
-8.00
2.00
WL
0.00
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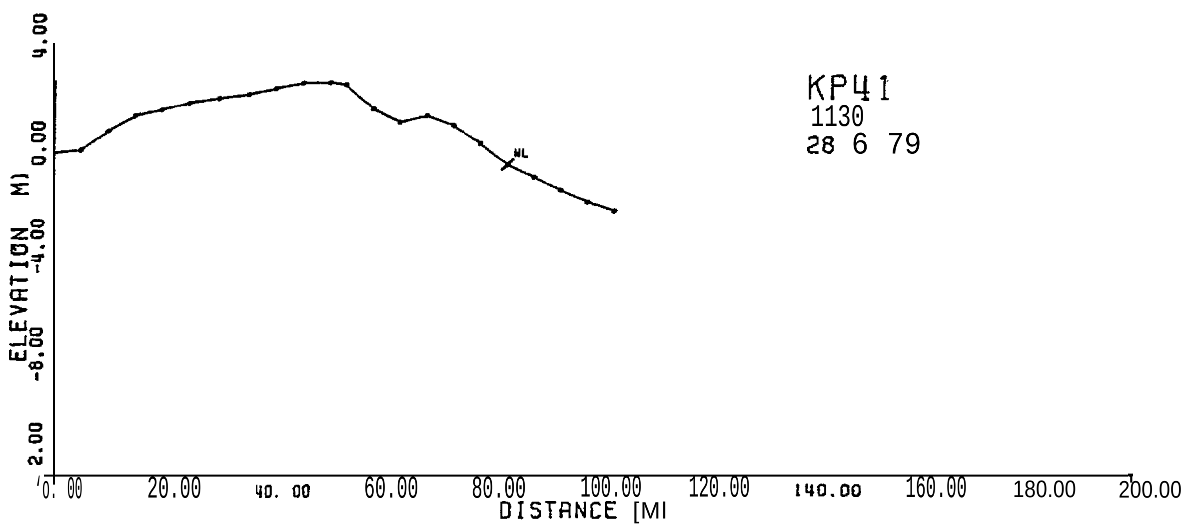
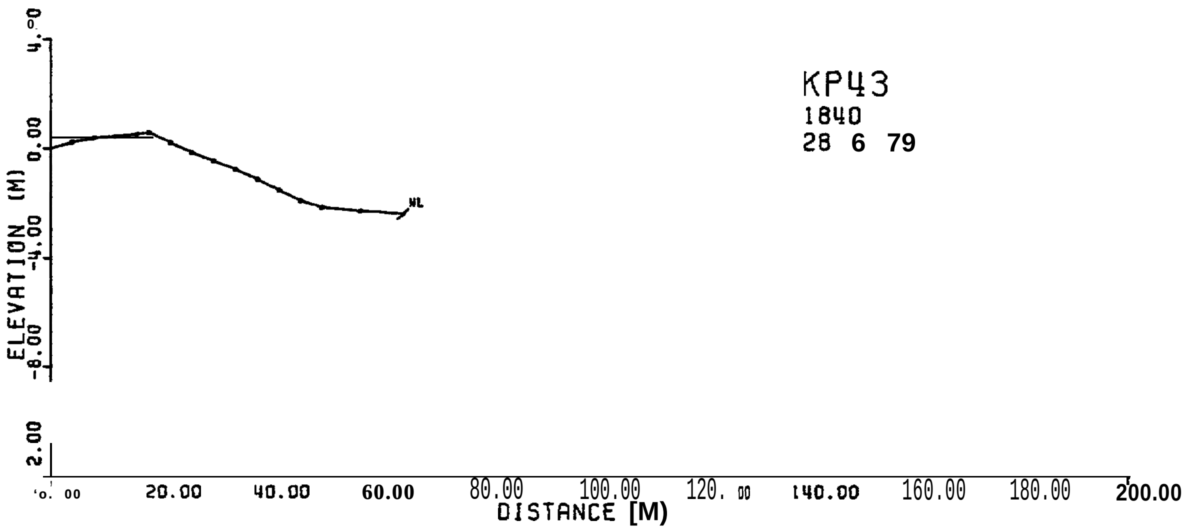
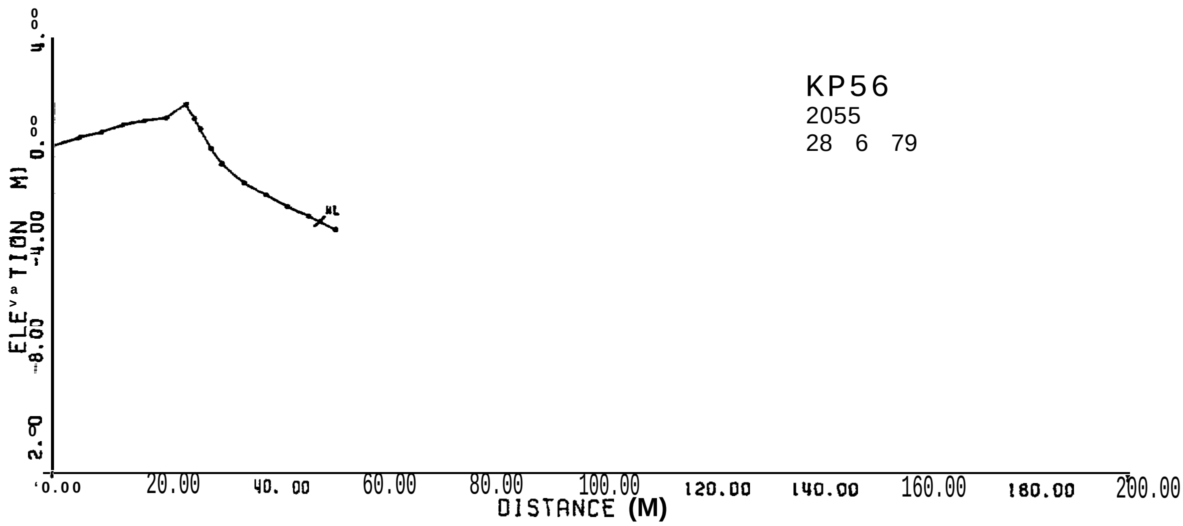
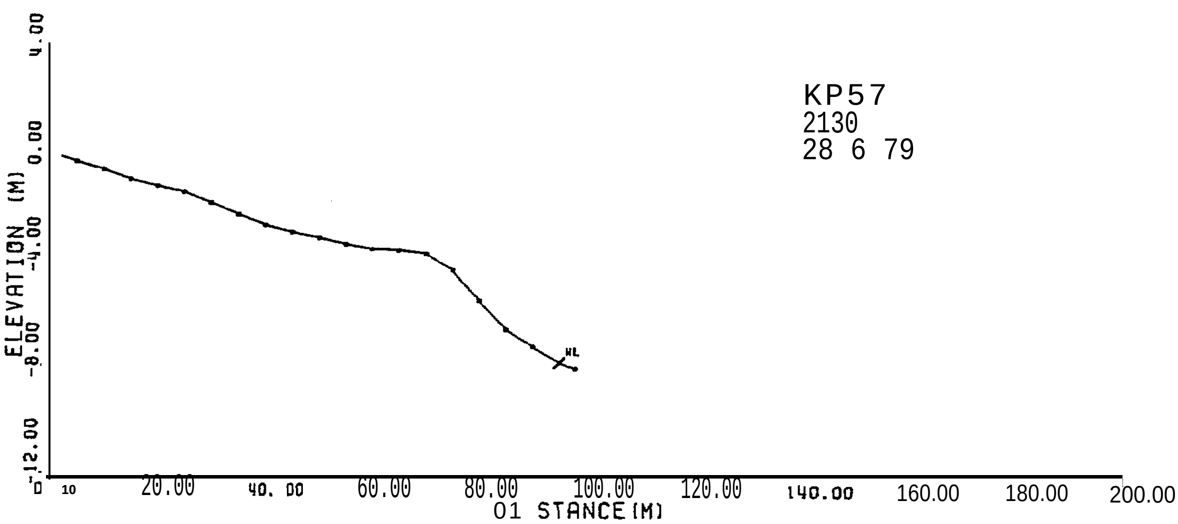
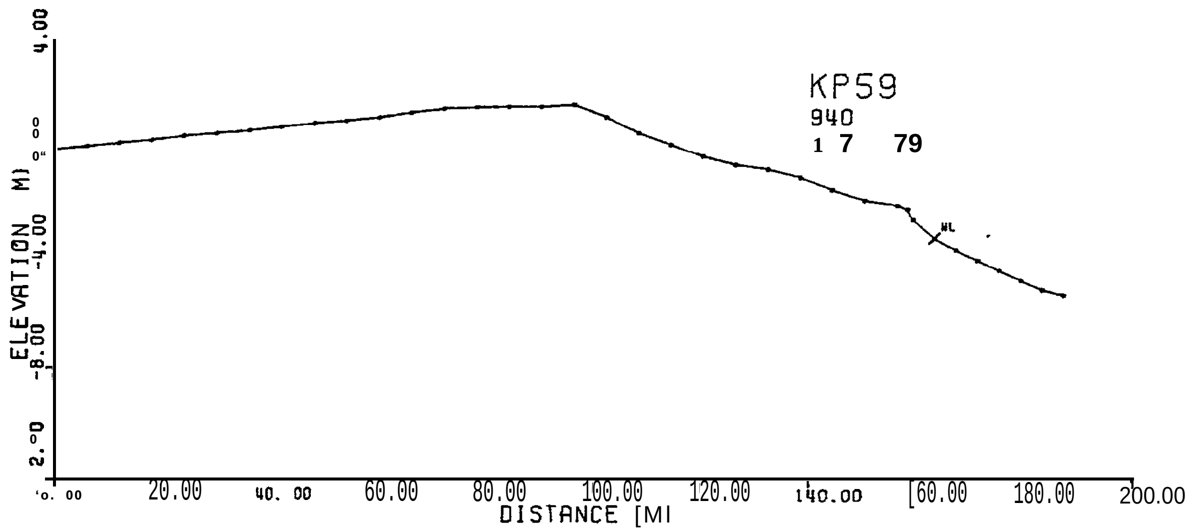
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
DISTANCE (M)

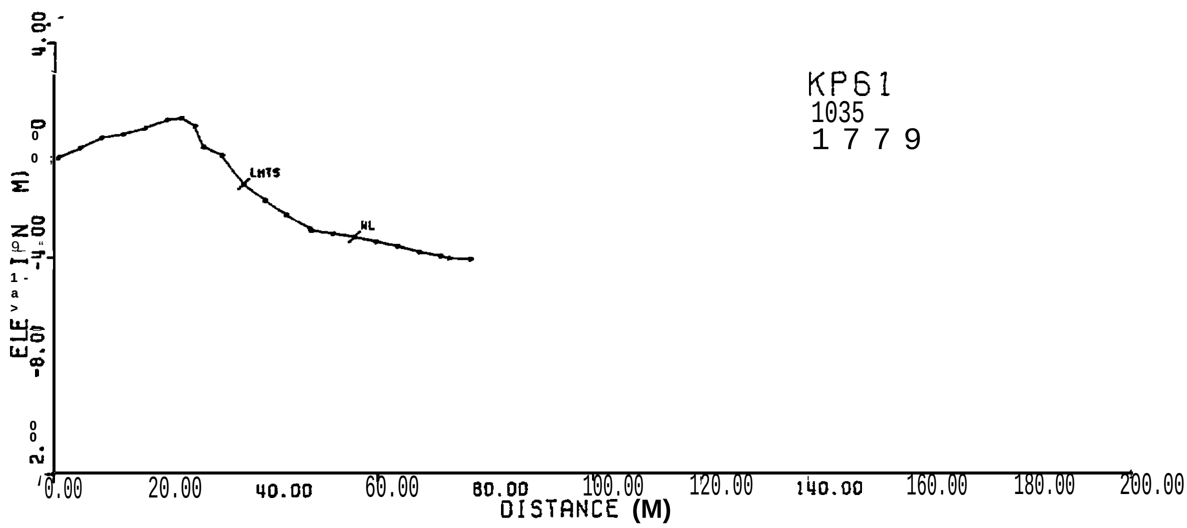

KP41
1130
28 6 79
ELEVATION (M)
4.00
0.00
-4.00
-8.00
2.00
WL
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
DISTANCE (M)

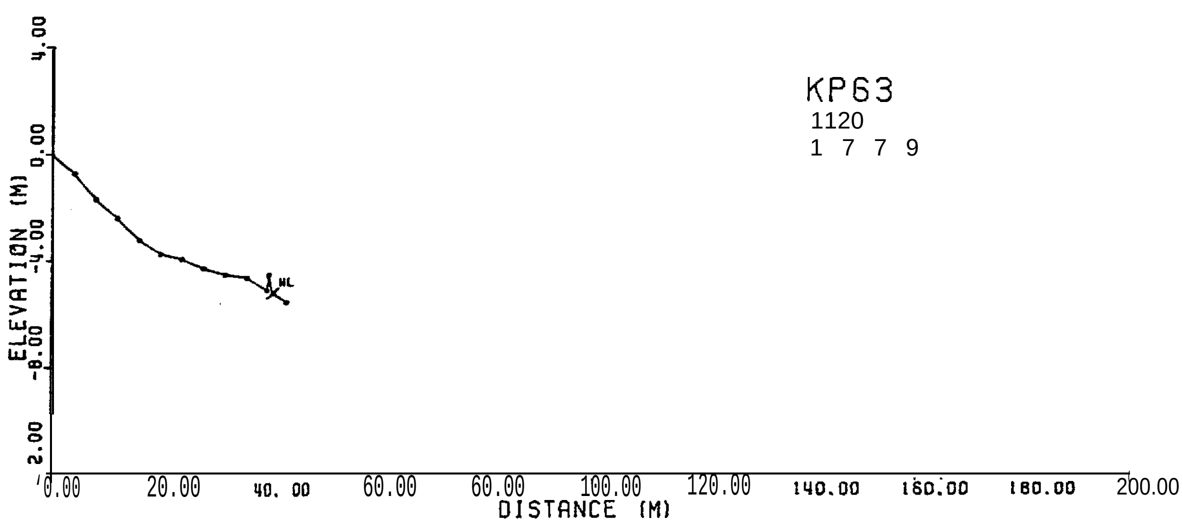

KP43
1840
28 6 79
ELEVATION (M)
DISTANCE [M]
WL

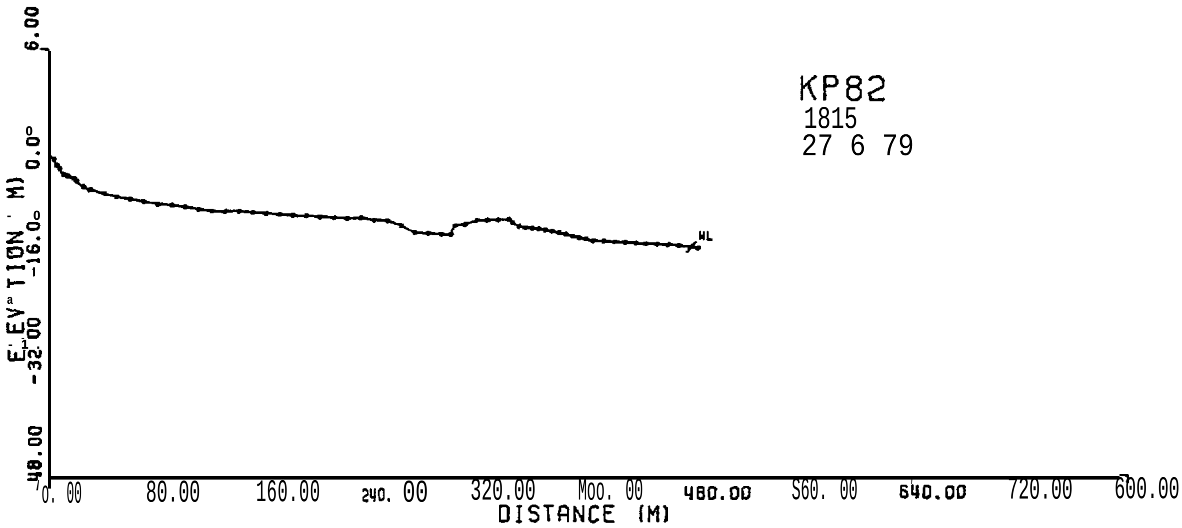

KP56
2055
28 6 79
DISTANCE (M)
WL

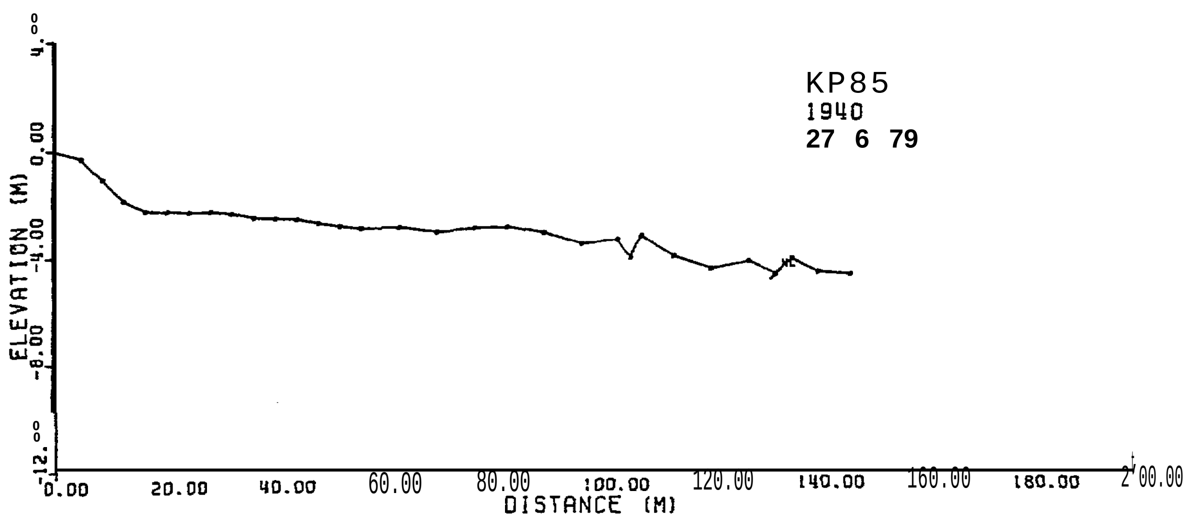

KP57
2130
28 6 79
ELEVATION (M)
WL

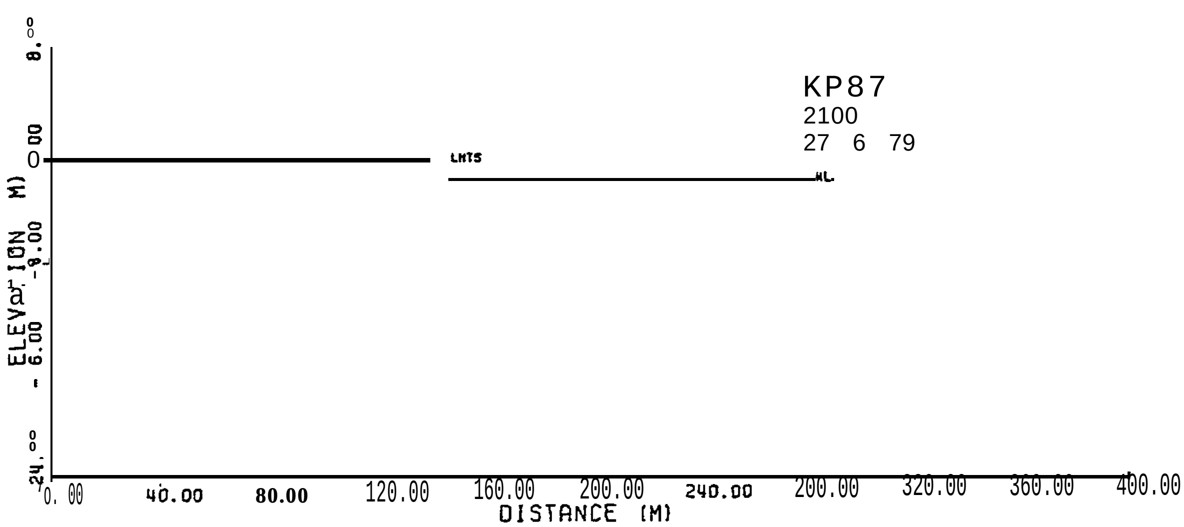

KP59
940
1 7 79
WL
ELEVATION (M)
DISTANCE (M)

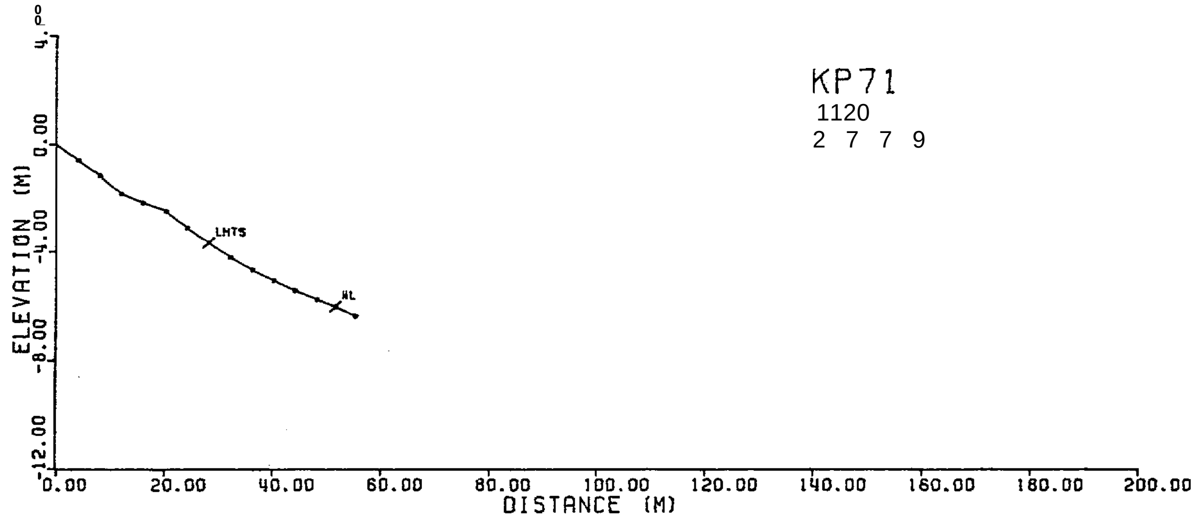

KP61
1035
1 7 7 9
LHTS
WL
ELEVATION (M)
DISTANCE (M)

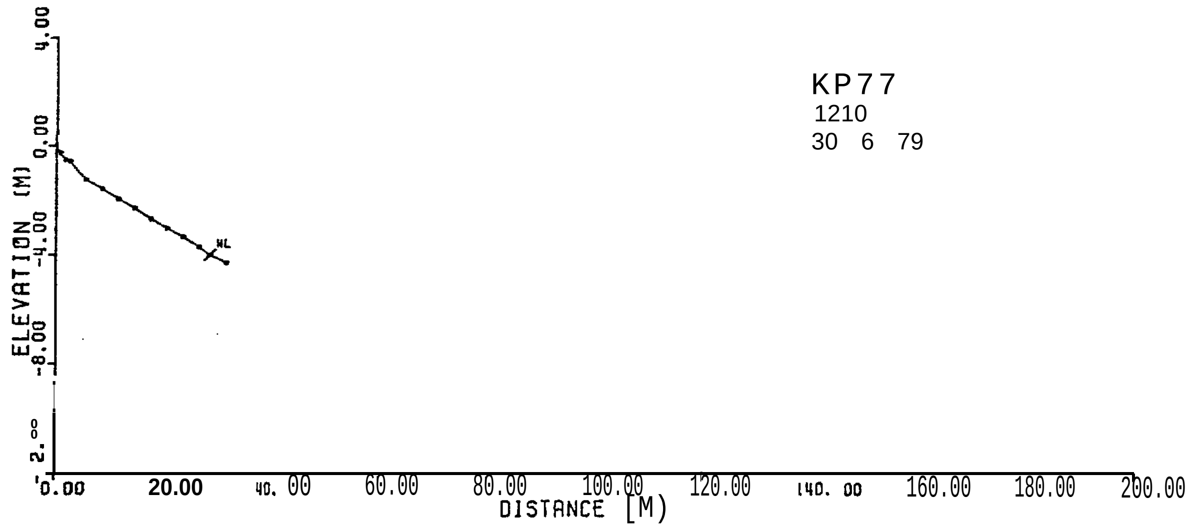

KP63
1120
1 7 7 9
WL
ELEVATION (M)
DISTANCE (M)

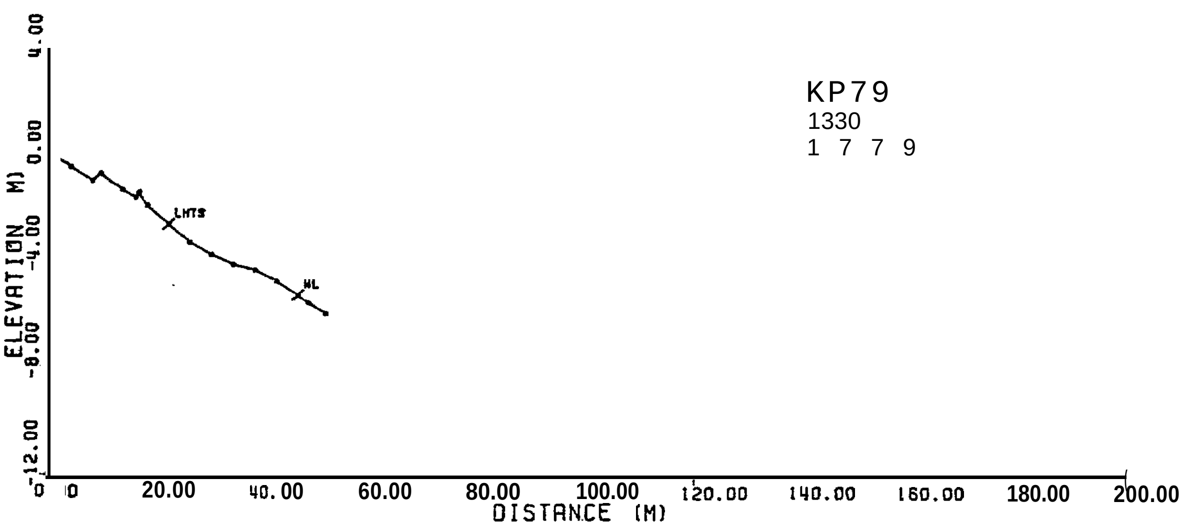

KP82
1815
27 6 79
ELEVATION (M)
DISTANCE (M)
WL

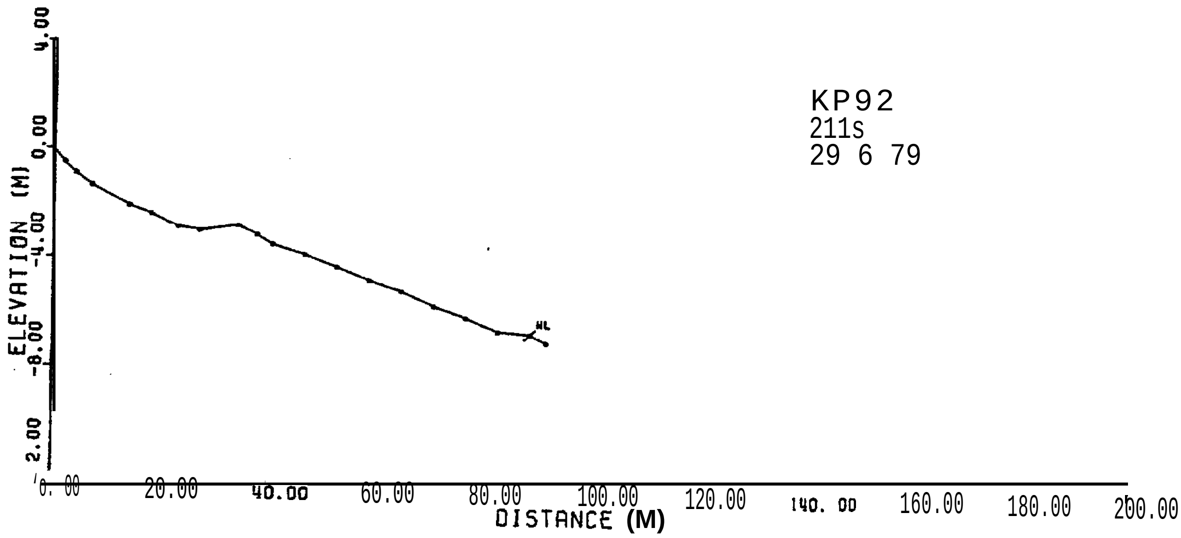

KP85
1940
27 6 79
ELEVATION (M)
DISTANCE (M)
WL

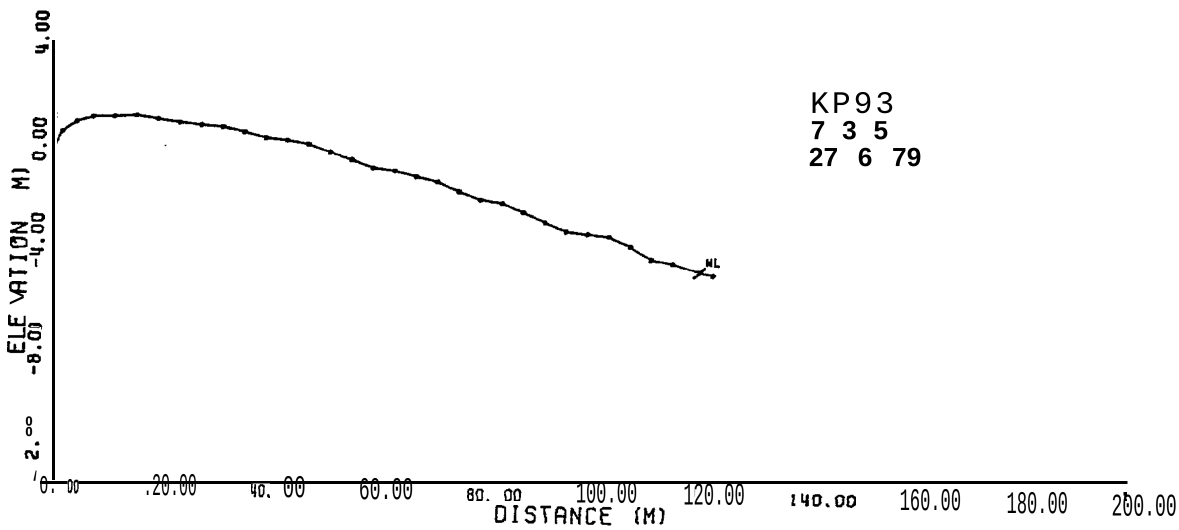

KP87
2100
27 6 79
LWTS
WL
DISTANCE (M)

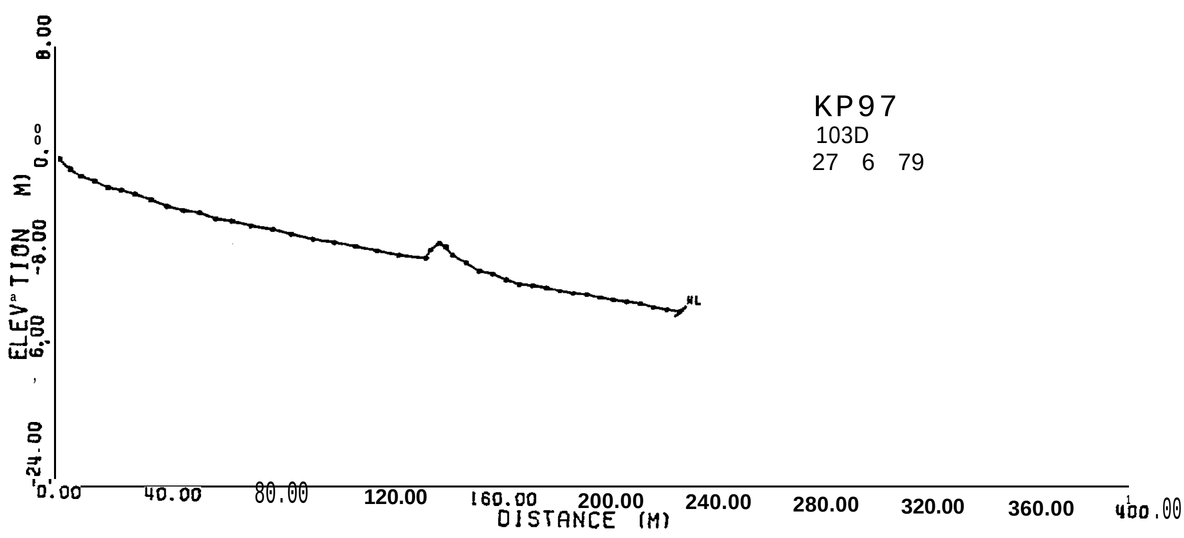

KP71
1120
2 7 7 9
ELEVATION (M)
4.00
0.00
-4.00
-8.00
-12.00
LHTS
WL
0.00 20.00 40.00 60.00 80.00 100.00 120.00 140.00 160.00 180.00 200.00
DISTANCE (M)


KP77
1210
30 6 79
ELEVATION (M)
4.00
0.00
-4.00
-8.00
WL
0.00 20.00 40.00 60.00 80.00 100.00 120.00 140.00 160.00 180.00 200.00
DISTANCE (M)


KP79
1330
1 7 7 9
ELEVATION (M)
4.00
0.00
-4.00
-8.00
-12.00
LHTS
WL
20.00 40.00 60.00 80.00 100.00 120.00 140.00 160.00 180.00 200.00
DISTANCE (M)


KP92
211S
29 6 79
ELEVATION (M)
DISTANCE (M)
WL


KP93
7 3 5
27 6 79
ELEVATION (M)
DISTANCE (M)
WL


KP97
103D
27 6 79
DISTANCE (M)
WL

APPENDIX IV.

GRAIN SIZE STATISTICS

The results are shown of both sieve and settling tube grain size analysis and later computer synthesis for all sediment data collected. Samples were taken along profile lines with the same designation shown in Appendix III. Samples A, B and C were spaced 1/4, 1/2 and 3/4 the length of the profile lines, respectively. This corresponds to the upper, mid and lower beachface.

Station No.		Mean Grain Size (ϕ)	Standard Deviation (ϕ)	Skewness	Kurtosis
KNP-1	B	-1.67	1.55	0.40	0.97
KNP-5	A	-4.32	0.74	0.43	0.98
	B	-4.38	0.43	-.41	0.88
	C	-4.13	0.79	0.34	1.11
KNP-7	A	-3.27	1.45	0.34	0.98
	B	-3.40	1.05	-0.26	0.72
	c	-3.20	1.20	-0.13	0.88
KNP-9	A	-0.56	1.73	-0.72	0.98
	B	-1.14	0.52	0.10	0.99
	c	-2.26	1.03	-0.09	0.68
KNP-11	B	0.46	2.52	-0.63	0.81
KNP-15	B	-4.00	1.03	0.47	1.17
KNP-17	A	1.37	0.35	-0.01	1.01
	B	-1.15	2.48	-0.67	0.52
	c	-1.06	2.43	-0.75	0.56
KNP-19	B	-3.08	0.81	0.14	1.39
KNP-25	A	-0.20	0.36	-0.04	1.04
KNP-34	A	-3.03	1.48	-0.24	1.32
	B	-2.61	2.06	0.31	1.17
KNP-36	A	-2.05	1.45	-0.12	0.73
	B	0.16	0.48	-0.03	1.00
KNP-37	B	-2.34	0.78	0.10	1.25
	C	-0.65	0.39	0.02	0.96
KNP-41	A	-2.78	1.93	0.43	0.53
	B	-1.41	2.65	-0.79	2.38
	C	0.23	1.36	-0.56	3.52
KNP-43	A	-0.51	1.01	-0.53	4,66
	B	-0.82	2.38	-0.81	3.07
	c	-0.66	2.14	-0.79	1.64
KNP-59	B	-2.12	-1.56	-0.37	0.61
	c	-3.20	1.97	0.64	0.54
KNP-71	A	-1.61	1.66	-0.61	0.67
	B	-1.96	2.05	-0.71	1.07
	C	-2.33	1.66	-0.24	0.59

Station No.		Mean Grain Size (ϕ)	Standard Deviation (ϕ)	Skewness	Kurtosis
KNP-75	A	-2.41	2.16	0.23	0.55
	B	-1.87	1.26	0.06	0.87
	C	-5.13	1.03	0.88	0.90
KNP-82	A	1.79	0.33	-0.11	1.15
	B	1.25	0.24	-0.45	1.12
	C	1.37	0.32	-0.02	0.90
KNP-87	A	2.15	0.18	0.05	1.22
	B	2.13	0.13	0.06	1.31
	C	1.86	0.17	-0.04	1.26
KNP-95	A	-3.53	0.42	0.14	1.52
	B	-2.06	2.64	0.42	0.46
	C	-4.62	0.69	0.77	0.72
KNP-97	A	-4.36	0.50	0.48	1.76
KNP-99	A	2.44	0.19	0.03	1.12
	C	-2".71	2.31	0.49	0.76
KNP-100	A	-3.57	0.49	-0.14	1.75
	C	-0.37	0.90	-0.36	2.98