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Outer Continental Shelf Environmental Assessment Program

Final Reports of Principal Investigators

Volume 62 **July 1989**

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Oceanography and Marine Assessment
Ocean Assessments Division
Alaska Office

U.S. DEPARTMENT OF THE INTERIOR
Minerals Management Service
Alaska OCS Region
OCS Study, MMS 89-0063

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Anchorage, Alaska

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Outer Continental Shelf Environmental Assessment Program
Final Reports of Principal Investigators

VOLUME 62 JULY 1989

CONTENTS

NATURAL OIL SEEPS IN THE ALASKAN MARINE ENVIRONMENT

by

Paul R. Becker and Carol-Ann Manen

National Oceanic and Atmospheric Administration
National Ocean Service
Office of Oceanography and Marine Assessment
Alaska Office, Ocean Assessments Division
Anchorage, Alaska 99513

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 703

May 1988

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PREFACE

Given our limited understanding of how marine ecosystems function and the causes of their variability, the question of whether chronic low-level petroleum contamination poses a serious threat to life in the sea is particularly difficult to answer. The potential value of using natural petroleum seeps as "laboratories" to investigate some of the questions concerning impacts of chronic petroleum input to coastal areas has been recognized by the National Research Council (1985), based on the results of natural seep studies conducted in southern California.

Anticipating that petroleum seeps might provide future opportunities to address such questions in the Alaskan marine environment, the Outer Continental Shelf Environmental Assessment Program (OCSEAP) reviewed the literature on Alaskan petroleum seeps. The objective of this review was to synthesize all available information on: (1) the marine and coastal oil seeps in Alaska, with emphasis on the arctic, and (2) the effects of chronic oil pollution on arctic marine biotic communities and ecological processes.

The result of this review is the following report which hopefully provides a basis for the development of future studies involving Alaskan marine and coastal oil seeps.

Paul R. Becker

Carol-Ann Manen

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

A petroleum seep is defined as visible evidence at the earth's surface of the present or past leakage of oil, gas, or bitumens from the subsurface (Hunt, 1979). With the increase in the sophistication of instrumentation in subsurface exploration, the importance of surface seeps in oil and gas exploration has been de-emphasized. However, historically surface seeps have been very important in exploration. Hunt (1979) states that, "..many, if not most, of the important oil-producing regions of the world were detected or discovered through surface oil and gas seeps." This is certainly the case in Alaska, where the oil producing potentials of Katalla, Cook Inlet, and the North Slope were first proposed based on the presence of oil seeps.

Oil seeps have been reported from earliest recorded history, dating back to 3,000 BC in the Middle East (Owen, 1975). These reports have not been limited to terrestrial seeps. The oil and gas seeps present in the Dead Sea were responsible for the name the Romans gave to this body of water, "Mare Asphalticum" (Landes, 1973), which can be translated as "Sea of Pitch". Figure 1 in Landes (1973) is a photograph of a block of asphaltic material grounded on the west shore of the Dead Sea. This piece of weathered material originating as seepage has an estimated weight of 20 tons. Offshore seeps were discovered in the mid- to late 19th century during oil and gas explorations in the Red Sea, along the coast of New Zealand, and in the Caspian Sea (Owen, 1975).

Oil seeps in North America were reported as early as the late 18th Century. The best known offshore seeps in North America occur in the Santa Barbara Channel off California. These seeps and the associated tar on the beaches were first reported by the Spanish Franciscan priests in 1776, and additional description of surface oil in the Channel was provided by Vancouver in 1792 (Yerkes et al., 1969 as cited in Landes, 1973).

Hunt (1979) classifies seeps into three categories:

1. Active seeps, composed of gas, light oil, heavy oil, or mounds of sticky black asphalt.
2. Inactive seeps, generally asphaltites or pyrobitumens not connected to any liquid material.
3. False seeps, which appear to be hydrocarbon accumulations, but are actually stains of organic or inorganic origin. For example, accumulations

of manganese dioxide, metallic sulfides, or metallic oxides may be mistaken for oil seeps.

The substance most frequently mistaken in Alaska for oil seepage is the iron oxide film found on the surface of pools or sluggish streams in swampy areas or tidal flats, or found in association with iron-rich springs (Miller et al., 1955). Oil films and gas derived from decaying vegetation and oily distillation products of burned coal beds can also be mistaken for petroleum (Martin, 1922).

Documenting and describing land seeps were important in oil and gas exploration during the early years of the petroleum industry. This has resulted in fairly extensive characterization of many of these seeps. Data and information on land seeps is important in documenting and describing marine seepage. Natural seeps from both areas can be expected to behave in a similar manner and to be functions of the same geologic and geochemical parameters (Wilson, et al., 1973).

Wilson et al. (1973, 1974) have used information derived from land seeps plus the limited information on marine seeps to derive geologic criteria for evaluating the seepage potential of offshore areas and to derive an estimate of the amount of petroleum entering the marine environment via natural seepage. Their estimate was 0.6×10^6 metric tons per year, with a range estimate of 0.2 to 6.0×10^6 metric tons per year. Although it has been argued that this range could vary by at least an order of magnitude both below and above these limits, the estimates made by Wilson et al. (1973, 1974) still remain the best available (National Research Council, 1985).

The relative importance of natural seeps to the input of petroleum into the marine environment has been discussed in numerous reports including Blumer (1971), Landes (1973), Wilson, et al. (1973, 1974), National Academy of Sciences (1975), National Research Council (1985). The most recent estimates indicate that natural seepage represents less than 10 percent of the input into the world's oceans. The estimate of the National Academy of Sciences (1975), based on the work of Wilson, et al. (1973), was 9.8 percent. The revised estimate of the National Research Council (1985) is $0.02 - 2.0 \times 10^6$ metric tons per year, with a best estimate of 0.2×10^6 metric tons. This is based on an order of magnitude change in the upper and lower values of the range presented by Wilson, et al. (1973) and results in a value which is 6.25 percent of the total input of petroleum into the marine environment.

Offshore and onshore seepage frequency data are strongly correlated with areas of current tectonic activity and structuring (Wilson et al. (1973). Margins of basins and sediments that have been folded, faulted, and eroded are areas that are conducive for seepage. Link (1952) categorized seeps into five types based on their origins:

1. Seeps arising from the ends of homoclinal beds exposed at the earth's surface (Figure 1.a). This type is usually small in volume, but persistently active.

2. Seeps associated with the beds and formations in which the oil was formed (Figure 1.b). An example would be asphaltic oil generated by shales feeding into fissures and into sand interbedded with shales (Green River Formation of Utah).

3. Seeps from large petroleum accumulations that have been uncovered by erosion or the reservoirs ruptured by faulting and folding (Figure 1.c). Seepages originating from the erosion of reservoirs on anticlines are quite common and indicate good prospects for finding oil in nearby anticlines where the same formations have not been eroded. The seeps on the Alaskan North Slope and along the shoreline of the Gulf of Alaska appear to be of this type.

4. Seeps at the outcrops of unconformities (Figure 1.d). An example is the Athabasca oil sands which represents the largest known seep of this type (Hunt, 1979).

5. Seeps associated with intrusions such as mud volcanoes, igneous intrusions, and piercement salt domes (Figure 1.e). Seeps of this type are quite common in Mexico and on the U.S. Gulf Coast.

Petroleum leaking to the earth's surface undergoes a series of weathering processes, regardless of whether it issues from a terrestrial or a submarine seep. There is a loss of volatile and light hydrocarbons up through C_{15} in the earlier stages and continued loss of hydrocarbons up through C_{24} after several months (Hunt, 1970). Water soluble elements and compounds, such as nitrogen, sulfur, and low molecular weight aromatics are leached out in the groundwater. Microbial degradation begins in the groundwater, leading to the oxidation of n-alkanes, isoalkanes and napthalenes. As water, carbon dioxide or hydrogen are eliminated from the seepage, polymerization of intermediate molecules occurs. Sediments are incorporated in submarine seepages. In the presence of sunlight and oxygen, polymers are oxidized and a rigid surface forms on the oil. These processes result in the formation of asphaltic mounds in both submarine and terrestrial seepages.

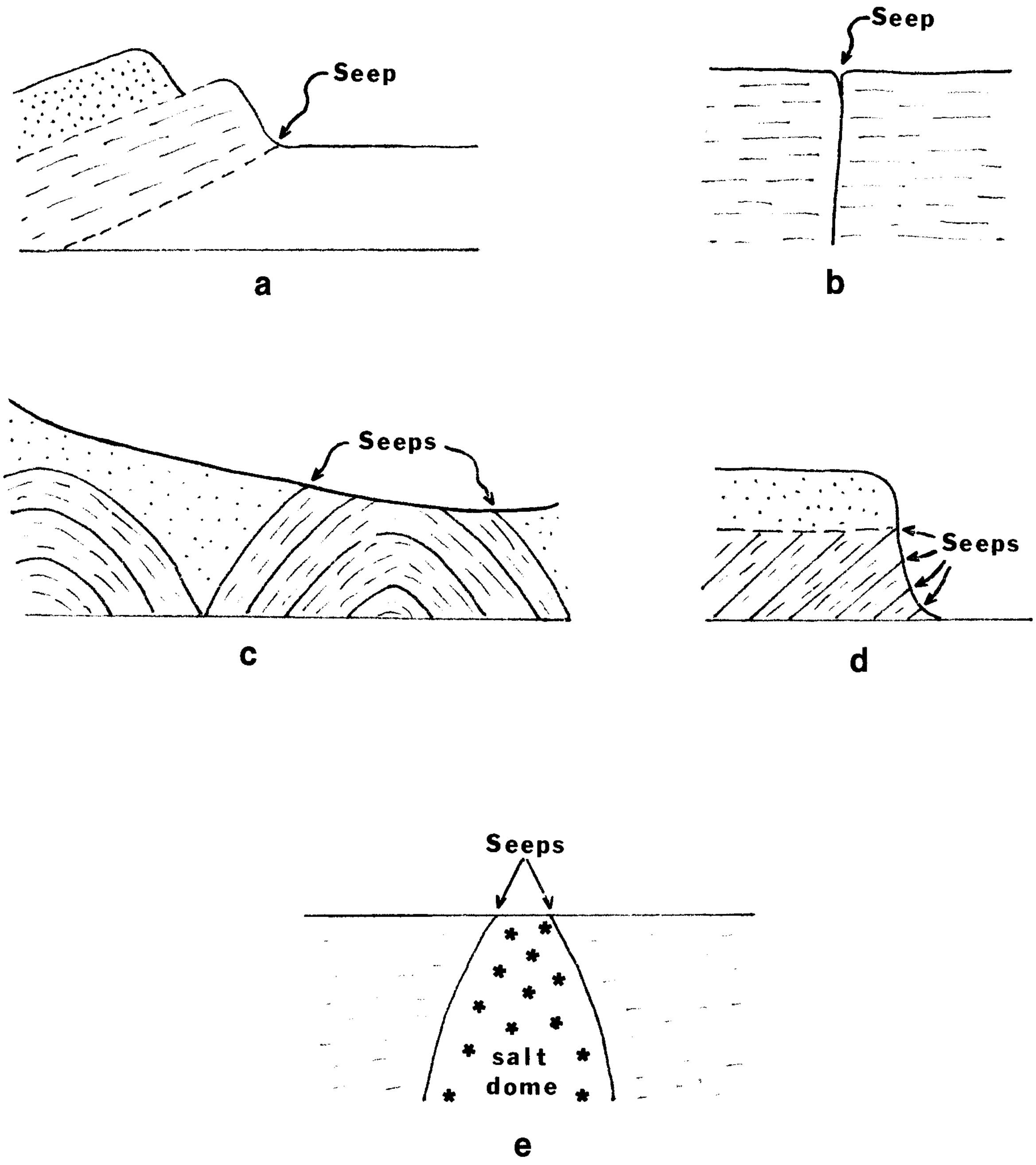

Figure 1. Types of Oil Seeps. Based on the classification of Link (1952).

Enlargement of these mounds depends on a continual supply of fresh oil being released to the surface of the seep.

Although many of the world's oil seeps have histories that go back several centuries, many seeps are intermittent and the volume of released oil may vary over time. Seepage can increase, decrease, or stop entirely in response to seismic activity (Rosenburg, 1974). The tapping of the oil source by industrial drilling and production can decrease or stop seep activity. Both industrial and seismic activity may play major roles in the pattern of oil and gas seepage in Alaska.

Wilson et al. (1973, 1974) classified the continental margins of the world into potentially high, medium, and low seepages assuming the following:

1. More seeps exist in offshore basins than have been observed.

2. Factors that determine the total seepage in an area are related to the general geologic structural type of the area and to the stage of sedimentary basin evolution.

3. Within each structural type, seepage depends primarily on the area of exposed rock and not rock volume. This assumption presumes that there is sufficient sediment volume and organic matter for maturation and generation of petroleum.

4. Most marine seeps are clustered within the continental margins where the thickness of sediments exceeds a certain minimum.

5. Seepage rates are lognormally distributed (based on the distribution of known oil field volumes). There are many seeps with low flow rates but only a few with high individual rates; however, the latter probably provide much of the total seepage. The National Research Council (1985) point out that seepage rates might be exponentially distributed, since they probably reflect volumes of all oil accumulations and not just oil field volumes, which are lognormal in distribution.

Using tectonic history, earthquake activity and sediment thickness in their analysis, Wilson et al. (1973, 1974) identified continental areas of high, medium, and low seepage potential based on the following geological criteria:

1. High potential for seepage is characterized by strike-slip faulting associated with high

incidence of earthquakes, tight compressive folding associated with high incidence of earthquakes, igneous activity, and thick geochemically mature Tertiary sediments.

2. Moderate potential for seepage is characterized by strike-slip faulting associated with low incidence of earthquakes, trench associated margins with high incidence of deep earthquakes, early active phase of pull-apart margins, growth faulting associated with giant, river-fed submarine fans, and diapiric or intrusive structures (shale, salt, or igneous rocks).

3. Low potential for seepage is characterized by pull-apart margins, little indication of recent structuring, little or no earthquake activity, and older sediments or geochemically immature young sediments.

The continental margin of greatest petroleum seepage appears to be the circum-Pacific. Wilson, et al. (1973, 1974) estimated that 40 percent of the world's total seepage input to the marine environment originated from this area. Based on the geological criteria presented above, Alaska's continental margins have been classified by Wilson, et al. (1973, 1974) as:

1. High potential- Gulf of Alaska

2. Medium potential- Arctic, northern Bering Sea, Aleutian Chain, and Cook Inlet

3. Low potential- southern Bering Sea

Figure 2 shows the distribution of known coastal seeps in Alaska as related to the classification of Wilson et al. (1973, 1974). The high potential for the Gulf of Alaska is well reflected in the large numbers of seeps that have been identified along the coastline of the central part of this region.

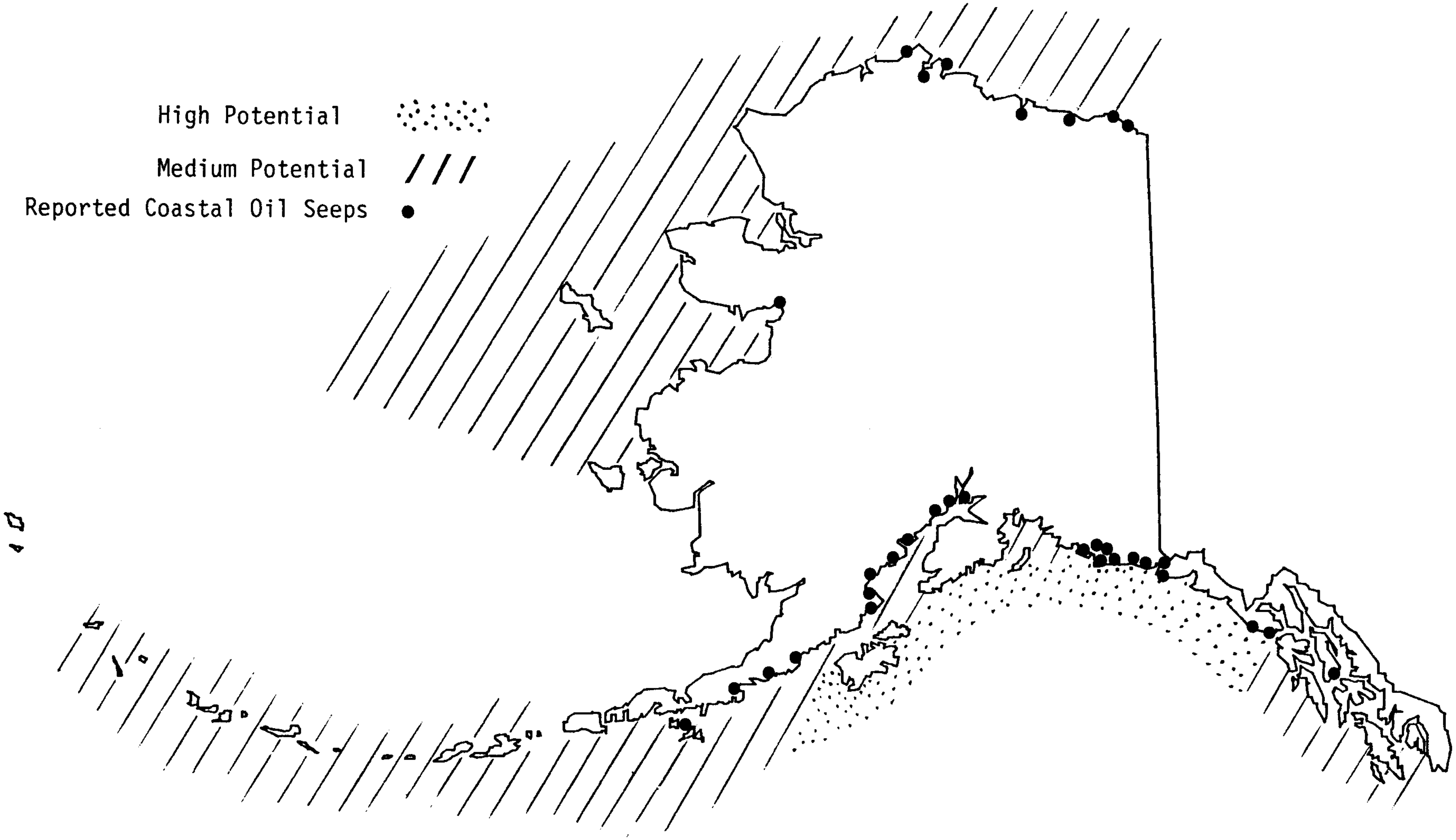

Figure 2. Seepage Potential of the Alaskan OCS. Based on Wilson et al. (1973, 1974) and reported coastal seeps presented in Table 1.

ALASKAN OIL SEEPS

Locations of Coastal Oil Seeps

Based on available information, 29 oil seepage areas have been identified to occur within the coastal regions of Alaska (Figure 3). "Oil seepage area" in this report refers to a geographic area that contains a single seep or any number of seeps that are in proximity to each other and that appear to derive their oil from the same source and through the same mechanism of seepage. Of these 29 areas, 14 are confirmed as containing actual oil seeps and 15 are unconfirmed reports; all of the latter are located in the Gulf of Alaska. None of the confirmed seeps are subtidal, but range in distribution from just above the low tide datum on a beach face, to inland sites that could influence the marine environment through input via freshwater streams. Each of the 29 oil seepage areas are identified by name in Table 1. This table also includes references which either identify the locations of such sites or provide site descriptions, characterizations of oils, etc. The numbers identifying each seepage area in Figure 3 and Table 1 are used throughout this report in reference to specific seeps.

History of Petroleum Seep Studies in Alaska

Since documenting and describing petroleum seeps have been historically important in oil and gas exploration, the study of seeps in Alaska began at the turn of this century primarily through the efforts of the U.S. Geological Survey and the U.S. Bureau of Mines. USGS exploration was started in northern Alaska in 1901 as part of a systematic scientific exploration of the Territory (Miller et al. 1959). The U.S. Bureau of Mines has been involved in petroleum source evaluation in Alaska since the early 1920's (Blasko, 1975). The emphasis of these agency efforts was to map the geological structures in areas containing indications of the presence of petroleum (seeps and outcrops of oil shale). Using this geological information, plus physical and chemical characteristics of the petroleum traces, suitable areas for test drilling were identified.

Most of the early discoveries of both coastal and inland oil seeps in Alaska were based on information provided to explorers by local natives. Probably many of these sites had been known for centuries by the local inhabitants, and in some cases native names for geographical locations incorporate characteristics resulting from these seeps. For example, the Inuit name for Griffin Point (Ugsrugtalik) may be translated as, "the place where there is oil on top of the ground" (Jacobson and Wentworth, 1982) and Ungoon

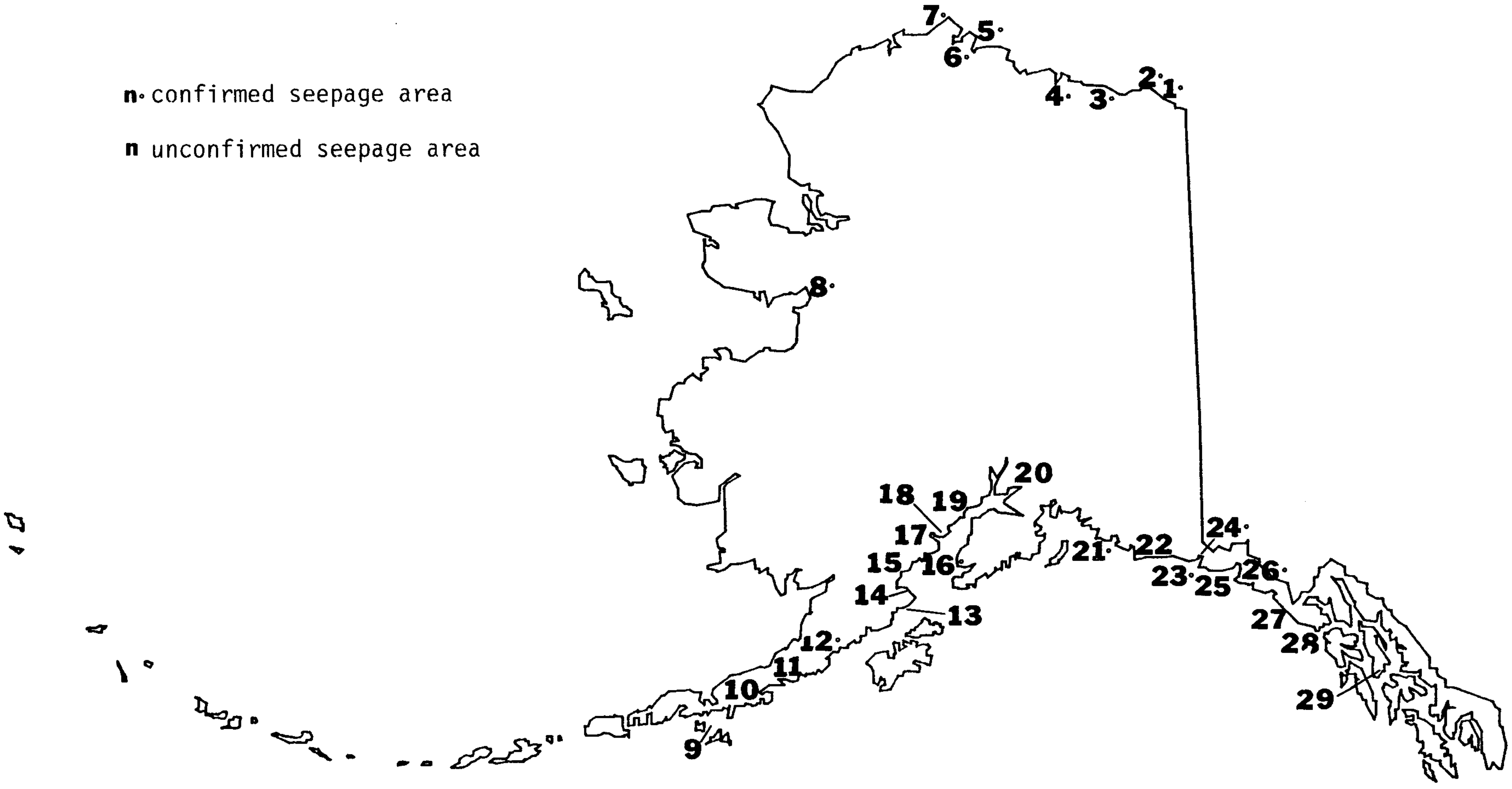

Figure 3. Locations of Alaskan Coastal Oil Seepage Areas

Table 1. Alaskan Coastal Oil Seepages

Site No. & Name	References
1. Angun (Ungoon) Point	Leffingwell (1919) Page, et al. (1925) Bureau of Mines (1944) Miller, et al. (1959) Hanna (1963) Ball Associates (1965) Grantz, et al. (1976) Grantz, et al. (1980) Magoon & Claypool (1981) Alaska Clean Seas (1983) Bader (1984) Anders and Magoon (1985)
2. Manning Point, Barter Island	Bureau of Mines (1944) Miller, et al. (1959) Hanna (1963) Ball Associates (1965) Johnson (1971) Grantz, et al. (1976) Grantz, et al. (1980) Magoon & Claypool (1981) Alaska Clean Seas (1983) Bader (1984) Anders and Magoon (1985)
3. Mouth of Canning R.	Grantz, et al. (1976) Grantz, et al. (1980)
4. Oil Lake, Colville River	Grantz, et al. (1976) Grantz, et al. (1980)
5. Cape Simpson	Brooks (1909) Leffingwell (1919) Page, et al. (1925) Bureau of Mines (1944) Miller, et al. (1959) Hanna (1963) Ball Associates (1965) Johnson (1971) Barsdate, et al. (1972) McCown, et al. (1972) Grantz, et al. (1976) Grantz, et al. (1980) Magoon & Claypool (1981) Alaska Clean Seas (1983)

Table 1. (continued)

Site No. & Name	References
6. Dease Inlet	Bureau of Mines (1944) Miller, et al. (1959) Hanna (1963) Ball Associates (1965) Johnson (1971) Grantz, et al. (1976) Grantz, et al. (1980) Alaska Clean Seas (1983)
7. Skull Cliff, Chukchi Sea	Webber (1947) Miller, et al. (1959) Johnson (1971) Grantz, et al. (1976) Grantz, et al. (1980) Magoon & Claypool (1981)
8. Inglutalik River, Norton Sound	Johnson (1971) Miller et al. (1959)
9. Andronica Island, Alaska Peninsula (unconfirmed)	Martin (1921) Keller and Cass (1956) Johnson (1971) McGee (1972)
10. Chignik Bay (unconfirmed)	McGee (1972) Miller, et al. (1959)
11. Aniakchak Area (unconfirmed)	Martin (1921) Smith and Baker (1924) Miller, et al. (1959) McGee (1972)
12. Puale Bay (Cold Bay[1], Wide Bay, Oil Creek)	Martin (1905) Martin (1921) Capps (1922) Smith (1926) Miller, et al. (1959) Johnson (1971) McGee (1972) Blasko (1976a) Blasko (1976b) Blasko (1976d)

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[1] Early references to Puale Bay refer to it as "Cold Bay" (Martin, 1905; Martin, 1921; Capps, 1922; Smith, 1926; Miller et al., 1959).

Table 1. (continued)

Site No. & Name	References
13. Shelikof Strait (unconfirmed)	Miller, et al. (1959) McGee (1972)
14. Douglas R. (unconfirmed)	Martin (1905) Miller, et al. (1959)
15. Bruin Bay (unconfirmed)	Martin (1905) Martin (1921) Mather (1925) Miller, et al. (1959) Johnson (1971) McGee (1972)
16. Iniskin Peninsula (Oil Bay)	Martin (1905) Martin (1908) Moffit (1922) Johnson (1971) McGee (1972) Blasko (1976a) Blasko (1976d)
17. Iniskin Bay (unconfirmed)	Moffit (1922) Miller, et al. (1959)
18. Chinitna Bay (unconfirmed)	Moffit (1922) Miller, et al. (1959)
19. Tyonek and Mouth of Little Suisitna River (unconfirmed)	Martin (1921) Miller, et al. (1959) McGee (1972)
20. Anchorage near Knik Arm (no longer active?)	Brooks (1922)
21. Katalla, Controller Bay	Martin (1905) Martin (1908) Miller (1951) Miller, et al. (1959) Johnson (1971) Reimnitz (1970 as cited in Johnson, 1971) McGee (1972) Rosenberg (1974) Blasko (1976c)

Table 1. (continued)

Site No. & Name	References
22. Katalla Area East, Cape Suckling (unconfirmed)	Martin (1908) Miller, et al. (1959) McGee (1972)
23. Yakataga	Martin (1908) Miller, et al. (1959) Palmer (1971) McGee (1972) Rosenberg (1974) Blasko (1976c)
24. Samovar Hills, Malaspina Glacier	Miller, et al. (1959) Johnson (1971) Palmer (1971) McGee (1972) Rosenberg (1974) Blasko (1976c)
25. East Shore of Icy Bay (unconfirmed)	Miller, et al. (1959) McGee (1972)
26. Yakutat	Miller, et al. (1959) Ball & Associates (1965) McGee (1972) Rosenberg (1974)
27. Lituya Bay (unconfirmed)	Miller, et al. (1959) McGee (1972)
28. Cape Spencer (unconfirmed)	Martin (1921) Miller, et al. (1959) McGee (1972)
29. Admiralty Island (unconfirmed)	Martin (1921) Miller, et al. (1959) McGee (1972)

(Angun) Point has been translated to mean, "pitch" point (Bureau of Mines, 1944).

The reports of early surveyors also indicated that some of these seeps were mined for their oil soaked peat by the natives for use as fuel. The seeps on the east shore of Dease Inlet and at Angun Point were reported by Ebbley and Joesting (Bureau of Mines, 1944) to be used by the natives for this purpose.

Oil seeps on the Iniskin Peninsula, west shore of Cook Inlet, were supposedly known to the Russians in 1853 (Martin, 1905). This was probably through the 1850 geological survey of the Cook Inlet area by the Russian mining engineer, Petr Doroshin. The seeps in the Katalla and Yakataga districts, Gulf of Alaska, and Kanatak district (Puale Bay/Cold Bay) were documented by explorers and prospectors in the mid-1890's; those on the Chukchi and Beaufort Sea coasts were probably first documented by non-native explorers at the beginning of the 20th century.

The oil seeps on the Iniskin Peninsula of Cook Inlet resulted in the staking of claims in 1892, a restaking in 1896, and drilling for oil at Oil Bay in 1898 (Martin, 1905). Claims were staked and drilling began at the Katalla-Controller Bay seeps in 1901, and at Puale Bay in 1902. The drilling on the Iniskin Peninsula and Puale Bay was abandoned about 1904, but periodic test drilling continued in both areas through the 1950's.

Drilling continued sporadically at Katalla during the first decade of the 20th century, but was halted during 1910-1920 when the U.S. government withdrew all federal lands from oil and gas leasing. Exploration and development activities at Katalla eventually resulted in the only commercial petroleum production in Alaska (1920 through 1933) up to 1955.

Active exploration began again during the 1920's after the passage of the Oil and Gas Leasing Act of February 25, 1920. In anticipation of this increased activity, the USGS produced a summary of information on petroleum resources and likely areas of petroleum resources in Alaska (Martin, 1921). The location and characteristics of petroleum seepages played a prominent part in this report.

The earliest report of oil seepage in the North American Arctic was by Thomas Simpson of Hudson's Bay Company. During his coastal survey of 1836-37, he reported oil deposits along the Canadian Arctic shore (Hunt, 1970).

The earliest report on the petroleum potential of the Alaskan North Slope was from the year, 1886. Ensign W.L. Howard, a member of the U.S. Navy's exploration expedition headed by Lt. George M. Stoney, explored the head of the

Colville River during the winter of 1886 and brought back a specimen initially believed to have been petroleum residuum (Paige et al. 1925). This sample was later found to be oil shale (Smith and Mertie (1930), which is common along the north front of the Brooks Range.

The first recording of true petroleum seepage on the Alaskan North Slope was by E. deK. Leffingwell as a result of his 1906-1914 explorations. Although he did not personally visit the site, Leffingwell reported the presence of petroleum seeps near the Arctic Coast, 50 miles southeast of Point Barrow, on Dease Inlet (the Cape Simpson Seeps) (Brooks, 1909; Leffingwell, 1919). He obtained a sample of this seepage from C.D. Brower of Point Barrow which analysis indicated was a petroleum residue. These seeps were visited by A.M. Smith in 1917, whose oral description led to geologists from Standard Oil of California and General Petroleum inspecting and mapping the area in 1921 (Paige et al. 1925; Miller et al., 1959; Hunt, 1970).

Another seep was reported by the natives to Leffingwell as being on the Beaufort Sea coast about 300 miles farther east, or about 35 miles west of the Alaska-Yukon boundary between Humphrey Point and Aichillik River (Leffingwell, 1919). This was probably the seepage at Angun Point, which has a history of being mined by the Natives for its asphalt.

At about the same time that Leffingwell was being briefed on the presence of the oil seeps at Cape Simpson and Angun Point, William Vanvalin, a teacher with the U.S. Bureau of Education, explored oil seeps on the eastern shore of Smith Bay reported to him by Natives at Wainwright (Hunt, 1970). He reportedly discovered two springs of oil flowing into a lake 400 by 200 feet in dimension located about one mile from the shore of the Beaufort Sea. Vanvalin staked claim to this deposit, naming it the "Arctic Rim Mineral Oil Claim." The claim was never developed and no additional information was found by the authors relative to this seep.

The major driving force behind the exploration and geological mapping of the western Alaska North Slope during the 1920's was the establishment of the Naval Petroleum Reserve (Pet-4), which encompassed about 37,000 square miles. The establishment of this reserve was part of a national security policy of providing adequate supplies of oil to the U.S. Navy. Pet-4 was established on February 27, 1923, by Executive order of President Warren G. Harding. The selection of this particular area for the reserve was partially due to evidence of the presence of a large oil field here. This evidence consisted of the presence of petroleum seeps coupled with what was known concerning the geology. In fact, oil seeps are actually mentioned in the Executive order (Paige, et al., 1923):

> "Whereas there are large seepages of petroleum along the Arctic coast of Alaska and conditions favorable to the occurrence of valuable petroleum fields on the Arctic coast; ...."

During the period 1923-26, geological surveys of the Pet-4 were conducted by the USGS at the request of the Department of Navy. The results were published in a series of reports, including those of Paige, et al. (1925) and Smith and Mertie (1930).

In the 1923 USGS expedition to the Pet-4, two oil seeps at Cape Simpson were surveyed. One sample was taken from a surface seepage (weathered oil) and analyzed by the Bureau of Mines. In their report, Paige, et al. (1925) provided maps of the seep locations, photographs of the seeps, plus results of chemical analysis of oil collected from one of the seeps. Page, et al. (1925) also mentioned in their report another oil seep reported by natives, 300 miles east of Point Barrow, near the international boundary. This was probably the same seep reported by Leffingwell. Although Barter Island is a possibility, this was probably the seepage area at Angun Point.

Little additional attention was given to the Alaska North Slope until World War II. In 1943, the Bureau of Mines again examined the Cape Simpson area and continued to search for reported seeps. The results of this exploration were published in Bureau of Mines War Minerals Report 258 (1944). The following additional seeps were described: Umiat Mountain, Fish Creek, Dease Inlet, Manning Point and Angun Point. The latter three seep locations are coastal.

The Navy Department resumed its program of exploration of Pet-4 in 1944 as part of the wartime effort. The USGS resumed its mapping program in northern Alaska and in 1945, at the request of the Navy, it carried out the geologic phases of the Pet-4 exploration (Miller et al. 1959). As part of this effort, two gas seeps (on the upper Meade River and on the Colville River) and the oil seep at Skull Cliff were discovered. The Skull Cliff seepage, which occurs on the Chukchi Sea just north of Peard Bay, was described in a report by Webber (1947).

Similar to the situation in the Gulf of Alaska, the first test wells on the North Slope were drilled near oil seeps: Cape Simpson (coastal) and Umiat (inland up the Colville River). The test drillings began in 1945 and continued throughout promising locations in the Pet-4 until 1951. The Umiat oil field was discovered in 1950. The oil reserves at Cape Simpson were found to be small (2.5 million barrels), while the test well at the Fish Creek oil seep (1949) found heavy oil with an asphalt base (Miller et al. 1959). A result of this exploration was the discovery of the small oil and gas fields of Umiat, Cape Simpson, and South Barrow. Exploration of the area between the Pet-4 and the William O. Douglas Arctic Wildlife Range (now known as the Arctic National Wildlife Refuge) was stimulated, in part, by the presence of seepages reported at Kuparuk. This exploration resulted in the 1968 discovery of the Prudhoe Bay oil field.

Additional exploration of Pet-4 was conducted by the Navy during 1974-1977. In 1977, jurisdiction of Pet-4 was reassigned to the Department of Interior and the reserve was renamed the National Petroleum Reserve in Alaska (NPRA).

The Alaskan North Slope continues to be surveyed and explored for oil and gas deposits. In addition, known oil and gas fields are being delimited. The chemical characterization of oils from test wells, producing wells, and surface seeps for oil/source-rock correlation analyses has been an important part of this exploration and study (Magoon and Claypool, 1981; Anders and Magoon, 1985; Magoon and Claypool, 1985).

Oil/rock correlation analyses involve the evaluation of source rock for organic matter richness, kerogen type and thermal history and analysis of the oil type to determine:

API gravity
carbon isotope ratios
sulfur and nitrogen content
relative amounts of odd- and even-numbered n-alkanes
pristane/phytane ratios
relative amounts of sulfur and nitrogen isotopes

From a geochemical standpoint the oils from some of the North Slope coastal oil seeps have been relatively well characterized. Surface seepage and more than 25 separate oil-and-gas accumulations have been discovered on the North Slope (Magoon and Bird, 1985). Analyses of many, but not all, of these seepages and accumulations show that there are several distinguishable types of oil present.

Oil/rock correlation analyses indicate that the oil types of the various coastal seepages are chemically different from and appear to have different sources than the Prudhoe Bay oil (Anders and Magoon,1985; Curiale, 1985; Magoon and Claypool, 1981; Magoon and Claypool, 1985b; Magoon and Anders, 1987). Prudhoe Bay crude oil originates from the Kingak Shale/Shublik Formation (Figure 4) and is characterized as an isotopically light oil relatively high in vanadium, nickel, sulfur, and tricyclic terpanes (Curiale, 1985). The other oil types are:

<u>Angun Point Seep, Jago Oil Type</u>- probably originates from type II organic-rich facies of the Cretaceous Hue Shale (Figure 4) based on similarities in carbon

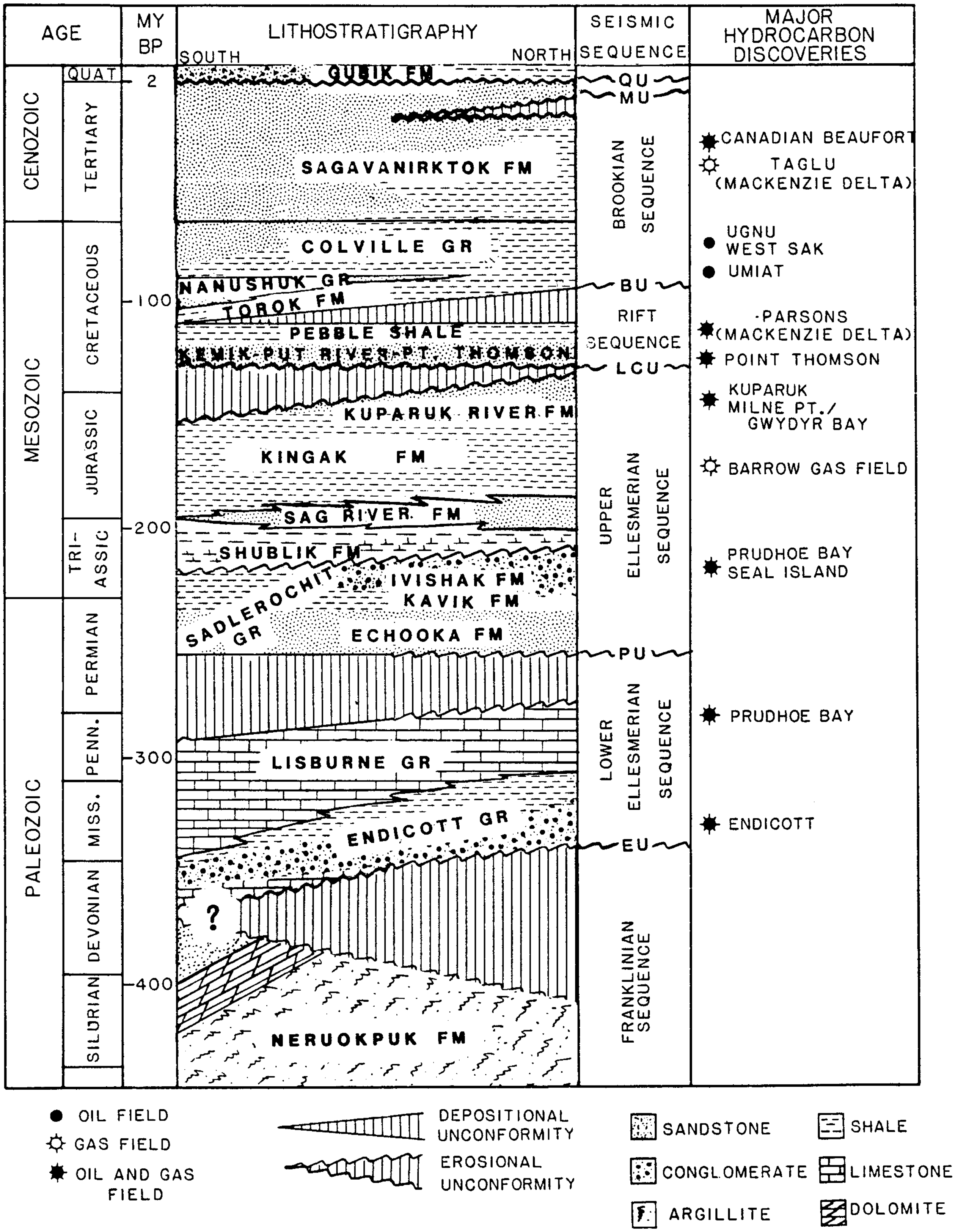

Figure 4. Generalized Lithostratigraphic Column of the Alaskan North Slope (Craig et al., 1985).

isotope values of the saturate and aromatic hydrocarbon fractions and their C_{19}/C_{23} tricyclic terpane ratios (Anders and Magoon, 1985). It is a high gravity, low sulfur oil, with no or slightly odd-numbered n-alkane predominance. The pristane/phytane ration is greater than 1.5 (Magoon and Claypool (1981).

Manning Point Seep, Manning Oil Type- of unknown source (Anders and Magoon, 1985). This is a high gravity, low sulfur oil, with no or slightly odd-numbered n-alkane predominance. The pristane/phytane ration is greater than 1.5 (Magoon and Claypool (1981).

Cape Simpson and Skull Cliff Seeps, Simpson-Umiat Oil Type- appears to be associated with the "pebble-shale"/Torok Formation (Figure 4) (Magoon and Claypool, 1985b). This is a high gravity, low sulfur oil, with no or slightly odd-numbered n-alkane predominance. It is also characterized as being low in vanadium and nickel (Curiale, 1985). The pristane/phytane ratio is greater than 1.5 (Magoon and Claypool, 1981).

Studies of oil seeps in the Alaskan Arctic, beyond geochemical characterization for delimitating petroleum bearing formations, began during the early development of the Trans Alaska Pipeline. Concern for the possible impacts on the tundra biological communities of oil spilled from the proposed pipeline led to a series of ecological studies, some of which used inland and coastal seeps as part of the experimental procedures (Agosti and Agosti,1972; Barsdate et al., 1972; McCown et al., 1972; Zobell and Agosti, 1972).

DESCRIPTIONS OF SELECTED ALASKAN COASTAL SEEPS

Those Alaskan coastal seepage areas that appear to be most closely associated with the marine environment and which have the most background information are described in this section. These descriptions include basic observations (from earliest explorers to present-day observers), maps of the locations, geological sources, chemical characteristics of the oil, and any other pertinent information. Although emphasis is being placed on those seeps located in the Arctic, well known areas in the Gulf of Alaska will also be included in these descriptions. The seeps included are:

Arctic-

Site No. 1,	Angun Point
Site No. 2,	Manning Point
Site No. 5,	Cape Simpson
Site No. 7,	Skull Cliff

Gulf of Alaska -

Site No. 12,	Puale Bay
Site No. 16,	Iniskin Peninsula
Site No. 21,	Katalla
Site No. 23,	Yakataga

A short list of other coastal oil seeps reported in Alaska will also be included at the end of this section.

Angun (Ungoon) Point

This seepage area consists of at least two oil seeps located on the coastal point at the Nuvagapak Entrance to Beaufort Lagoon (Figure 5) (Alaska Clean Seas, 1983). The exposed point is located on scarps 5-10 ft above the narrow beaches. To the east of this point, the exposed beaches consist of gravel and sand, while to the south they are composed of sand-silt (less-exposed). Based on measurements conducted over a period of 20 years, Hopkins and Hartz (1978) estimated the coastal erosion rate of the area to be 1.5 m/yr.

These seeps were probably reported to explorers by natives at a very early date. Both Leffingwell (1919) and Page, et al. (1925) reported secondhand information on coastal seeps in this general location. The seeps are specifically indicated on maps in Grantz et al. (1976; 1980), Map 76 of the Alaskan Beaufort Sea Coastal Resources Manual (Alaska Clean Seas, 1983), and USGS Open-File May 84-569 (Bader, 1984).

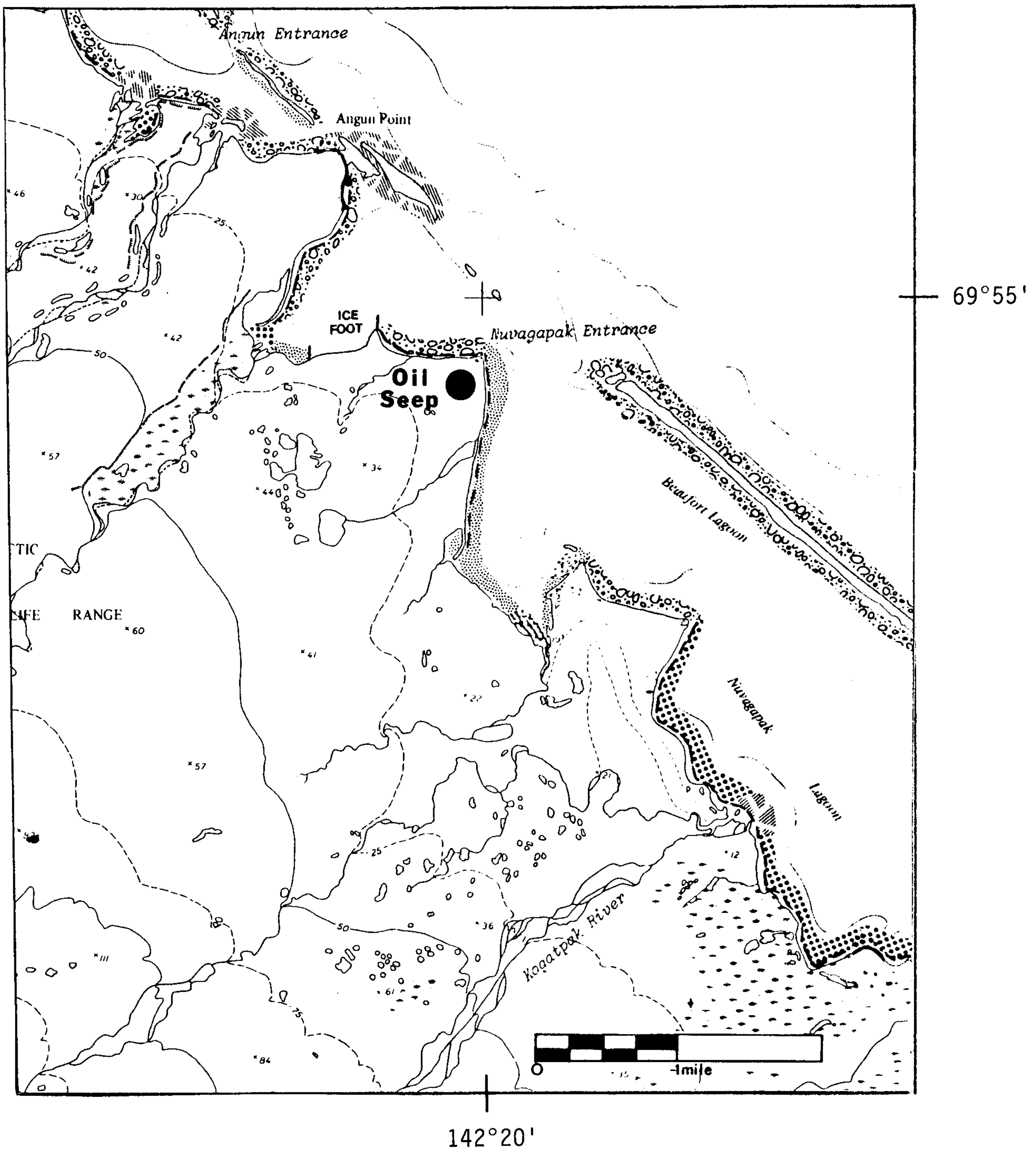

Figure 5. Angun Point Oil Seepage Area (Alaska Clean Seas, 1983).

The Bureau of Mines (1944) first described this site:

> "Location is 7 miles east of Humphrey Point and about 40 miles west of Demarcation Point. "Ungoon" is the Eskimo term for pitch. Three evidences of petroleum seepages were found on Ungoon Point. The largest of these is mile and a quarter south from the sod house on the Point. The pitch is black and hard and is extremely difficult to dig. A small amount of mining has been carried out and the pitch has appeared in several small holes where the tundra has been removed. The general area is approximately 300 feet north and south and 100 feet east and west."
>
> "Six hundred yards east and about 250 yards from the east beach a small pool has been excavated in the center of a small hummock. Sample No. 16 was taken from this material which has the same consistency as the larger exposure. On the east side of Ungoon Point and in line with the two seepages mentioned above, an exposure of oil bound sand four feet thick appears along the bank for a distance of about 30 feet. This deposit is located one and one half miles southeasterly from Ungoon Point proper."

This description from the mid-40's has been the basis for the Angun seep descriptions produced by Miller et al. (1959), Hanna (1963), and Ball Associates, Inc. (1965).

Samples of this seepage were recently collected by the USGS for oil/source rock correlation analysis. Based on geochemical analysis of this oil, Anders and Magoon (1985) have designated this as Jago Oil Type. It probably originates from type II organic-rich facies of the Hue Shale (Figure 4) and has also been identified as occurring in oil-stained rocks from Katakturuk River and Jago River. Jago Oil Type is a high gravity, low sulfur oil, with no or slightly odd-numbered n-alkane predominance, and has a pristane/phytane ration greater than 1.5 (Magoon and Claypool, 1981).

The oil from the Angun seeps contain biodegraded hydrocarbons and no measurable amounts of n-alkanes or regular chain isoprenoids. The hydrocarbons are dominated by those with boiling points $>n\text{-}C_{20}$. Other characteristics of this oil are presented in Table 2.

Manning Point

This oil seepage is located at tidewater on Manning Point, which is a narrow strip of land lying between Kaktovik and Jago lagoons, 3 km southeast of Barter Island (Figure 6). Manning Point is protected by gravel barrier islands. Both

Table 2. Geochemical Characteristics of Oil from Alaskan Arctic Coastal Seepages. Data are from Magoon and Claypool (1981) and Anders and Magoon (1985).

VARIABLE	ANGUN POINT	MANNING POINT	CAPE SIMPSON #1	CAPE SIMPSON #2	CAPE SIMPSON #3	SKULL CLIFF
°API Gravity[1]	Solid	26.7	20.2	----	18.8	18.4
^{o}/o. Sulfur[2]	0.22	0.14	0.34	0.08	0.32	0.32
^{o}/o. Nitrogen	0.43	0.02	-----	0.03	0.05	
^{o}/oo delta^{34}S	-10.59	- 4.91	-----	- 5.46	- 6.11	-10.3 - 4.9
^{o}/oo delta^{15}N	1.13	2.75	-----	3.81	2.85	
o/oo delta^{13}C[3] (whole oil)	-28.71	-28.23	-----	-28.94	-29.09	-29.1
^{o}/oo delta^{13}C (C^{15+} Sat. HC)	-29.21	-28.52	-----	-29.31	-27.8 -29.34	
^{o}/oo delta^{13}C (C^{15+} Arom. HC)	-28.57	-27.84	-----	-28.19	-28.48	
Extraction data:						
% Non-HC	73.6	26.8				
% HC	24.4	73.2				
S/A[4]	2.9	5.2				
Biomarker data:						
(C_{19}/C_{23} tricyclic terpane)	0.6	2.1				
Hopane/C_{23} tricyclic terpane	?	15.7				

---

[1] Average for crude oil is 35° API; Prudhoe Bay crude oil is 26.1° API.
[2] Prudhoe Bay crude oil is 0.95% Sulfur.
[3] Prudhoe Bay crude oil is -29.83^{o}/oo delta^{13}C.
[4] Saturate/aromatic hydrocarbon ratio

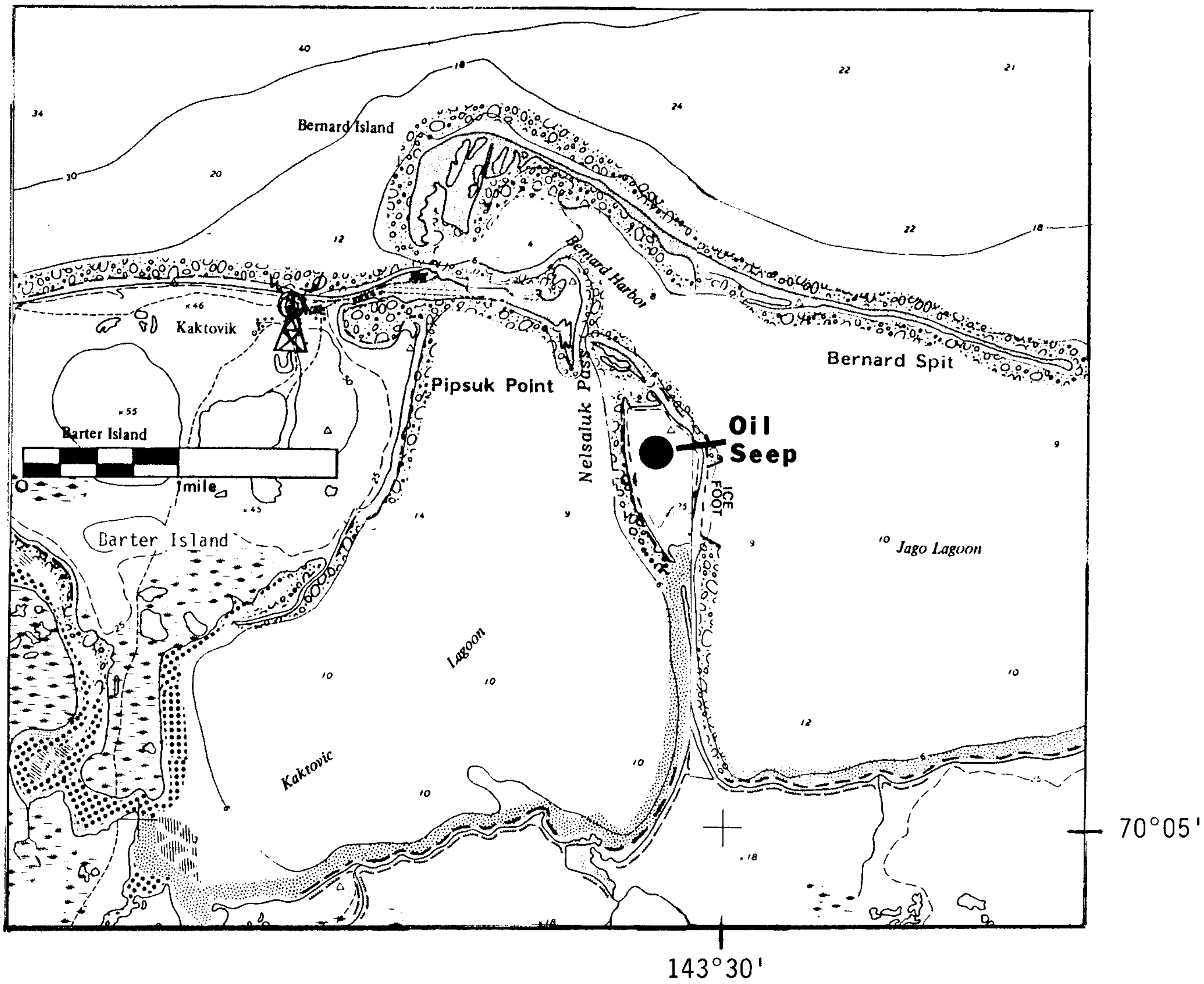

Figure 6. Manning Point Oil Seepage Area (Alaska Clean Seas, 1983).

Kaktovik and Jago lagoons are relatively shallow, not exceeding 4 m in depth; tidal range is less than 20 cm (Johnson, 1971). The shoreline of Manning Point is steep, 3-4 m high, and consists primarily of coarse gravel (Alaska Clean Seas, 1985). The shoreline of Kaktovik Lagoon extending along the spit from the oil seepage to the mainland (about a mile in length) is composed of sand-silt.

The Manning Point seep is specifically indicated on maps in Grantz et al. (1976; 1980), on Map 71 of the Alaskan Beaufort Sea Coastal Resources Manual (Alaska Clean Seas, 1983), and on USGS Open-File Map 84-569 (Bader, 1984).

The Manning Point seep was first described by Ebbley and Joesting (Bureau of Mines 1944):

> "No actual pitch residue was noted; however, the northwest and northeast beaches which form the point are lined with oil froth for a mile and a half. A considerable portion of the beach particularly on the northwest side, consists of an oil bound silt and numerous boulders of soft oil bound reddish-brown sand were observed. Several trickles of water-carrying oil film cross the narrow beach. Oil soaked peat was noted at several places along the sloughed bank."

Samples were collected by Ebbley and Joesting from this seepage and their API gravity determined (Bureau of Mines, 1944):

17.3° API-	Oil bound silt found in layers along the northwest beach
19.0° API-	Sample skimmed from the several small streams of water flowing from the bank to the ocean
2.6° API-	Exposures of an unconsolidated oil bound brownish-red sand which appeared in places along the bank
21.3° API-	Oil soaked vegetable debris found along the bank throughout the entire mile and a half distance

The above information from Bureau of Mines (1944) is the basis for descriptions presented in Miller et al. (1959), Hanna (1963), Ball Associates, Ltd. (1965), and Johnson (1971).

Based on carbon isotope values of the saturate and aromatic hydrocarbon fractions, saturate/aromatic hydrocarbon ratios, C_{19}/C_{23} tricyclic terpane ratios, and hopane/C_{23} tricyclic terpane ratios, the oil from this seep has been designated as a separate oil type ("Manning Oil Type") sufficiently different geochemically to suggest a source that has not been evaluated as yet (Anders and Magoon, 1985). Manning Oil Type is a high gravity, low sulfur oil, and has a pristane/phytane ratio greater than 1.5 (Magoon and Claypool, 1981). The hydrocarbons are biodegraded, containing no measurable amounts of n-alkanes or regular chain isoprenoids; it is dominated by hydrocarbons with boiling points $<n\text{-}C_{20}$.

Other characteristics of this oil are presented in Table 2.

Cape Simpson

The best known oil seepage area on the North Slope of Alaska consists of those seeps located on the west shore of Smith Bay at Cape Simpson (Figure 7). Sylar (1987) mentions that this is one place where one can see oil bubbling from the ground in subzero weather. Eyewitness descriptions have been provided by Leffingwell (1919), Page et al. (1925), Bureau of Mines (1944), Hanna (1963), Agosti and Agosti (1972), Barsdate et al. (1972), and McCown et al. (1972). The seepage area is specifically indicated on maps in Grantz et al. (1976; 1980) and on Map 17 of "Alaskan Beaufort Sea Coastal Resources Manual" (Alaska Clean Seas, 1983).

The earliest description of this site is provided by Leffingwell (1919):

> "At Cape Simpson on the west side of Smith Bay, there are two conspicuous mounds. The writer has been informed by natives that the northern mound contained a petroleum residue, but, according to information furnished by Stefansson, this residue is contained in a pool a few hundred yards from the mound. A sample was secured from a keg of the material collected by natives in the employ of Mr. C.D. Brower, of Barrow. It resembles axle grease. An analysis by David T. Day is given below. The deposit is near the seashore, and the natives say that a considerable amount could easily be dug out with spades."

"Water and soluble matter	22 %
Alcoholic extract (resins and some oil)	8 %
Naphtha extract:	
Light oil	12 %
Heavy oil	16 %
Benzol extract (asphaltic material)	11 %
Clay and vegetable fiber	29 %"

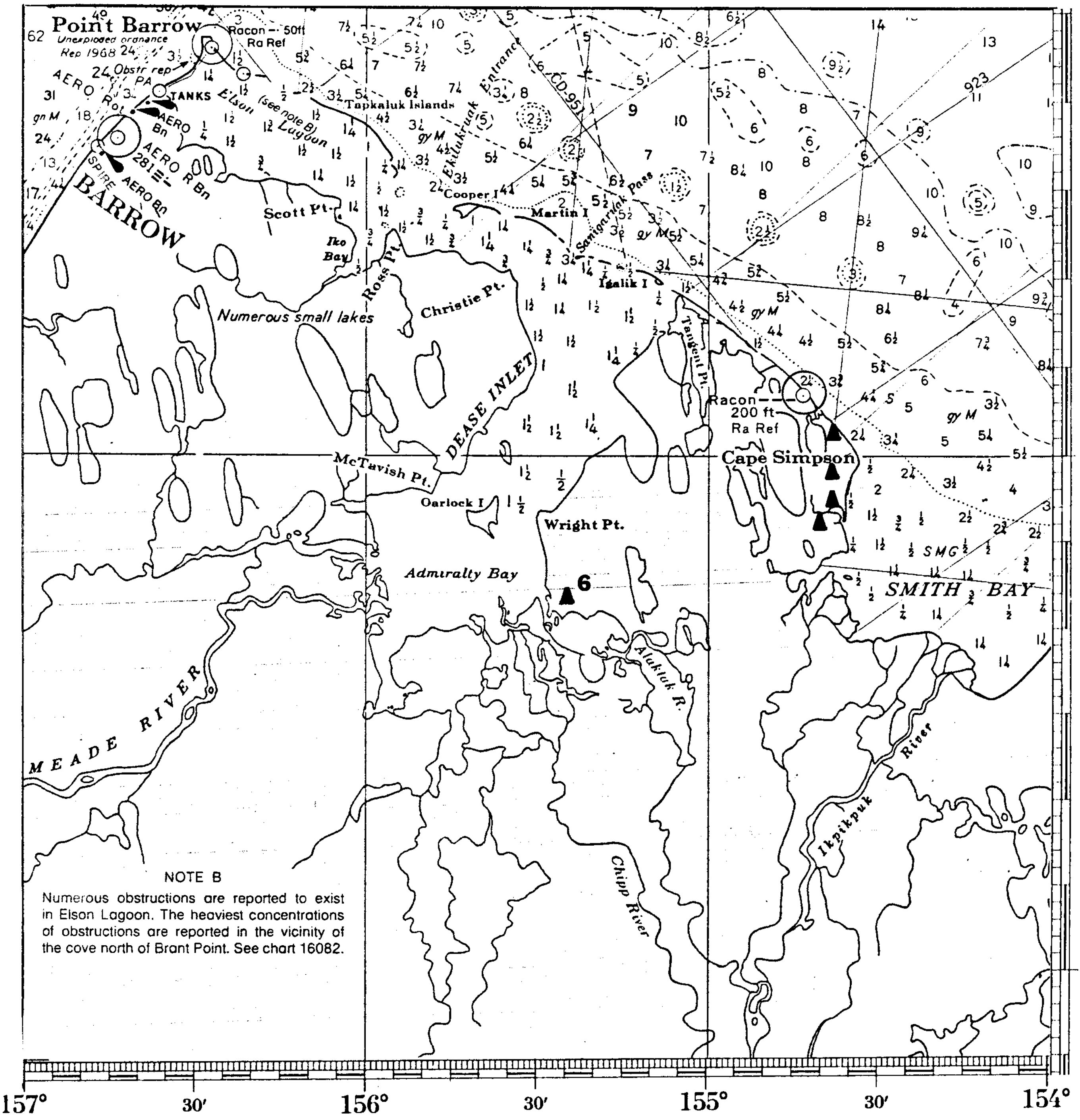

Figure 7 . Cape Simpson Oil Seepage Area.   Seeps - ▲

The earliest map showing the seepage mounds were published in Page, et al. (1925) (Figure 8). According to Page:

> "A low moss-covered ridge of irregular shape stretches for 2 miles along the Arctic Ocean, its southeast terminal about a mile north-west of Cape Simpson. Its highest point is about 50 feet above the sea....Seepage No. 1 occurs near the inland base of this ridge, a third of a mile from the ocean and 20 feet above tidewater, from which it is visible. Here in an irregular area several hundred feet in diameter the moss is soaked with petroleum which also slowly seeps from the gentle slope.
>
> Seepage No. 2 is on the southern top, 40 feet high, of a small double knob 3 miles almost due south of seepage No. 1 and 1 1/4 miles west of Smith Bay. Here the residue from the seepage covers several acres...
>
> The main petroleum flow moves southward down the slope for 600 or 700 feet to a lake; this active channel is 6 to 10 feet wide, though the area covered by residue is several hundred square feet and indicates that a considerable flow is coming from this seepage. The ridge at these two seepages is covered with moss and muck, and there are no surface indications that it is made up of hard rock..."

Analysis of samples collected from the seeps cited above resulted in the following:

API gravity-	18.6°
Sulphur-	0.36%
Water-	7.5%
Pourpoint-	< 5°F

Later descriptions are provided by Ebbley and Joesting (Bureau of Mines, 1944), Hanna (1963) and McCown et al. (1972).

The area of seepage at Cape Simpson is located between Sinclair Lake and Smith Bay, and extends approximately 10 mi along the coast with Cape Simpson, itself, in the center of the eastern boundary (Figure 9). Shoreline erosion rates in the Beaufort Sea are quite high, the shoreline at Cape Simpson being the highest (Craig et al., 1985). Leffingwell (1919) reported that the rate of erosion was 30 m/yr at Cape Simpson. Based on measurements conducted over a period of 20 years, Hopkins and Hartz (1978) estimate the erosion rate at Cape Simpson to be 11.4 m/yr. Quite possibly, significant amounts of petroleum hydrocarbon may be entering the Beaufort Sea via coastal erosion in this seepage area.

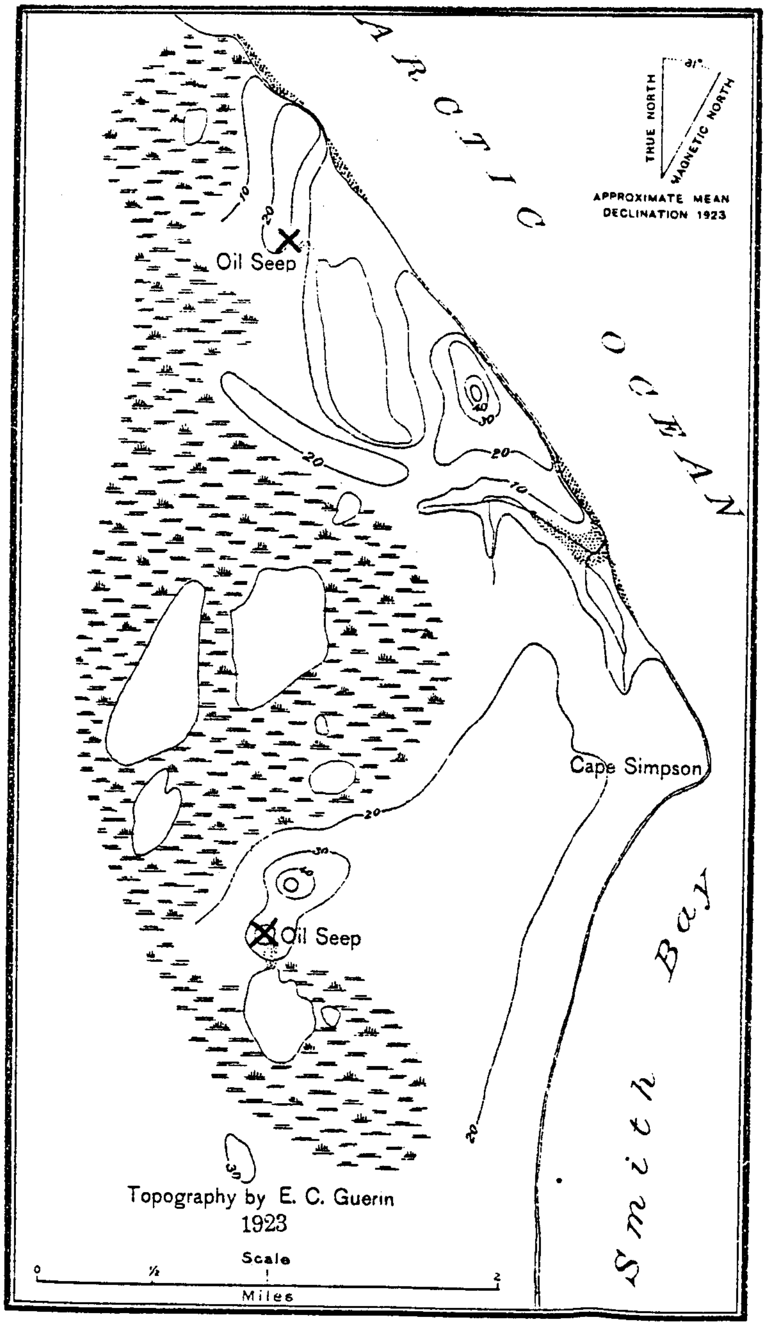

Figure 8 . Cape Simpson Oil Seeps from Page et al. (1925).

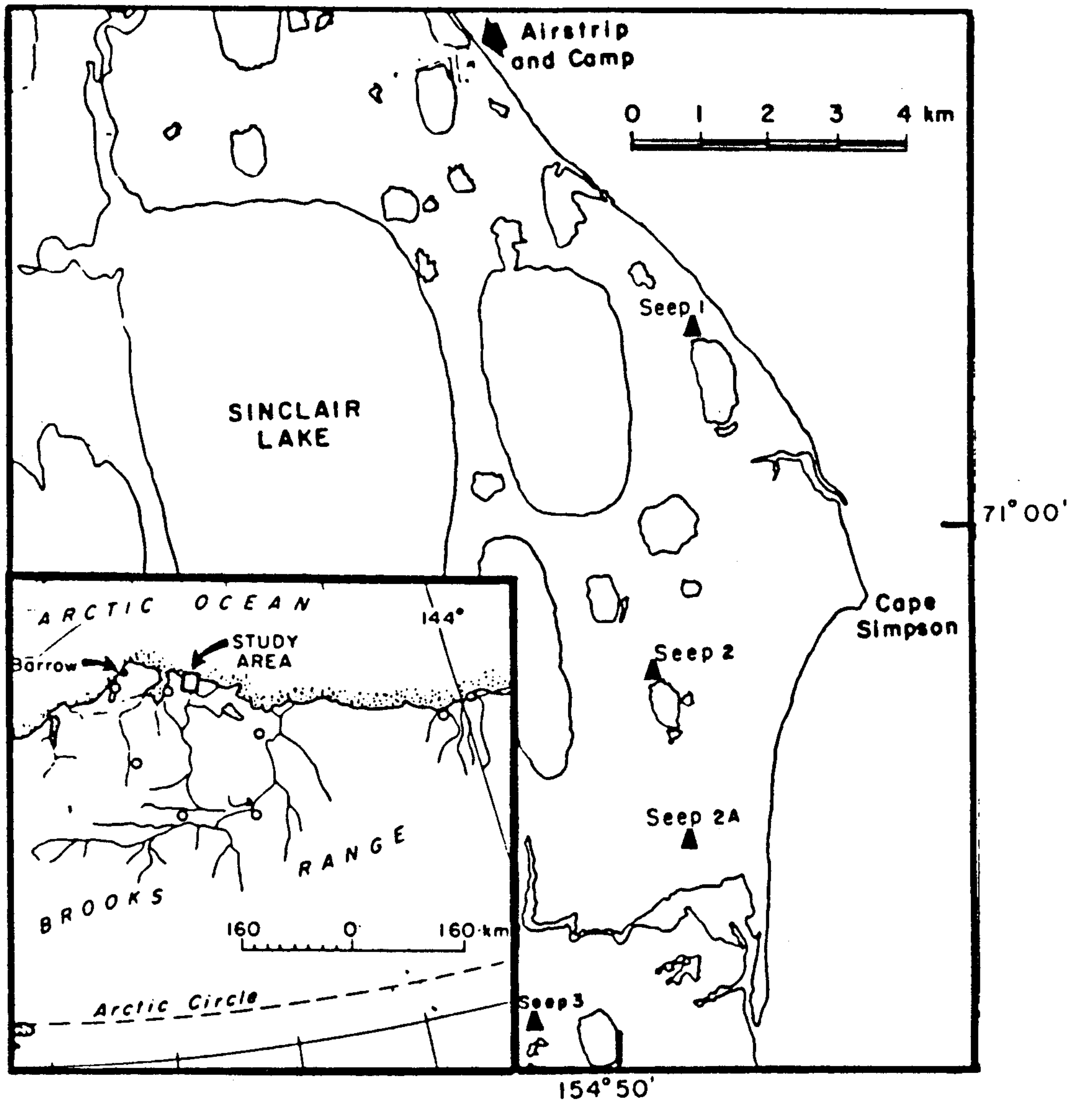

Figure 9. Cape Simpson Oil Seeps from McCown et al. (1972)

Although evidence of seepage is found throughout the area, four seeps are the best known and have been repeatedly referred to as seeps 1, 2, 2A, and 3 (Bureau of Mines, 1944; Hanna, 1963; Barsdate et al., 1972; McCown et al., 1972). Seep 1 is located about 3 mi northwest of Cape Simpson and 500 yds from the shore of Smith Bay. The beach here consists of high energy, narrow sand-gravel shores less than 20 ft wide and scarpes 2-6 ft in height (Alaska Clean Seas, 1985).

Seep 2 is on a prominent hill 3.5 mi south of No. 1. It is about 1.25 mi west of the Bay. The viscous oil flows down hill and eventually reaches a lake which covers several acres. At times it covers the surface of the water; this led to early reports of "a lake of Oil". Ebbley and Joesting reported evidence of removal of residue from this seepage by Natives for fuel (Bureau of Mines, 1944).

Seep 2A is located north of the outlet to Sinclair Lake and slightly less than 1 mi west of the shore of Smith Bay. The shoreline south of the outlet is vegetated and is generally a complex subsiding tundra area with submerged ponds and a river channel (Alaska Clean Seas, 1985).

Seep 3 is about 2 mi southwest 2A and about 2 mi from the ocean. Ebbley and Joesting reported that the residue at this seep covered an area about 800 feet x 1000 feet (Bureau of Mines, 1944). The API gravity of oil samples collected by the Bureau of Mines from seeps 1, 2, and 3 ranged from 13.6° to 17.6° (Bureau of Mines, 1944).

The oil issuing from these seepages is relatively viscous (13.6° - 20.2° API). It tends to creep downslope in elongated streams from its point of issue. Fresh oil flows most often in the centers of the asphalitic areas, along contraction cracks, and sometimes along the periphery of the seepages (McCown et al., 1972). All observers have noted that the evaporation of volatiles appears to be quite rapid. Remnants of inactive seeps are found scattered among the active sites. At dry sites, these remnants have weathered to a dry, oxidized, crumbly material. This evidence, plus the occurrence of tar deposits within the tundra soil at various depths, indicates that the center of seepage activity might change with time. Revegetation of inactive seepage sites was noted by McCown et al., (1972).

McCown et al. (1972) found that the relatively higher temperatures of the oil flows (3-5°C warmer during the day and 1-2°C warmer during the night than the undisturbed tundra at 10 cm depth) affected permafrost integrity. Depressions along the margins of the seeps appeared to be themokarst features which formed ponded water. Ponds covered by floating oil were found to be 0.6-1.6°C warmer than unaffected ponds.

In all four of the seeps studied by McCown et al. (1972), plants were found growing in close association, both on the periphery and when encompassed by flows. Eriophorum scheuchzeri (Alaska cotton) and Carex aquatilis (a sedge) occurred in the wet areas while Arctagrostis latifolia (a grass) was dominant in the drier sites. A more detailed study of Seep 1 showed that plants growing near the edge of the seep (C. aquatilis) were larger and more advanced phenologically in flower and fruiting than those a few meters away (McCown et al., 1972). The authors suggested that this is due to stimulation of growth by the warmer microclimate at the seep. Oil content of the soils adjacent to the seep was <0.1 mg/g wet soil except where tar was encountered in the profile.

Lakes and ponds in the seepage area are variously affected by oil from the seeps. The oil forms the characteristic mousse emulsion when in contact with the water with white floating paraffin deposits and associated bacterial flora.

Barsdate et al. (1972) found that phytoplankton productivity and abundance and bacterial numbers were higher in waters in contact with old tars and asphalts at the Cape Simpson seeps than those in either oil-free ponds or ponds recently impacted by fresh oil. The seeps appeared to have little effect on the ionic composition of the ponds, although elevated phosphate levels were recorded for the most heavily affected pond (Table 3). They suggested that the higher productivity at the moderately affected ponds might be due to reduced grazing pressure. The affected ponds were dominated by very small forms of zooplankton and relatively sensitive filter feeders, such as Brachinecta sp. and Polyartemia sp. (both fairy shrimp characteristic of tundra ponds), were absent.

The Cape Simpson seeps appear to be in line with the known horst structure (Ball Associates, Inc., 1965). The oil apparently migrates up along the fault planes and fissures into the overlying Pleistocene Gubik Formation. The Cape Simpson seep mechanism appears similar to that of the oil seeps on the east shore of Dease Inlet (Figure 7) where similar faulting may be responsible for the latter seepage (Ball Associates, Inc., 1965).

Magoon & Claypool (1981) indentified the oil from these seeps as Simpson-Umiat Type. The source rock appears to be from the "pebble shale"/Torok Formation (Magoon and Claypool, 1985b) (Figure 4). This is a high gravity, low sulfur oil, with no or slightly odd-numbered n-alkane predominance. The Pristane/phytane ratio is greater than 1.5. Delta ^{13}C are -29.1 to -27.8 ^{o}/oo and Delta ^{34}S are -10.3 to -4.9 ^{o}/oo. Additional characteristics of the oil are presented in Table 2.

Table 3. Limnological factors in arctic ponds at Barrow and Cape Simpson from Barsdate et al. (1972) Values given for Barrow Control Ponds B and C are means of determinations on samples taken at five intervals throughout July, 1970. The oil seep ponds were sampled July 19-20, 1970.

	BARROW CONTROLS		CAPE SIMPSON OIL SEEPS				
Parameter*	B	C	2-2	2-1	3-1	2-3	3-2
Potential oil stress	None	None	None	Light	Light	Medium	Heavy
Bacteria (cells/ml)	6.1x10^{4}	4.5x10^{4}	--	--	1.0x10^{7}	3.0x10^{9}	6.8x10^{5}
Plankton algae (cells/liter)	1.7x10^{6}	2.6x10^{6}	--	--	3.3x10^{6}	1.8x10^{7}	4.8x10^{5}
^{14}C productivity (μg C/liter-day)	2.3	5.6	3.0	67	57	69	7.8
Conductivity (μmho/cm, 25° C)	131	131	178	141	--	135	--
Calcium (mg/liter)	6.1	4.9	4.8	6.1	--	4.5	--
Magnesium (mg/liter)	3.8	3.7	2.4	2.3	--	2.0	--
Potassium (mg/liter)	0.82	0.66	0.92	0.80	--	0.66	--
Sodium (mg/liter)	11.7	11.3	19.5	15.9	--	13.8	--
Dissolved reactive phosphorus (μg/liter)	2.3	2.2	0.6	1.7	1.4	1.0	30
Particulate phosphorus (μg/liter)	5.8	11	12	19	10	22	43

*Potential oil stress was evaluated subjectively (see text); direct cell counts were made on samples preserved in Lugol's solution using a Carl Zeiss 5 cc counting cell; productivity and chemical analyses were done by routine methods (8).

Skull Cliff

Skull Cliff is located on the Chukchi coast, northeast of Peard Bay (Figure 10). It consists of a steep sandstone cliff exposed to high wave energy. The cliff slopes are greater than 45^{o} and the fringing beach is composed of sand, gravel and shells (Robilliard et al, 1985). The sea bottom deepens gradually to 20 meters at 6.5 km offshore.

The oil seep at Skull Cliff was first described by Webber (1947) as part of the 1945 geological mapping program of the USGS. It is specifically indicated on maps in Grantz et al. (1976 and 1980). The seepage occurs as a light petroleum slowly dripping from a bed of fine-grained Tertiary sandstone. The area of seepage is only a few inches across. The thickness of the exposed sandstone is eight feet. The coastline here is exposed to the open sea and erosional. The comparatively high wave exposure and the substrate of the fringing beach probably prevents oil penetration (Robilliard et al., 1985). The small amount of oil released here is probably rapidly flushed away from the site (Johnson, 1971).

Based on geochemical analyses by Magoon & Claypool (1981) the oil from this seep has been identified as Simpson-Umiat Type. The source rock appears to be from the "pebble shale"/Torok Formation (Magoon and Claypool, 1985b) (Figure 4). It is a high gravity, low sulfur oil, with no or slightly odd-numbered n-alkane predominance. The pristane/phytane ratio is greater than 1.5. Other characteristics of this oil are presented in Table 2.

Puale Bay

The Alaska Peninsula from Wide Bay to Puale Bay (Figure 11) contains numerous terrestrial oil and gas seeps, that have been known since the beginning of the 20th century. Some of these seeps have an associated paraffin residue accumulation covering up to two acres (Johnson, 1971). The best known seeps occur on the Bear Creek and Oil Creek anticlines, and south of Becharof Lake on the Ugashik Anticline (McGee, 1972). Gas seeps have also been reported in the lake (Blasko, 1976b).

Because of the surface evidence, the area was the site of early exploratory drilling (1903-1904). Early references to these seeps (Martin, 1905; Martin, 1921; Capps, 1922; Smith, 1926; Miller, et al., 1959) refer to "Cold Bay", now known as Puale Bay. In addition to the activity at the beginning of this century, exploratory drilling was also conducted in

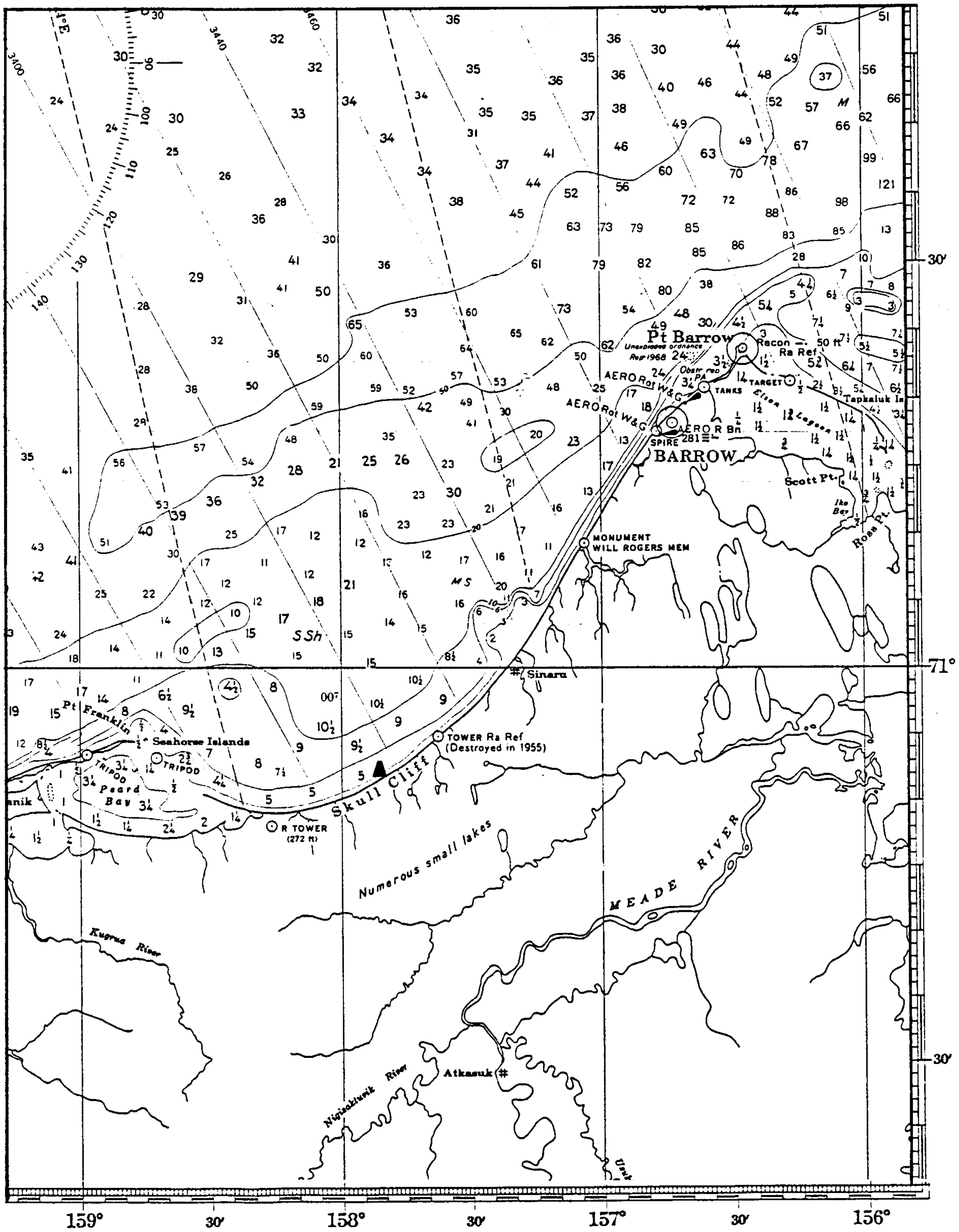

Figure 10. Skull Cliff Oil Seep ▲.

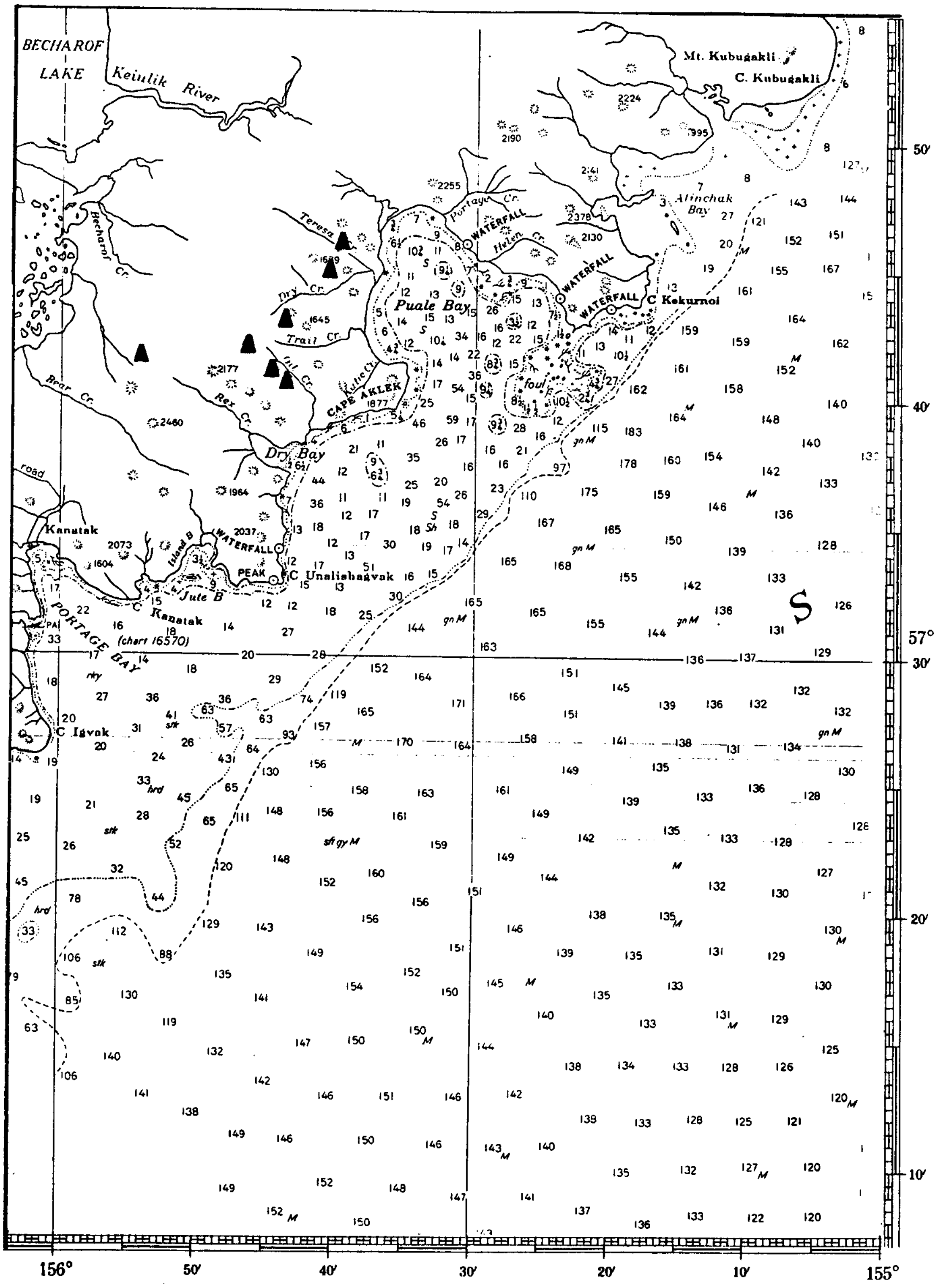

Figure 11. Puale Bay Oil Seepage Area, Alaskan Peninsula.

1938-1940 and 1957-1959, none of which resulted in commercial finds (Blasko, 1976b).

The most prolific seeps occur at the head of Oil Creek (Figure 12). This appears to have been the situation from earliest reports and also appears to be the case today. The earliest estimate of seepage from the head of Oil Creek was 0.5 bbl/day (21 gal/day) (Capps, 1922). McGee (1972) estimates that the total quantity of oil from all the seeps in the area (Wide Bay to Puale Bay) does not exceed 0.75 bbl/day (31.5 gal/day), emphasizing the relatively greater size of the Oil Creek seeps as compared to others in the area.

The seepages at the head of Oil Creek originate from two separate springs located at the foot of a small knoll on the south side of the creek (Blasko, 1976b). These seeps issue from the upper part of the Shelikof Formation (McGee, 1972). The descriptions provided by Capps (1922) and Blasko, 1976b) are very similar even though their visits to the seepages were 50 years apart. Seep A is active, bubbling intermittently. Oil collected from this seepage was 15.7° API with 0.58 % sulfur (Blasko, 1976b). The water and oil from this seep flow into a pond with dimensions of about 20 feet by 40 feet, which is lined with tar. The water and oil continue flowing over the grassy slope and into Oil Creek. The vegetation here appears to act as a filter, trapping the heavier portions. Blasko (1976b) stated that:

> "Lush, green growth at the seep sites often obscured the seep itself. In particular, the growth of grass through and on top of the asphalt deposit at Oil Creek was a stark and colorful contradiction to the barren surroundings. No attempt was made to determine whether the resultant growth on or near the seeps was because of or spite of the bitumen escaping."

Stimulation of vegetative growth in areas of oil seepages is not unusual and has been documented by McCown et al. (1972) at the Cape Simpson seeps. Such a response might be related to environmental temperature moderation by the warm seepage or to possible growth stimulation from associated trace elements.

The second seep (Seep B) is located 45 feet west of seep A. Blasko (1976b) reports it as originating from a series of five trickles that cover an area with a radius of 4 feet and collect at one point, forming a pool. This pool flows into a stream that discharges into Oil Creek. Oil collected from this seepage was 21.4° API with 0.21% sulfur (Blasko, 1976b). Oil staining and paraffin deposits were evident in the creekbed and adjacent vegetation.

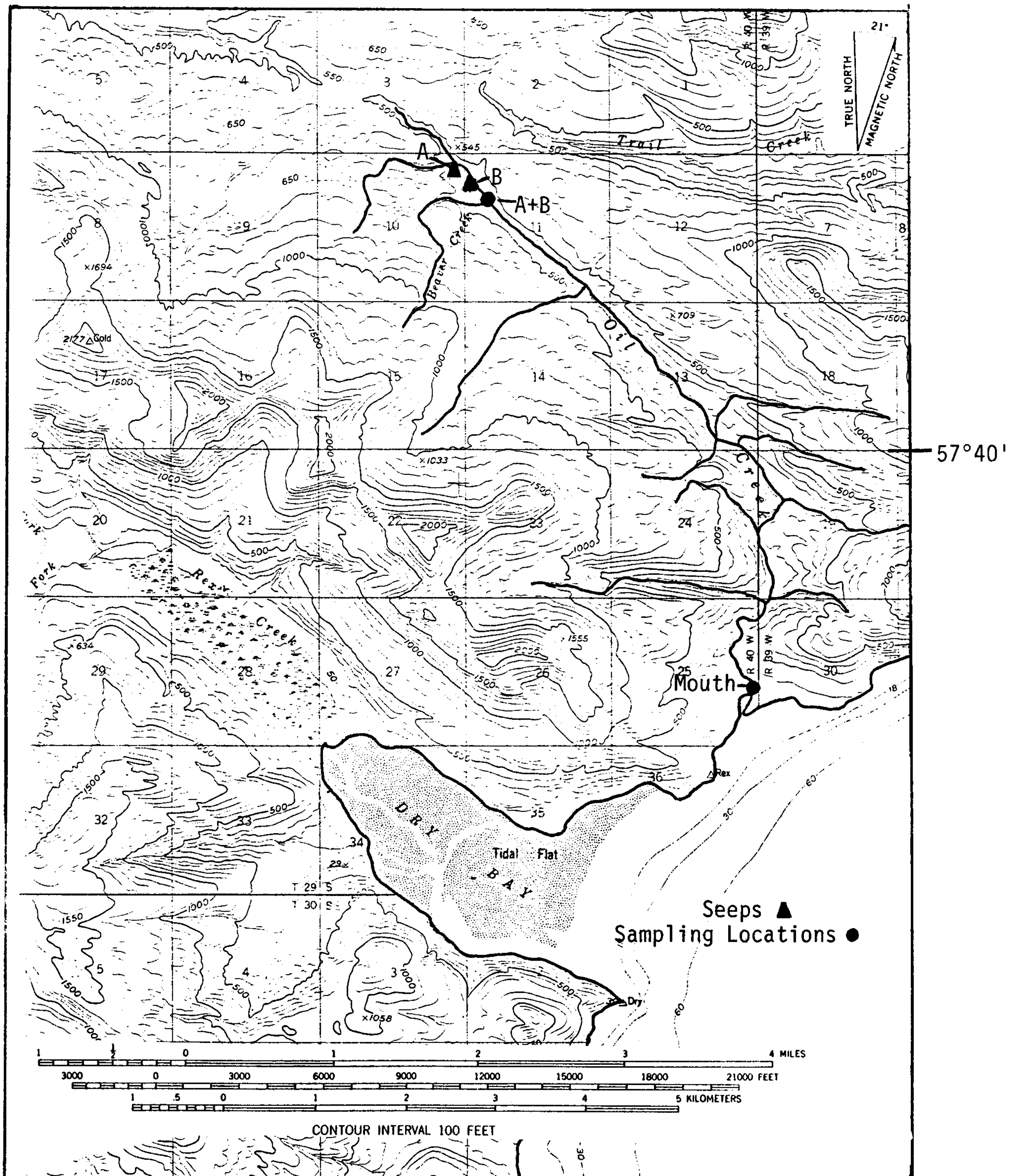

Figure 12. Oil Creek Oil Seeps, Puale Bay. (From Blasko, 1976b)

Although no recent estimates of seepage rates have been made, the area was resurveyed and samples collected by the Bureau of Mines for chemical analysis in 1973-1974 (Blasko, 1976a). Blasko (1976b) reported that the only seeps between the Gulf of Alaska and Becharof Lake that were active enough to be deemed significant were at the head of Oil Creek (Seeps A and B). Although the oil content of the water collected at the head of the creek was relatively high (Table 4), water samples collected from the mouth of Oil Creek in Puale Bay did not indicate very much oil being carried to the Bay (Blasko, 1976b). No oil was found on the beach of Puale Bay; however, the flow of oil from the seeps into the creek and from the creek into the bay could vary depending upon rainfall and runoff. Blasko (1976b) noted that at the time he sampled, the creek was running at a low level and little rainfall had been received. He speculated that runoff could possibly flush more oil into the creek and intermittently increase oil discharge to the bay.

Iniskin Peninsula

The Iniskin Peninsula is located on the west shore of Cook Inlet about 150 miles southwest of Anchorage (Figure 13). The peninsula is formed by the indentation of Chinitna Bay on the north and Iniskin Bay on the South. The peninsula's principal shoreline embayments are Oil Bay and Dry Bay, both of which have been known to contain oil and gas seepages in their drainages. The seeps are located on the eastern limb of a faulted anticline and are from fine-grained sandstones and claystones of the Tuxedni Formation (Middle Jurassic). McGee (1972) estimated that the oil released from these seeps amounts to no more than 1-2 gal/day.

Evidence of early oil well drilling and oil and gas seeps is present in the Well - Bowser Creek drainage of Oil Bay, the Brown Creek drainage of Dry Bay, and the Fritz Creek drainage of Chinitna Bay (Figure 14). The Bureau of Mines surveyed these areas in 1973 to determine if the seeps were still active and if they were introducing any significant amounts of oil into the coastal environment (Blasko, 1976d).

Two abandoned wells and four intermittently active seeps were identified on Well Creek (Figure 15). These ponds were located at the base of a northeast-trending ridge. The oil, which occurred on pools of water, appeared to be thick and weathered; it clung to the edges of the pools and adhered to the vegetation (Blasko, 1976d). These pools drained into Well Creek and produced a floating sheen.

Stream samples indicated discharge of oil into Bowser Creek from the Well Creek drainage (Table 5) (Blasko, 1976d). Levels of 377 mg oil per liter water was measured 100 ft downstream of the junction of the two creeks. Levels

Table 4. Chemical characteristics of Stream Water at Oil Creek, Puale Bay, June 1973 (Blasko, 1976b). Concentrations are in mg/l.

Variable	Seep A[1]	Seep B[2]	Seeps A + B[3]	Creek Mouth
pH	6.3	6.8	6.9	6.7
Oil	3.3	3.6	0.2	<0.1
TDS[4]	68	68	91	44
Na	26	26	37	18
K	Trace	Trace	Trace	Trace
Mg	Trace	Trace	Trace	Trace
Ca	2	1	1	Trace
CO_3	0	0	0	0
HCO_3	37	31	67	24
SO_4	5	10	Trace	Trace
Cl	17	16	20	14

[1] Sample from drainage creek about 100 yd downstream from Seep A at head of Oil Creek.

[2] Sample from creek about 300 yd downstream from Seep B at head of Oil Creek.

[3] Sample from about 50 ft below juncture of drainages from Seeps A and B at head of Oil Creek.

[4] Total dissolved solids.

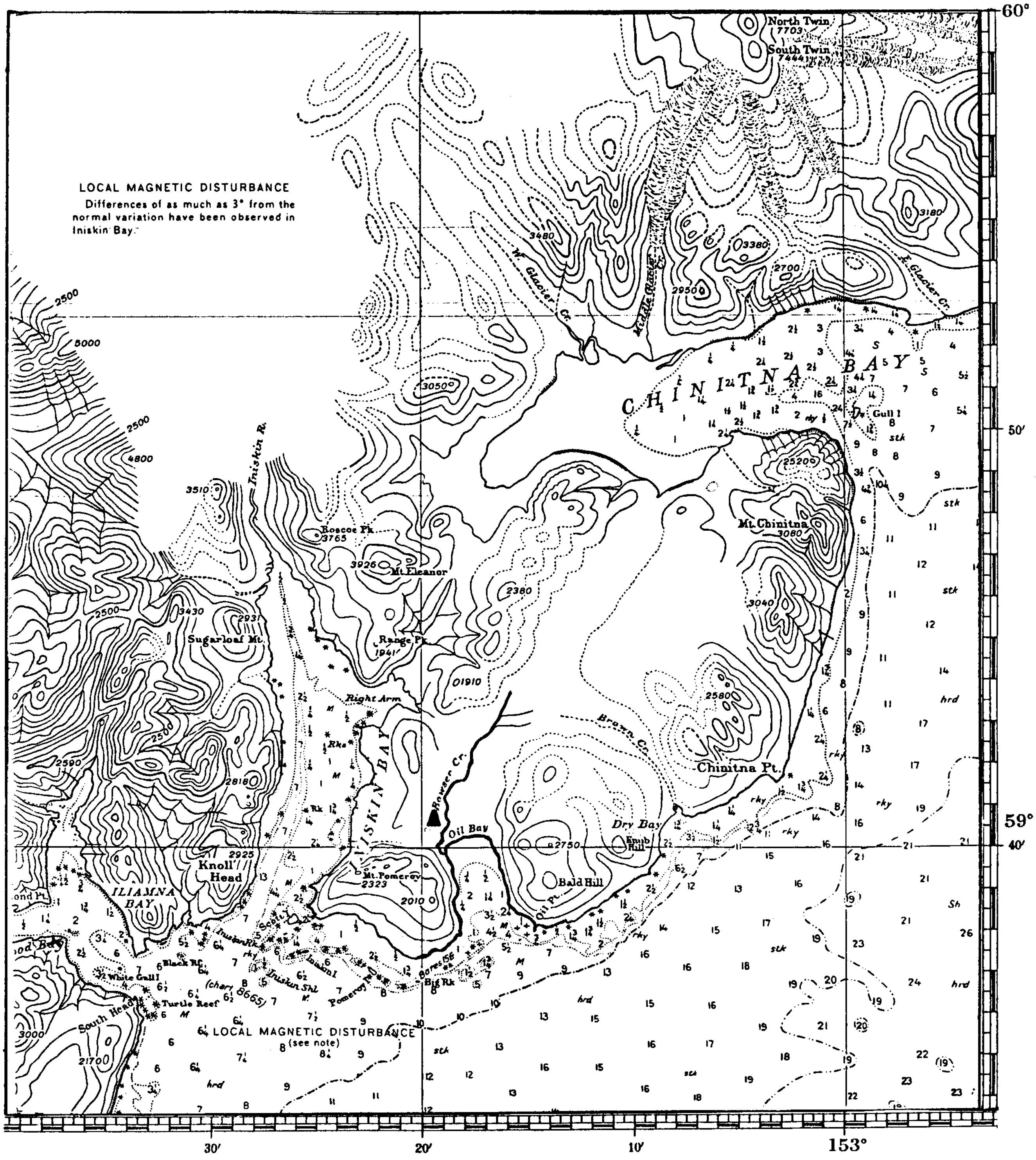

Figure 13. Iniskin Peninsula Oil Seepage Area.

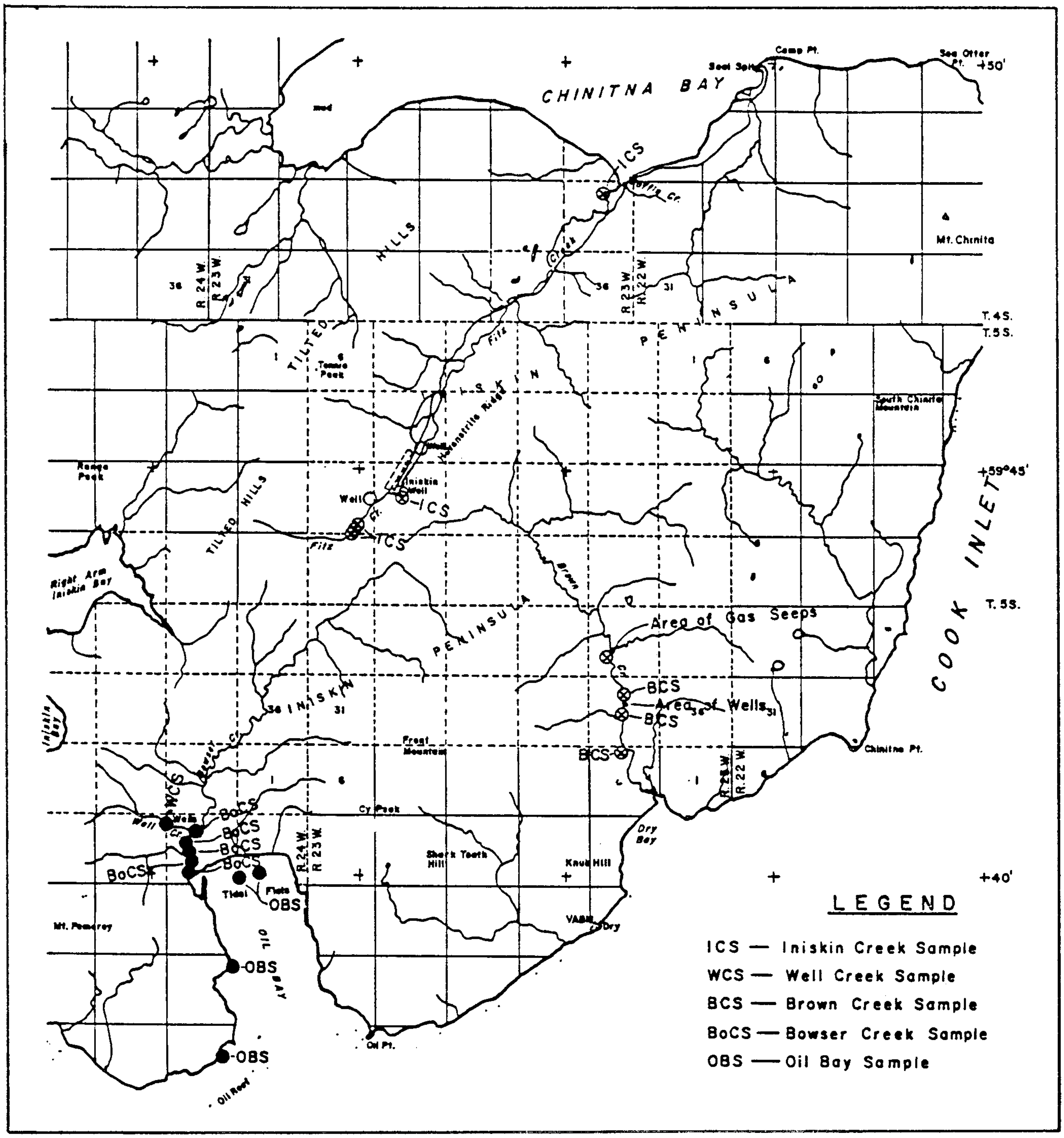

Figure 14. Oil Bay Oil Seeps, Iniskin Peninsula. (From Blasko, 1976d)

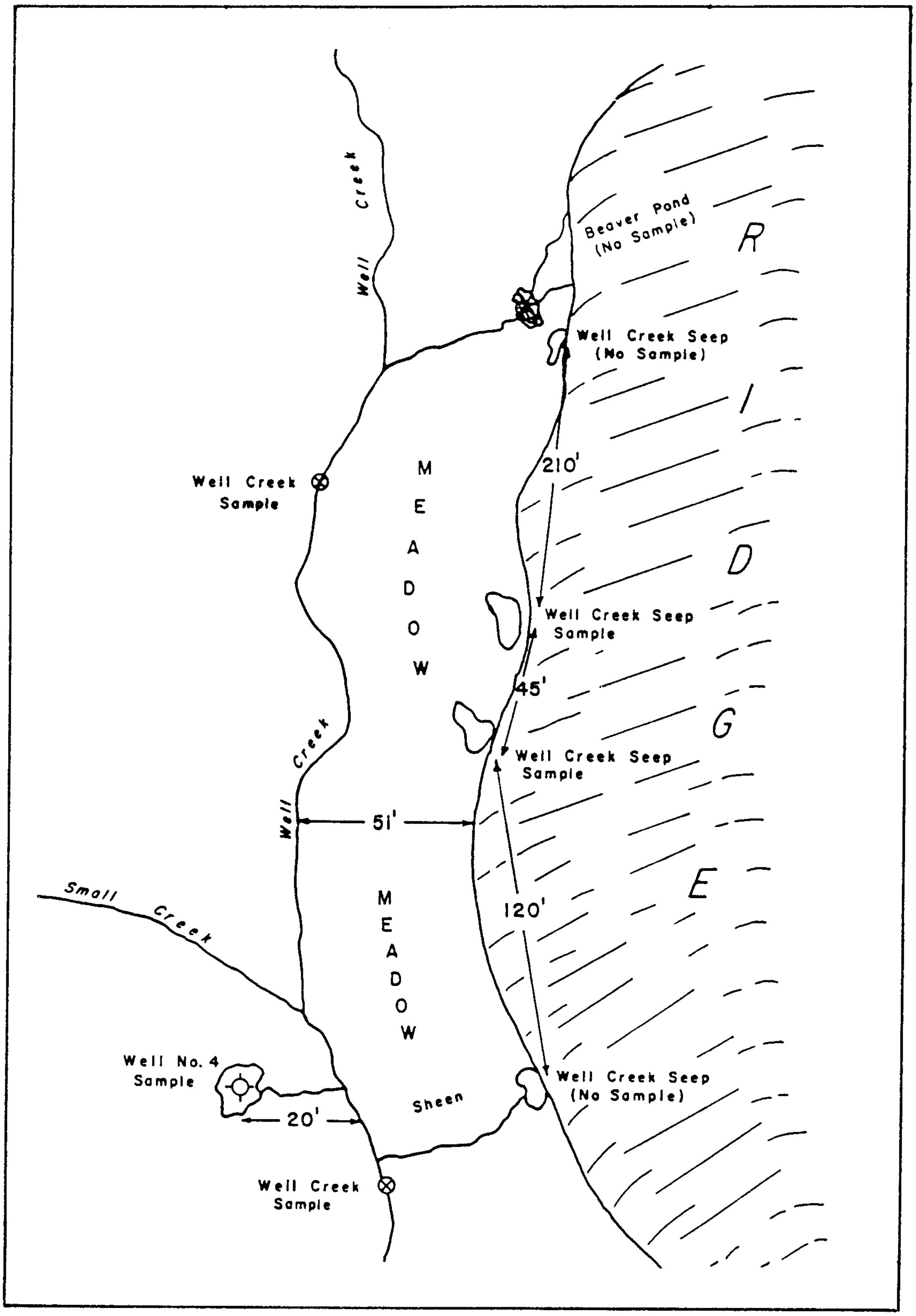

Figure 15. Oil Seeps on Well Creek, Iniskin Peninsula.(From Blasko, 1976d)

Table 5. Chemical characteristics of stream water at Iniskin Peninsula, June 1973 (Blaska, 1976b). Concentrations are in mg/l.

Variable	Bowser[1] Creek 1	Bowser[2] Creek 2	Bowser[3] Creek 3	Head of Oil Bay	Mouth of Oil Bay
pH	7.2	6.9	6.7	6.9	7.2
Oil	<0.1	377	14	0.1	<0.1
TDS[4]	122	103	835	7888	27,716
Na	43	36	285	2584	9,754
K	Trace	Trace	11	187	430
Mg	Trace	Trace	16	230	498
Ca	5	5	5	25	56
HCO_3	48	41	49	111	134
SO_4	12	8	66	7	12
Cl	38	34	428	4800	16,900

[1] 100 ft upstream of juncture of Well Creek and Bowser Creek.

[2] 100 ft downstream of juncture of Well Creek and Bowser Creek.

[3] 200 ft upstream at mouth of Bowser Creek at low tide.

[4] Total dissolved solids.

dropped to 14 mg/l near the mouth of Bowser Creek and 0.1 mg/l at the head of Oil Bay at the mouth of the creek. Sediments collected at the head of Oil Bay, about 100 yds east of the mouth of the creek had an oil content of 8.0 mg/kg. Reconnaissance of the beaches from Oil reef to Oil Point at high and low tides did not reveal any seeps or evidence of oil.

Although gas seeps were observed and sampled during the 1973 survey of the Bureau of Mines, no oil seeps were found in the Brown Creek drainage or in Dry Bay (Blasko, 1976d). The Fritz Creek drainage contains several abandoned exploratory wells but no oil or gas seeps. Blasko (1976d) indicated that, although some oil appears to be entering the creek from these abandoned wells, no significant amounts were reaching Chinitna Bay during the Bureau of Mines survey. The author also noted that the amount of release appears to be directly related to the amount of rainfall and the runoff through the drainage system.

Katalla, Controller Bay

This coastal seepage area extends along an eastward-trending belt about 25 mi long and 4-8 mi wide (Figure 16). This zone lies along the north shore of Controller Bay, extends to the east into the alluvial flats of the Bering River and to the west into the Copper River flats (McGee, 1972). Miller et al. (1959) reported that at least 75 oil seeps and 11 gas seeps have been observed in this area. Martin (1908) reported several large oils seeps on the banks of Mirror Slough near the mouth of the Martin River and had seen oil on the north beach of Strawberry Harbor. He also indicated surface accumulations of oil on the tide flats between Burls Creek and the mouth of the Bering river. Rosenberg (1974) pointed out that the nine-foot shoreline uplift during the 1964 earthquake has removed all of these sources to well above tidal influence.

Reimnitz (personal communication as cited in Johnson, 1971) indicated personal observations of a possible oil seep at tide level. This was in the vicinity of the Copper River Delta where oil was observed to be seeping near the level of mean higher high water in a salt marsh. This oil appeared to be flushed out of the marsh during the outgoing tide.

Nearly all of the reported seeps are located in the outcrop of the middle part of the Katalla Formation of Middle Oligocene to Middle Miocene age (Miller et al. (1956). The largest seeps are associated with sandstones or conglomerates and usually with depositional or structural features (joints and bedding planes) (McGee, 1972).

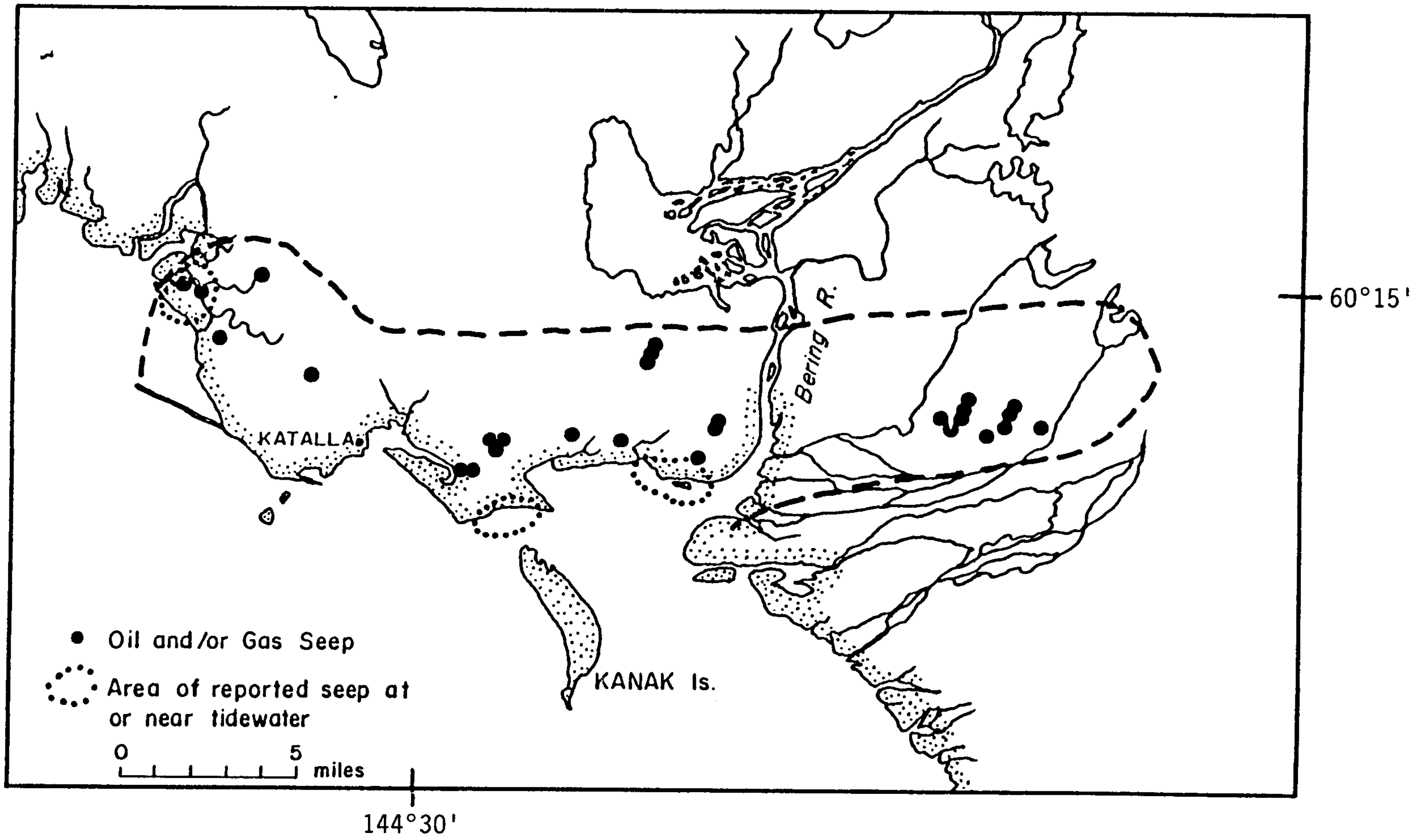

Figure 16. Katalla, Controller Bay Oil and Gas Seepage Area. (From Rosenberg, 1974)

According to McGee (1972), the abandoned oil wells in the Katalla area do not appear to be contributing oil to the coastal waters. The total quantity of oil issuing from the seeps in the area is 0.5-1.0 bbl/day (21-42 gal/day). Much of the light fraction of the 40°-45° API oil evaporates from the surfaces of the sloughs and ponds and the remainder appears to be absorbed into the soil. McGee (1972) estimated that <10% reaches the marine environment.

Most of the natural seeps in the Katalla area that have been reported in the literature were found to be active during the Bureau of Mines field surveys of 1973-1974 (Blasko, 1976c). The degree of activity varied from seep to seep. Some appeared to be dormant but showed some indications of past sporadic activity. Blasko found that determining seep activity in the Katalla oil field was very difficult because of past oil production there. The oil field had ponded water and most of the time these ponds were covered with an oil sheen. Analyses by the Bureau of Mines of streams draining the Katalla oil field indicated very small amounts of oil entering Katalla Bay via Katalla Slough (Figure 17) (Blasko, 1976c).

Mitcher Creek is located east of the Katalla oil field. It begins on the east side of Mount Hazelet and flows into Redwood Creek and then into Redwood Bay (Figure 18). An active seep was observed here by Blasko (1976c). Fresh oil was trapped by rocks near the edge of the creek; however, no oil was observed escaping from the creek bottom. Water collected downstream of the seep contained 7,130 mg/l of oil (Table 6). About 200 ft downstream of the site, the concentrations were found to have dropped to 10.7 mg/l, and at the mouth of Redwood Creek the levels were <0.1 mg/l.

Active oil seeps were also observed by Blasko (1976c) on Chilkat Creek. This creek drains a narrow valley west of the Bering River and discharges into Controller Bay (Figure 19). One seep was observed 0.5 mi upstream from the mouth of the creek. It was found to discharge into the creek and produce a sheen over an area of about 15 ft^2 immediately below the seep. The creek bottom from the seep downstream to its mouth was covered with a waxy precipitate. Oil concentrations in the water ranged from 73.9 mg/l at the seepage to 6.5 mg/l at the creek mouth (Table 6).

Yakataga

This area, which extends from Cape Yakataga to Icy Bay (Figure 20), contains probably the most extensive development of oil and gas seeps on the Gulf of Alaska coast. The surface evidence of petroleum in this area led to exploratory drilling during the periods 1926-1927, 1954-

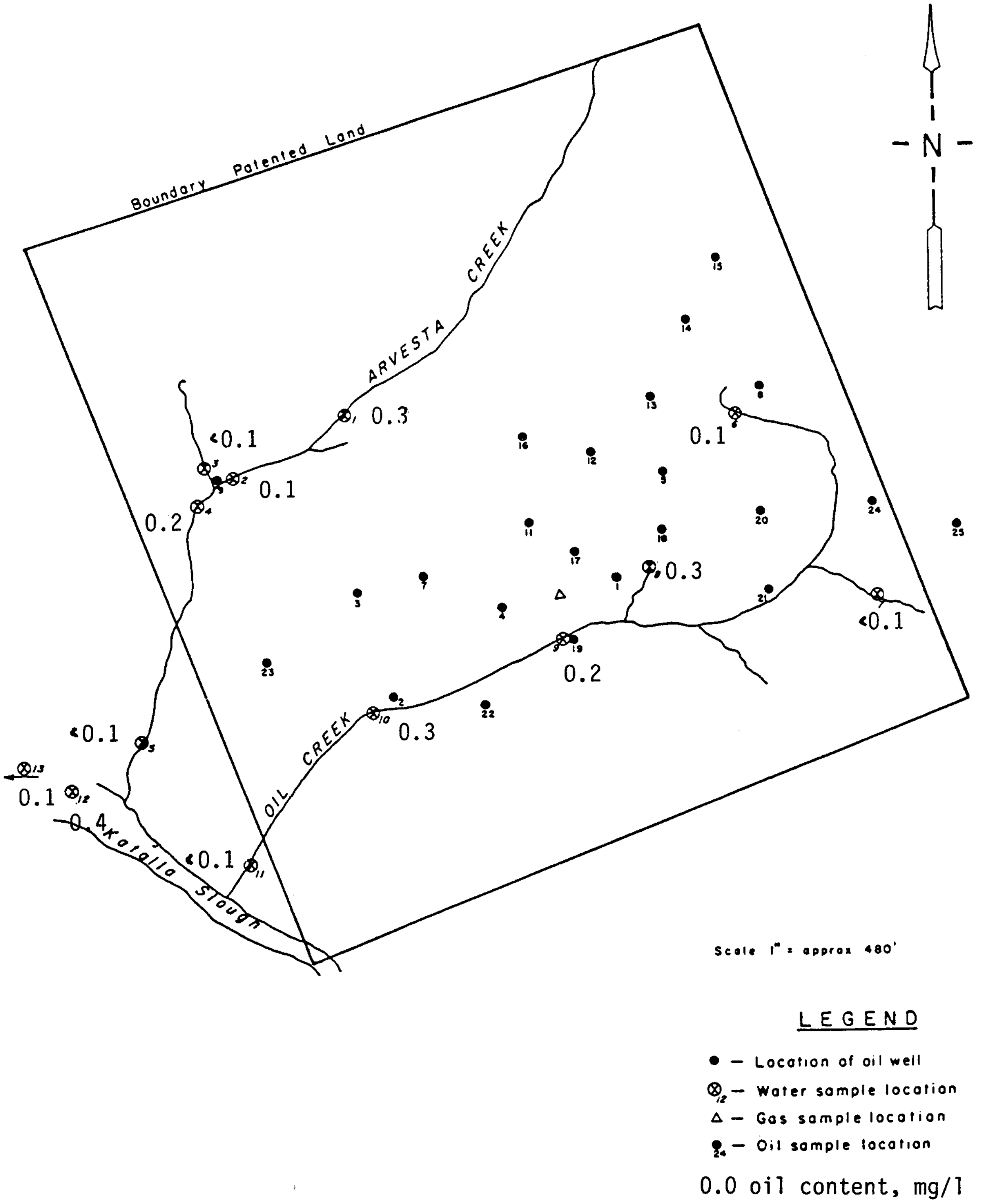

Figure 17. Stream Sampling Locations and Oil Concentrations, Katalla Oil Field. (From Blasko, 1976c)

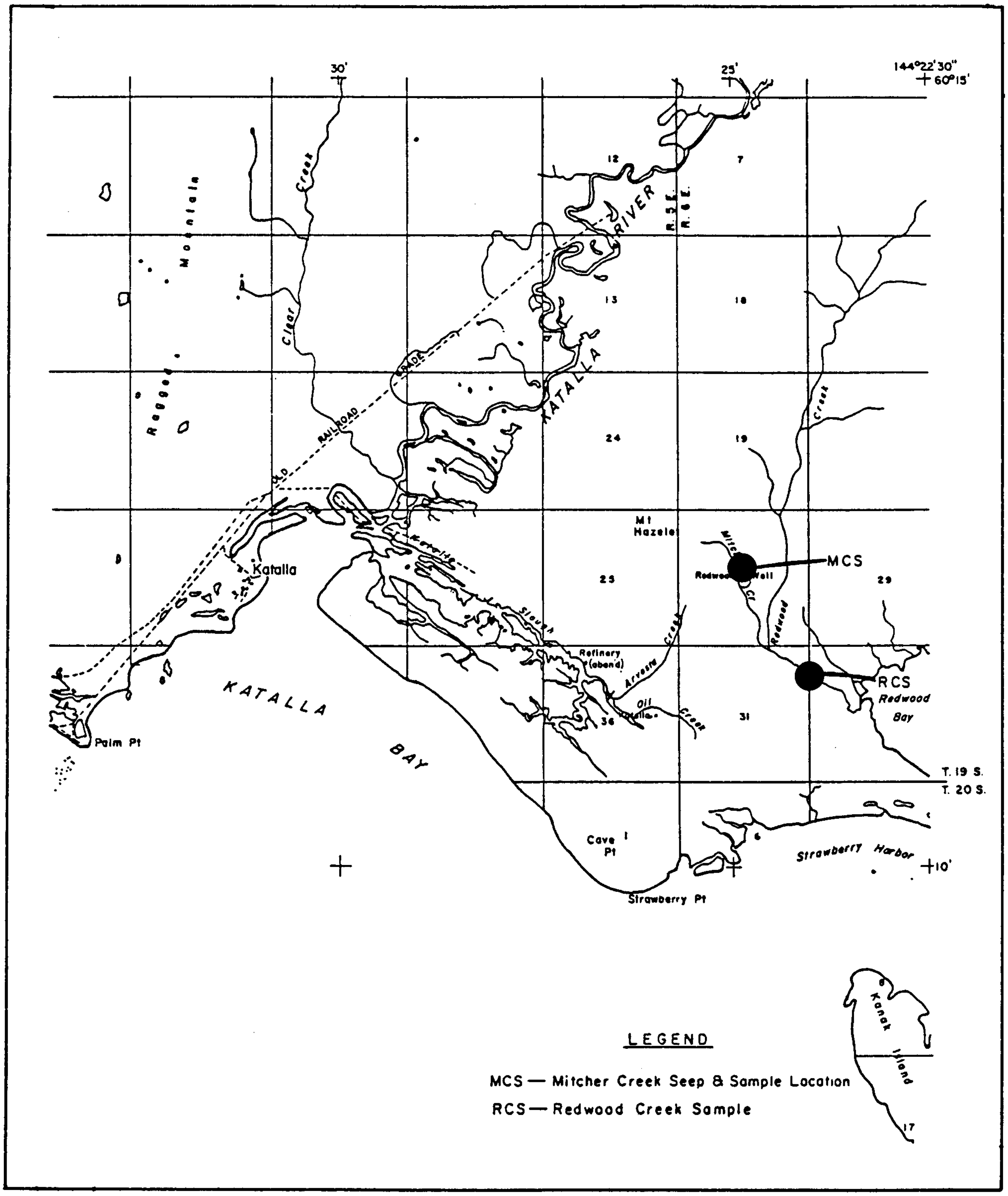

Figure 18. Mitcher Creek, Katalla Oil Seepage Area. (From Blasko, 1976c)

Table 6. Chemical characteristics of Streams in the Katalla, Controller Bay Oil Seepage Area, Sept. 1972 (Baska, 1976c). Concentrations are in mg/l.

Variable	Mitcher Creek 1[1]	Mitcher Creek 2[2]	Mitcher Creek 3[3]	Mitcher Creek 4[4]	Chilkat Creek[5]	Chilkat Creek 1[6]	Chilkat Creek Mouth
pH	6.7	6.6	6.7	7.1	7.0	6.5	7.0
Oil	7,310	<0.1	10.7	<0.1	73.9	182	6.5
TDS[7]	97	67	48	53	97	97	92
Na	25	15	7	14	17	20	19
K	1	1	trace	1	2	2	1
Mg	2	3	2	1	3	3	3
Ca	11	5	8	5	14	11	11
HCO_3	90	37	29	37	62	62	62
SO_4	8	17	11	8	18	18	15
Cl	6	8	6	6	12	12	12

[1] Below seep.
[2] Above seep.
[3] 300 ft downstream of Site 1.
[4] Mouth of Redwood Creek before draining into Redwood Bay
[5] At seepage 0.5 mi upstream from mouth
[6] 1,000 ft downstream of seepage
[7] Total dissolved solids

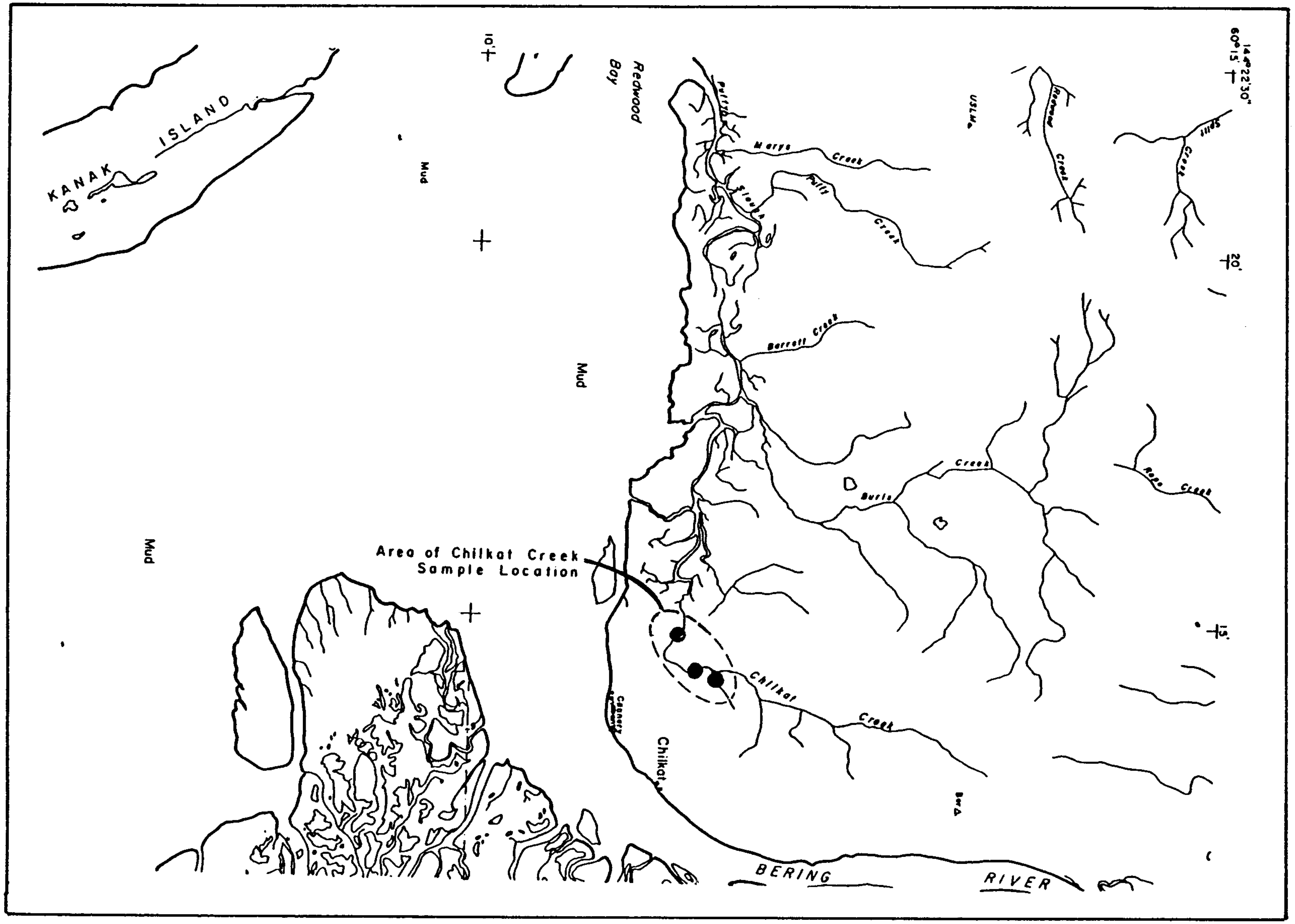

Figure 19. Chilkat Creek, Katalla Oil Seepage Area. (From Blasko, 1976c)

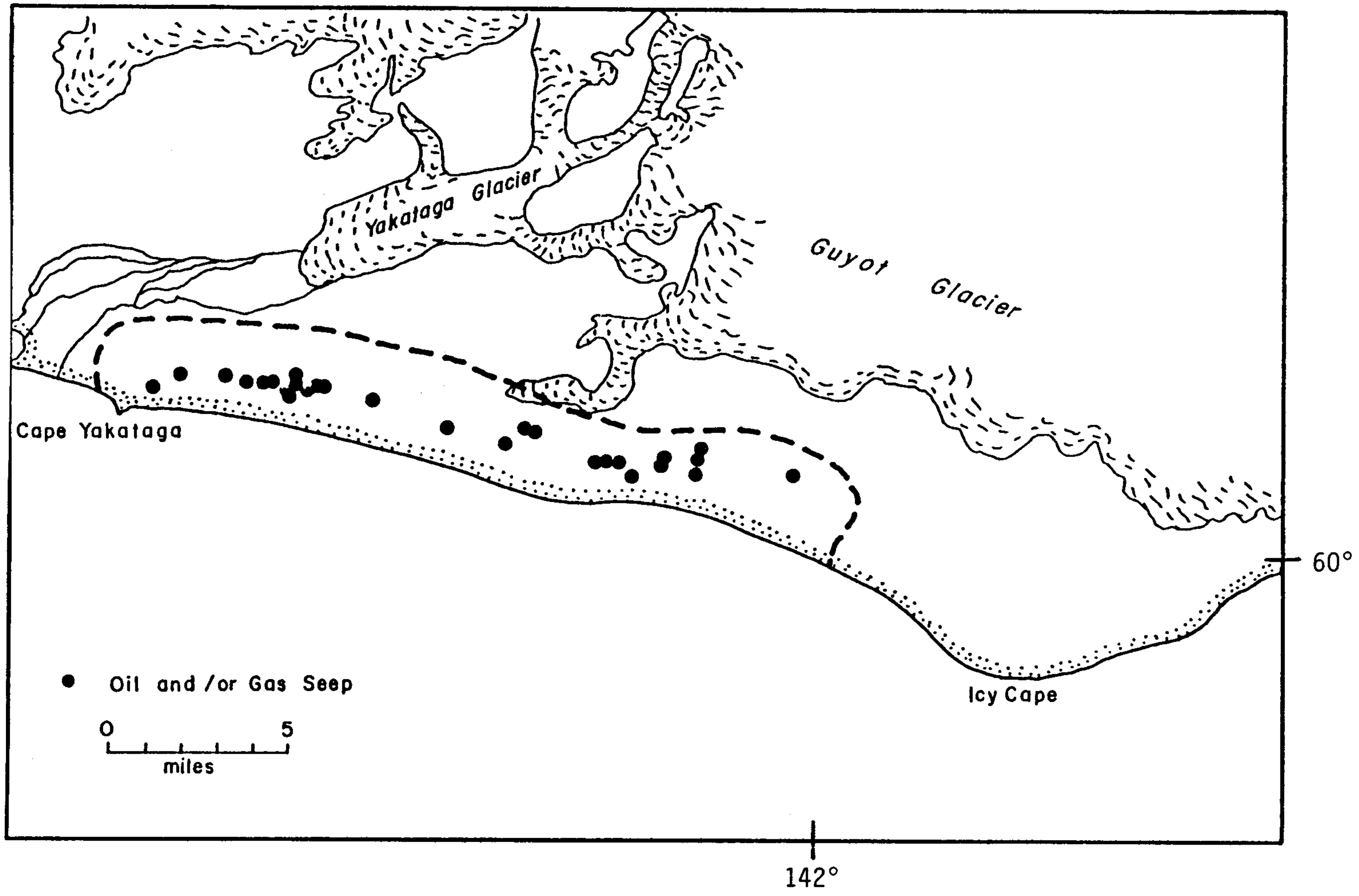

Figure 20. Yakataga Oil and Gas Seepage Area. (From Rosenberg, 1974)

1955, and 1959-1962 (Blasko et al., 1976c). There were no commercial finds.

Oil and gas seeps have been found on almost all of the rivers draining the Sullivan anticline (Blasko, 1976c). The Sullivan anticline runs parallel to the shoreline and all of the seeps have been reported to occur on the crest of the fault plane of this anticline, 0.5-2 mi inland. They are in areas of outcrops of the Poul Creek Formation (Miocene) and the lower part of the Yakataga Formation (Miocene - Lower Pliocene).

The map of Martin (1921) indentifies 10 seeps in this area. He indicated that the most prolific seep was on Johnston Creek and resulted in:

> "...appreciable quantities of oil are carried down its course to the ocean. A scum of oil residue also occurs on the cobble bars of Johnston Creek from its mouth up to the seepage. Probably a barrel or more of petroleum a day escapes from this seepage."

Active seeps have been reported through the years on One Mile Creek, Oil Creek, Hamilton Creek, Crooked Creek, Lawrence Creek, Poul Creek, Munday Creek, and Johnson Creek (Miller et al., 1959). Most of this oil discharges from joint cracks in sandstone and the quantity released is relatively small (McGee, 1972). Rosenberg (1974) also lists this area in his compilation of Gulf of Alaska petroleum seeps, citing 32 reported seeps based on Palmer (1971).

Known oil seeps were visited by the Bureau of Mines in 1973-1974 and samples were collected from seepages and stream water in order to characterize the oil and to determine how much is being discharged into the Gulf of Alaska (Blasko, 1976c). The following streams were included in this survey: Oil Creek, Crooked Creek, Lawrence Creek, Munday Creek, Poul Creek, Johnston Creek, Little River, Yakataga River, White River, Felton Creek, and Duktoth River (Figure 21). All of these creeks were walked from head to mouth, and the entire beachline from Yakataga to Icy Bay was observed in segments on foot several times.

Blasko (1976c) found that most of the seeps previously reported in the area were still active (Crooked Creek, Lawrence Creek, Munday Creek, Poul Creek, and Johnston Creek), but the amount of oil actually reaching the Gulf of Alaska was relatively small (Table 7). Descriptions of the seeps are presented below:

Crooked Creek- active oil and gas seeps are located 1.5 mi upstream on the west side of the creek about 30 ft from the creek bank. Blasko (1976c) observed light-green oil

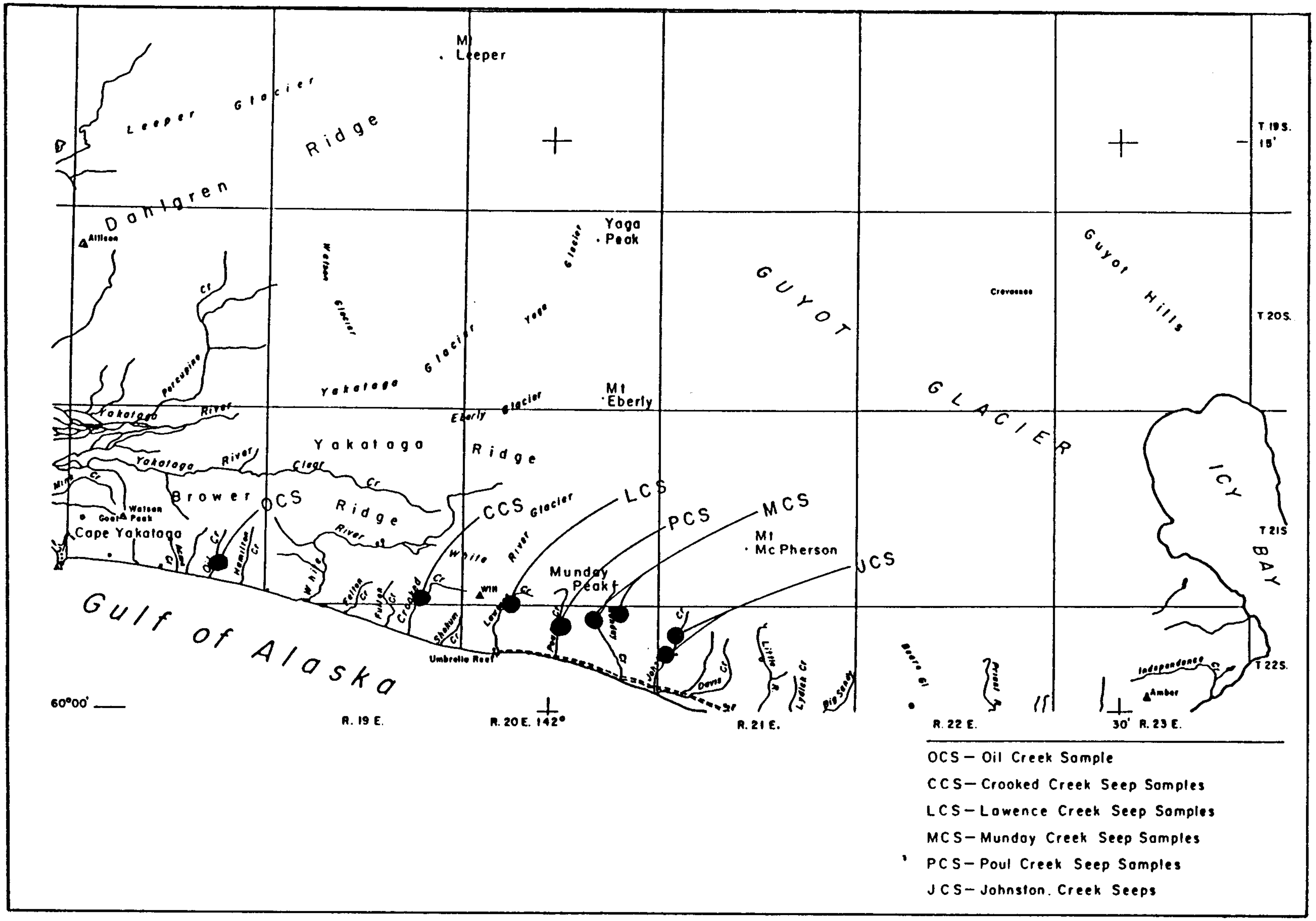

Figure 21. Stream Sampling Locations, Yakataga Oil Seepage Area. (From Blasko, 1976c)

Table 7a. Chemical Characterization of Streams in the Yakataga Seepage Area, July 1974. (Blaska 1976c) Concentrations are in mg/l.

Variable	Oil[1] Creek	Crooked[2] Creek 1	Crooked[3] Creek 2	Crooked[4] Creek Mouth	Lawrence[5] Creek 1	Lawrence[6] Creek 2	Lawrence[7] Creek Mouth
pH	7.6	6.7	7.2	7.1	7.8	7.4	7.5
Oil	0.1	3.2	1.6	<0.1	18.0	1.6	0.1
TDS[8]	204	595	91	82	213	76	73
Na	46	139	21	19	60	14	12
K	3	6	1	1	3	1	2
Mg	5	11	4	2	3	2	3
Ca	20	71	8	9	21	11	10
HCO_3	98	110	54	37	183	49	49
SO_4	56	2	11	9	4	14	12
CI	26	312	19	24	32	10	10

[1] 0.5 mi. upstream from beach

[2] 21.0° API; 0.90% S; sample from small stream that drains seep into Crooked Creek

[3] 200 ft below point where oil seep drainage enters Crooked Creek

[4] Mouth of Crooked Creek above entrance to Gulf of Alaska

[5] 12.9° API; 0.82% S; sample from small stream that drains oil seep into Lawrence Creek

[6] Below falls downstream of seep on Lawrence Creek

[7] Mouth of Lawrence Creek above entrance to Gulf of Alaska

[8] Total dissolved solids

Table 7b. Chemical Characterization of Streams in the Yakataga Seepage Area July 1974. (Blaska 1976c) Concentrations are in mg/l.

Variable	Munday[1] Creek 1	Munday[2] Creek 2	Munday[3] Creek 3	Munday[4] Creek Mouth	Poul[5] Creek 1	Poul[6] Creek 2	Poul[7] Creek Mouth
pH	6.8	7.0	7.2	7.2	7.7	6.9	7.1
Oil	3.7	1,336	0.1	0.1	114,800	8.3	0.1
TDS[8]	183	63	70	201	322	91	94
Na	47	12	16	44	78	20	15
K	2	1	1	12	7	2	3
Mg	4	2	2	4	10	2	3
Ca	19	9	8	17	29	10	13
HCO_3	98	48	49	73	256	49	49
SO_4	3	7	9	36	50	23	22
Cl	60	8	10	52	22	10	14

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[1] 17.2° API; 0.96% S; 100 ft downstream of seep on Mundy Creek
[2] Oil seep on east fork of Mundy Creek
[3] At mouth of east fork of Mundy Creek
[4] Mouth of Mundy Creek above its entrance to Gulf of Alaska
[5] 24.8° API; 0.68% S; at oil seep on Poul Creek
[6] 200 ft downstream of seep
[7] Mouth of Poul Creek above its entrance to Gulf of Alaska
[8] Total dissolved solids

Table 7c. Chemical Concentrations of Streams in the Yakataga Seepage Area July 1974. (Blaska 1976c) Concentrations are in mg/1.

Variable	Johnston[1] Creek 1	Johnston[2] Creek 2	Johnston[3] Creek 3	Johnston Creek Mouth	Johnston[4] Creek 4	Johnston[5] Creek 5	Johnston[6] Creek 6
pH	6.7	7.2	6.9	7.1	6.8	6.9	7.0
Oil	2,341	92.0	1.0	0.1	246,000	8.5	1.6
TDS[7]	162	91	67	118	705	72	874
Na	25	20	14	27	179	17	247
K	1	1	2	6	10	2	8
Mg	4	3	1	2	10	1	12
Ca	13	11	9	1	74	8	75
HCO_3	88	62	43	49	207	24	268
SO_4	10	3	11	18	20	2	trace
Cl	16	22	9	30	310	30	400

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[1] Lower seep - 15.4° API; 0.73% S; seep pond at discharge point

[2] Stream draining Johnston Creek from seep pond

[3] 300 yd above Johnston Creek Mouth

[4] Upper seep - 19.0° API; 0.70% S; sample from seep pond

[5] Stream draining from upper seep pond into Johnston Creek

[6] Johnston Creek, 100 ft below drainage stream

[7] Total dissolved solids

with gas bubbles emerging from the seep spring. A gas seep is located in a dry creekbed 10 ft east of the oil seepage.

Lawrence Creek- Several active and inactive oil seeps occur in a 600 ft^2 area of talus rubble on the east side of Lawrence Creek about 1.5 mi upstream from the mouth. Blasko (1976c) observed the sides of the creek and the creek banks downstream of the seeps to be oily with brown bitumen deposits occurring down to the creek mouth. Sheens were observed on the surface of the stream water. Blasko (1976c) stated that this area shows more evidence of oil seepage and transportation than any other between Cape Yakataga and Johnston Creek.

Munday Creek- An intermittent oil and gas seep is located 2 mi upstream from the creek mouth on the west side. Blasko (1976c) reported several greenish-black oil pools spread over a 50 ft^2 area. An active oil seep is located 0.25 mi upstream of the east fork of Munday Creek. Here Blasko (1976c) observed bubbles of oil emerging from the stream bed. A sheen was observed on the creek, although the stream was swift at the time with numerous riffles.

Poule Creek- numerous oil seepages (but no gas seeps) were observed in an area 1.75 mi upstream from the creek mouth. The seeps discharge oil directly into the creek at the water's edge.

Johnston Creek- two seepage areas were observed by Blasko (1976c) on Johnston Creek, which is a rapid, turbulent glacial stream. One seepage is located 1.5 mi from the mouth of the creek on the west side. It is in a marshy area of about an acre, 16 feet above the creek bed and consists of two ponds separated by meadows. Both oil and gas were reported by Blasko (1976c) to be released from this seep. For several hundred feet downstream from where the oil entered the creek, the rocks of the creek bed were observed to be covered with a thick layer of light-brown paraffin and a cover of black oil. Other seepages on Johnston Creek occur 0.25 mi upstream from the above seeps on the west bank of the creek.

Blasko (1976c) reported seeing oil on the beach only once and that was at the mouth of Johnston Creek. Blasko also observed that precipitation influenced the amount of oil entering the drainage from the seepage. Since the seeps on this creek are located in a pond about 15 ft above the creekbed, during heavy precipitation the water level rises and the oil accumulated on top of the water spills over the lip of the pond and into the creek. A sheen of oil at the mouth of the creek was most evident during heavy rainfall. The apparent heavy vegetative growth at the seepages observed by McCown et al. (1972 at Cape Simpson, Blasko

(1976b) at Puale Bay, and Blasko (1976b) at Katalla was also observed here.

Other Seepage Areas

A list of other oil seepages reported in Alaskan coastal areas is presented below:

Dease Inlet (Site 6- Figure 3; Table 1)
This seepage, commonly known as the "Admiralty Oil Seep," was first described by Ebbley and Joesting (Bureau of Mines, 1944) as being located on the east side of Dease Inlet, near the mouth of Chipp River, about 4.5 mi northeast of Thomas Brower's warehouse. The latter is indicated on U.S Geological Survey Map E of Alaska, 1954. This seepage area is also described in Miller, et al. (1959), Hanna (1963), Ball Associates, Inc. (1965), and Johnson (1971) and is indicated on the maps of Grantz et al. (1976; 1980) and Alaska Clean Seas (1983).

The seepage is a heavy black oil issuing from a low mound similar to that at Cape Simpson. Most of the oil has been exposed to the air and is hard enough to walk on. The API gravity was determined by Ebbley and Joesting to be 11.6° - 14.8° (Bureau of Mines, 1944). They also reported that, during their surveys, several hundred sackfuls had been mined by the local inhabitants for fuel.

Inglutalik River (Site 8- Figure 3; Table 1)
This seepage was reported by Miller et al. (1959) as being located in the Norton Sound region upstream of the Inglutalik River mouth. It is also listed in Johnson (1971).

Andronica Island (Site 9- Figure 3; Table 1)
This seep was reported by the USCG in 1913 to be in Cenozoic volcanic material on the eastern shore of Andronica Island (Johnson, 1971). The seepage is unconfirmed.

Chignik Bay (Site 10- Figure 3; Table 1)
Cited by Miller et al. (1959) and McGee (1972), but unconfirmed.

Aniakchak Area (Site 11- Figure 3; Table 1)
Cited by Martin (1921), Smith and Baker (1924), Miller et al. (1959) and McGee (1972), but unconfirmed.

Shelikof Strait (Site 13- Figure 3; Table 1)
This seep was reported to be located on the north shore of Shelikof Strait, 20 mi. southwest of Cape Douglas (Miller et al., 1959; McGee, 1972); however, the sighting is unconfirmed.

Douglas River (Site 14- Figure 3; Table 1)

A seep was reported by Martin (1905) from the upper Triassic Naknek Formation at the mouth of the Douglas River, Kamishak Bay; however, the sighting is unconfirmed (Miller et al., 1959).

Bruin Bay (Site 15- Figure 3; Table 1)

Oil seeps were reported by Martin (1905) at the entrance to Bruin Bay on the south side of Kamishak Bay. The sighting is unconfirmed (Johnson, 1972; McGee, 1972).

Iniskin Bay (Site 17- Figure 3; Table 1)

Oil seeps reported in Iniskin Bay by Moffit (1922) are unconfirmed (Miller et al., 1959).

Chinitna Bay (Site 18- Figure 3; Table 1)

Oil seeps reported in Iniskin Bay by Moffit (1922) are unconfirmed (Miller et al., 1959).

Tyonek and Mouth of Little Susitna River (Site 19- Figure 3; Table 1)

Oil seeps reported near Tyonek and at the mouth of the Little Susitna River (Martin (1921) are unconfirmed (McGee (1972).

Anchorage near Knik Arm (Site 20- Figure 3; Table 1)

Oil seepage was located near Knik Arm by Brooks (1922). A sample of this petroleum was collected and analyzed. No additional information is available. The seepage is probably no longer active.

Katalla Area East (Site 22- Figure 3; Table 1)

Seeps have been reported east of Katalla, but these have not been verified (McGee, 1972)

Samovar Hills (Site 24- Figure 3; Table 1)

Oil seeps exist on the north and west sides of Malaspina Glacier, the largest seep being on the northern margin of the glacier in the Eocene and Cretaceous strata of the Samovar Hills (Johnson, 1971). McGee (1972) estimated the total volume released from these seeps to be 2.5 bbl/day. This seepage area is documented by Rosenberg (1974) and Blasko (1976c) included it in his oil seep surveys and sample collections.

East Shore of Icy Bay (Site 25- Figure 3; Table 1)

These oil seeps have not been verified. McGee (1972) failed to find them during his surveys.

Lituya Bay (Site 27- Figure 3; Table 1)

A possible seep reported by Miller et al. (1959) to be associated with Tertiary sandstone on Topsy Creek is unconfirmed (McGee, 1972).

Cape Spencer (Site 28- Figure 3; Table 1)

McGee (1972) indicated that, although oil films have been reported near Cape Spencer, there is no reliable information indicating seeps are present in this area.

Admiralty Island (Site 29- Figure 3; Table 1)

In 1944 a prospector reported to the USGS that he had seen an oil seep near the southwest end of Admiralty Island, at a locality several miles inland from the head of Herring Bay. J.C. Roehm, in an unpublished report of the Territory of Alaska Department of Mines (1947) referred to oil-saturated black shale and an oil seep near the southwest end of Admiralty Island and to bituminous matter in limestone of Permian age on the Keku Islands (Miller, et al., 1955). These seeps are unconfirmed.

THE EVIDENCE FOR SUBMARINE OIL SEEPS IN ALASKA

The authors of this report found a limited amount of data in the available public record on the presence of submarine seeps in Alaska. All of the seeps described in the literature as associated with the Alaskan marine environment (Ball Associates, 1965; Johnson, 1971; McGee, 1972; Wilson, 1973; Landes, 1973; Rosenberg, 1974) are not subtidal but are associated with the coastal terrestrial environment, either not flowing into the sea (Angun Point), entering the sea through freshwater streams (Katalla, Yakataga) or located on a supratidal beach face (Skull Cliff). According to McGee (1972):

> "There are only four known active seep areas in proximity to Gulf of Alaska marine waters. The total amount of oil emitted by these areas is estimated to be 296 + or - gallons per day, most of which is evaporated or degraded by oxidation with the formation of hydrocarbon soils. The total amount of oil reaching the Gulf of Alaska marine waters is estimated at 10% of the total amount, or about 30 gallons a day. There are no known seeps within the Gulf of Alaska marine waters and there have been no reports of visual observations of oil films or tarry material that would indicate underwater oil seeps."

A statement quite similar to that of McGee's relative to the absence of reported submarine oil seeps in the Gulf of Alaska is also found in Rosenberg (1974).

Review of the literature, plus conversations with numerous agency and oil industry geologists indicates that, except for a possible site in the southeastern Bering Sea, there is no information available in the public sector identifying submarine oil seeps in the Alaskan OCS, including the Alaskan Arctic. All of the subtidal seeps that have been discovered in the World's oceans so far have been the result of observing obvious surface-floating oil globules and slicks. So far, none have been seen in the Alaskan Beaufort and Chukchi seas. Twenty-eight months of observations by USGS scientists in the Alaskan Arctic have recorded no obvious surface evidence of submarine oil seeps (Erk Reimnitz, Pers. Comm., 1988).

Hydrocarbon gases (C_1-C_4) have been found to be quite common in the surface sediments of the Beaufort Sea (Sandstrom et al., 1983). It is also believed that shallow gas (19-35 m depth) occurs quite extensively in this region (Craig et al., 1985). Shallow gas may be found in isolated pockets beneath permafrost, in association with faults that cut Brookian strata, and as isolated concentrations in the Pleistocene coastal plain deposits. Much of this gas may be biogenic in origin. Carbon isotope analysis of shallow gas collected from sediments at Flaxman Island indicated biogenic methane (Reimnitz, pers. Comm., 1988).

Of the several kinds of shallow faults identified on the Beaufort Sea Shelf, the shallow gas seems to be most commonly identified adjacent to high-angle faults along the Barrow Arch (Figure 22) which may act as conduits for gas migration (Craig et al. 1985). Such faults might also act as conduits for petroleum seepage.

Ventkatesan and Kaplan (1982) and Ventkatesan et al. (1983) in their review of the distribution and transport of hydrocarbons in surface sediments of the Alaskan outer continental shelf, found little evidence of surface or subsurface oil seepage. The exceptions were in Cook Inlet, north of Kalgin Island, and in the southeastern Bering Sea.

In the case of Cook Inlet, bottom sediments at a location north of Kalgin Island (60°34'N: 151°49'W) (Figure 23) contained an alkane distribution with a broad UCM over the entire boiling point range which is typical of weathered petroleum. In addition, an anthropogenic source of hydrocarbons was also indicated by the presence of a triterpenoid suite similar in pattern to Cook Inlet crude oil. Although the presence of an oil seep was not excluded by the authors, Ventkatesan and Kaplan (1982) suggested that these compounds could have originated from petroleum production in the upper Cook Inlet. Considering the relatively long history of oil production in the upper inlet, the latter source is very likely. Interestingly, this site is at the same location as the most western tidal rip which was observed to trap the crude oil spilled during the GLACIER BAY incident of July 1987.

Although no submarine oil seeps have been reported from the Bering Sea, sediment geochemical studies have indicated the presence of weathered crude oil from sediments at one location in the southeastern Bering Sea (station 35 - 56°12'N: 168°20'W, Figure 24) (Ventkatesan et al., 1981; Ventkatesan and Kaplan, 1982; Ventkatesan et al., 1983). Gas chromatograms of the hexane extract from these sediments, sediments from two other locations in the Bering Sea, as well as weathered oil contaminated sediments from the San Pedro Basin of California are presented in Figure 25. The n-alkane distribution with a broad UCM over the entire boiling point range is typical of microbial degraded petroleum. In addition, the titerpenoid distribution (Figure 26) and the delta ^{34}S value for the organic sulfur (about 10% more positive than the other samples from the eastern Bering Sea) are consistent with the n-alkane distribution in these sediments and suggest the presence of thermogenic hydrocarbons.

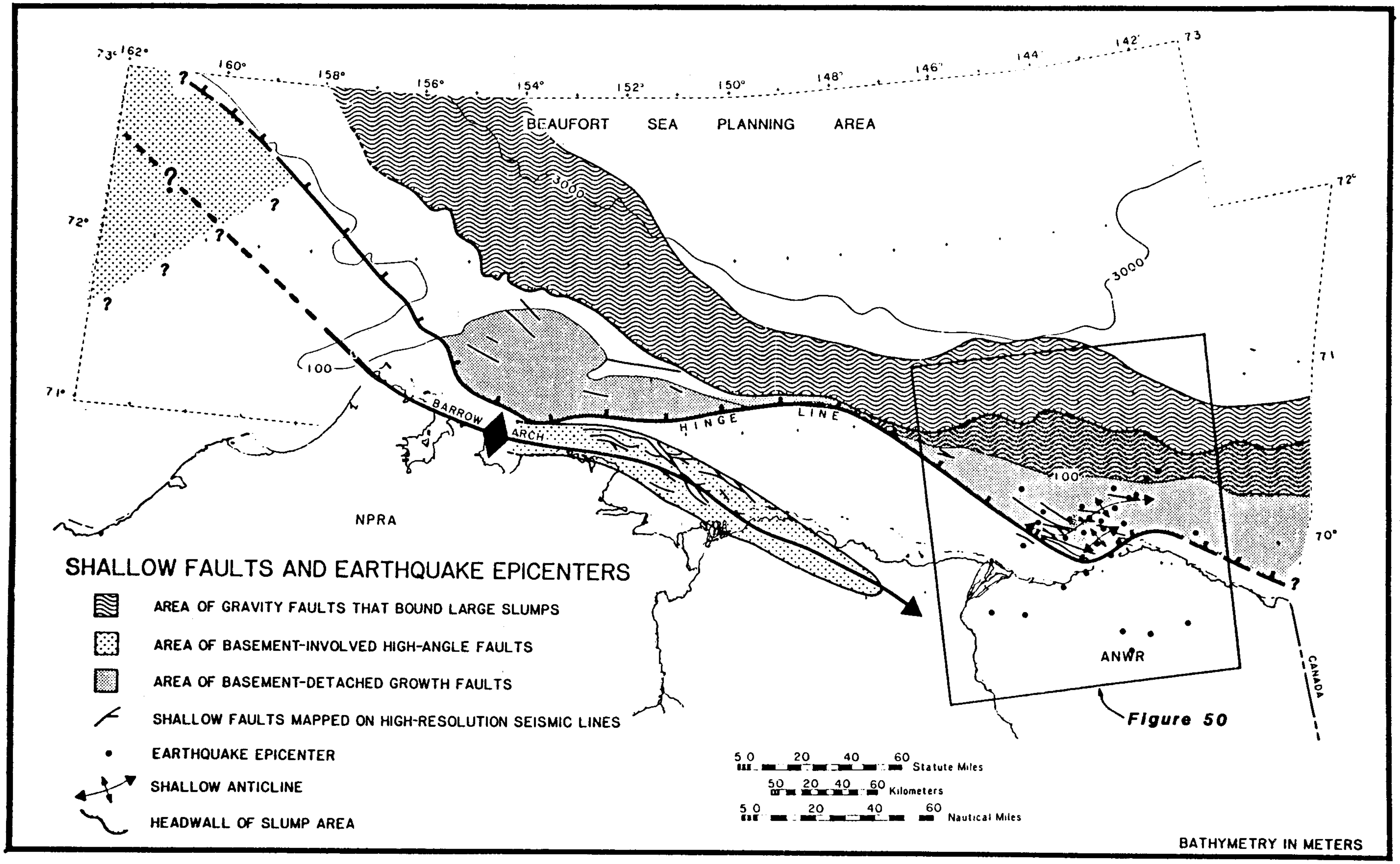

Figure 22. Shallow Faults, Mapped or Expected in the Beaufort Sea. From Craig et al. (1985)

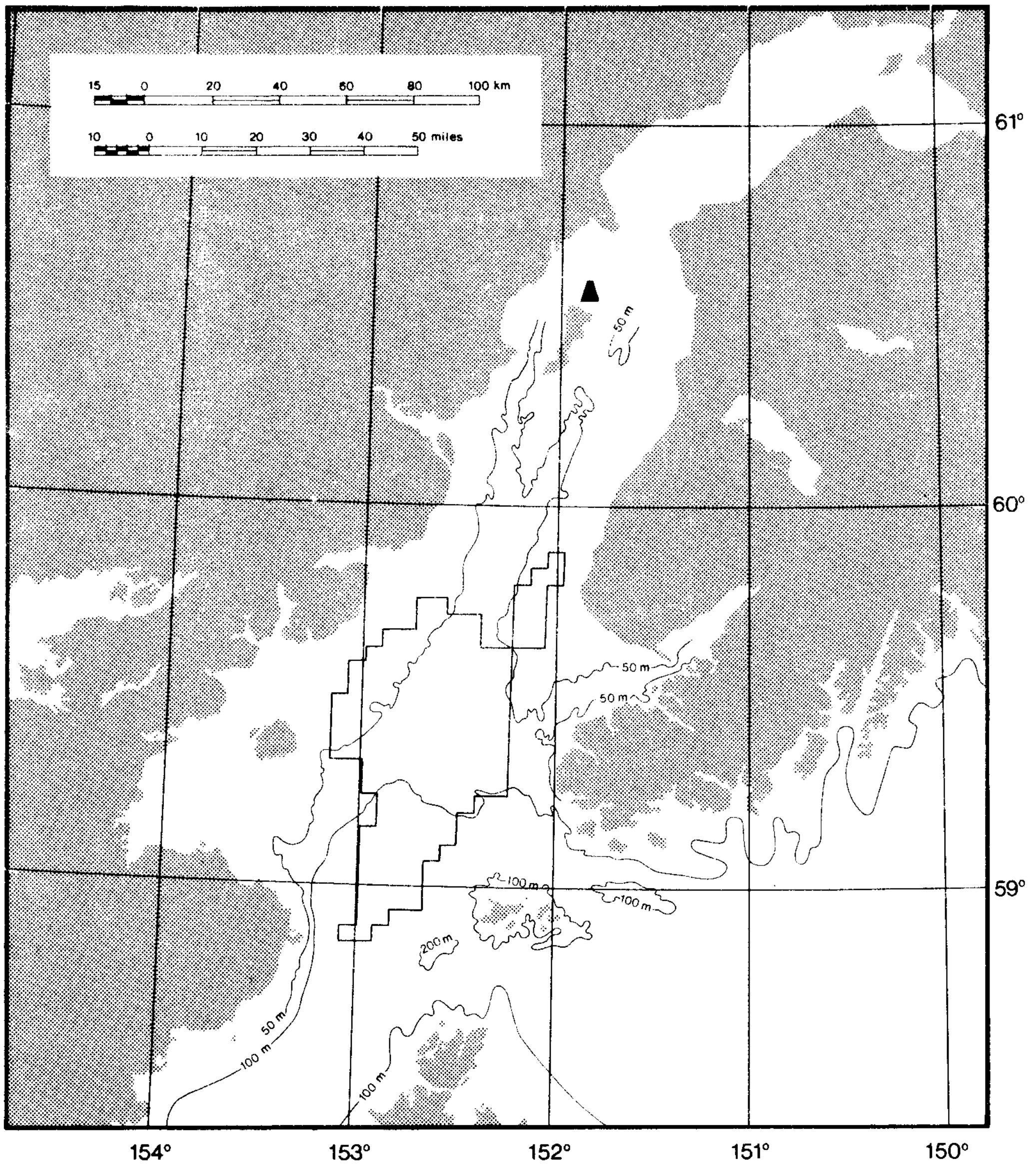

Figure 23. Locations of Elevated Levels of Anthropogenic Hydrocarbons in Sediments (▲) of Cook Inlet (Venkatesan and Kaplan, 1982).

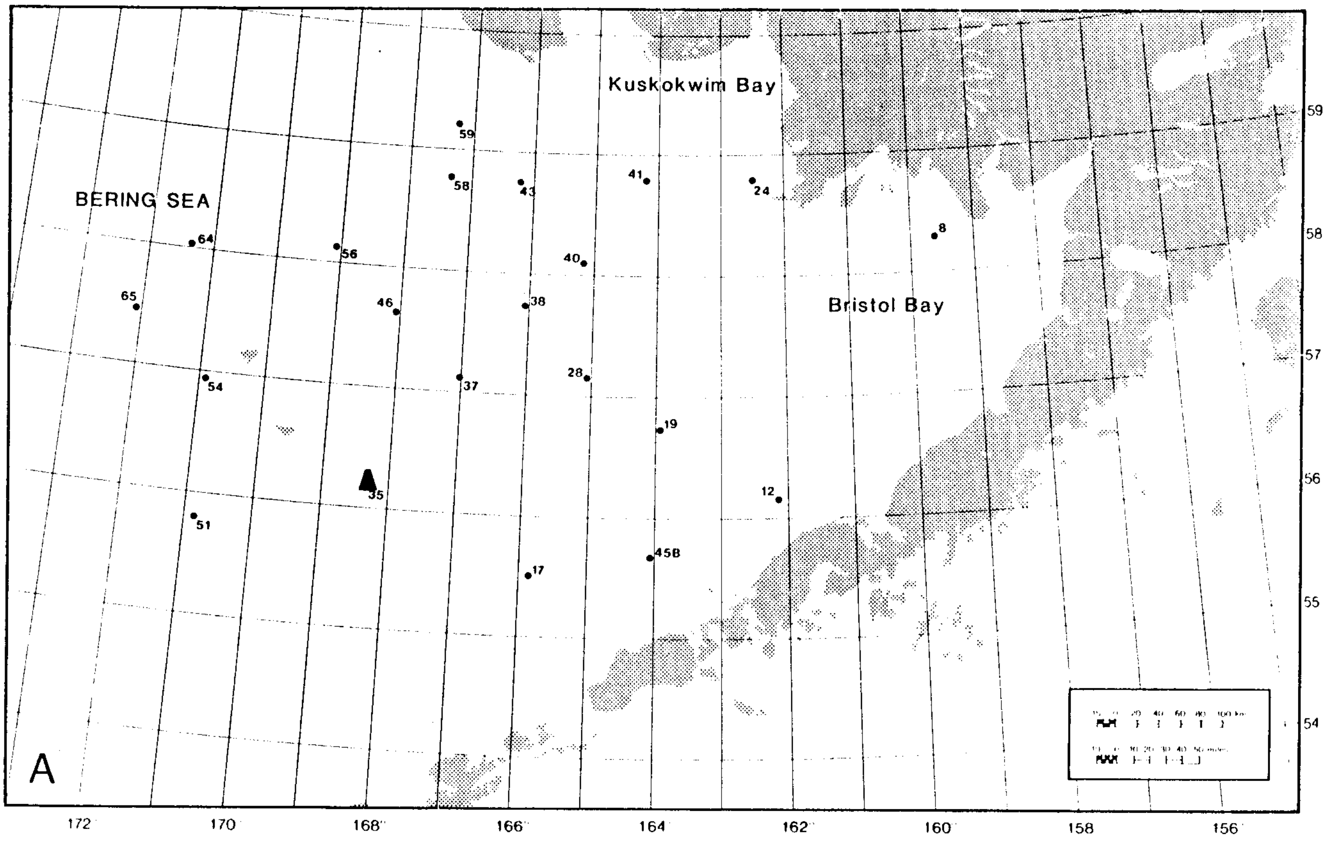

Figure 24. Locations of Elevated Levels of Anthropogenic Hydrocarbons in Sediments (▲) of the Bering Sea (Venkatesan and Kaplan, 1982).

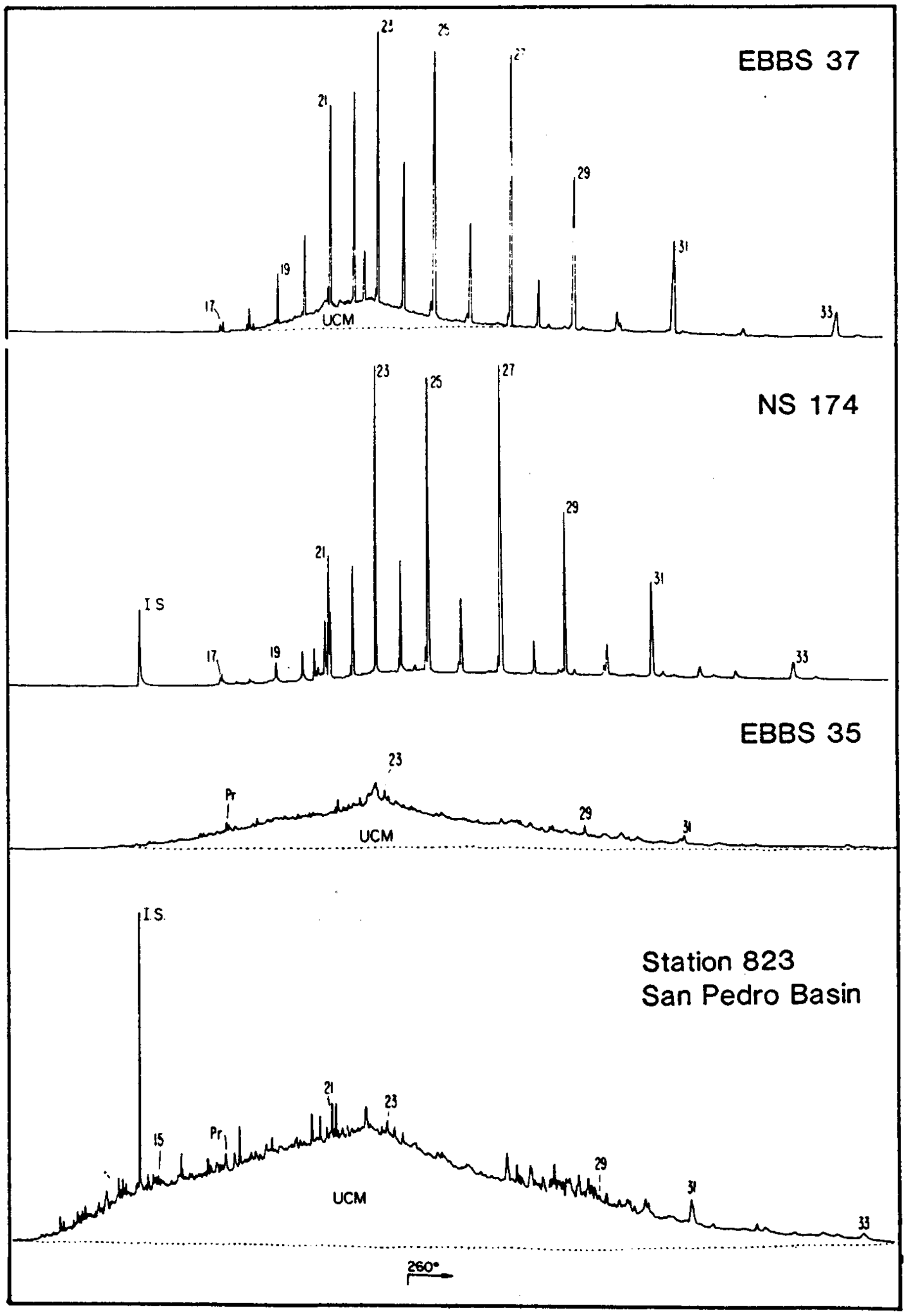

Figure 25. n-Alkane Distribution in Sediments from the Bering Sea and California (from Venkatesan et al, 1981). Gas chromatograms of hexan fraction from southeastern Bering Sea (EBBS) and Norton Sound (NS) sediments. Station 823 contaminated with weathered petroleum (Venkatesan et al., 1980). Numbers 15-33 refer to carbon-chain length of n-alkanes. Pr: pristane. UCM: unresolved complex mixture. LS: Internal Standard hexa-methyl benzene.

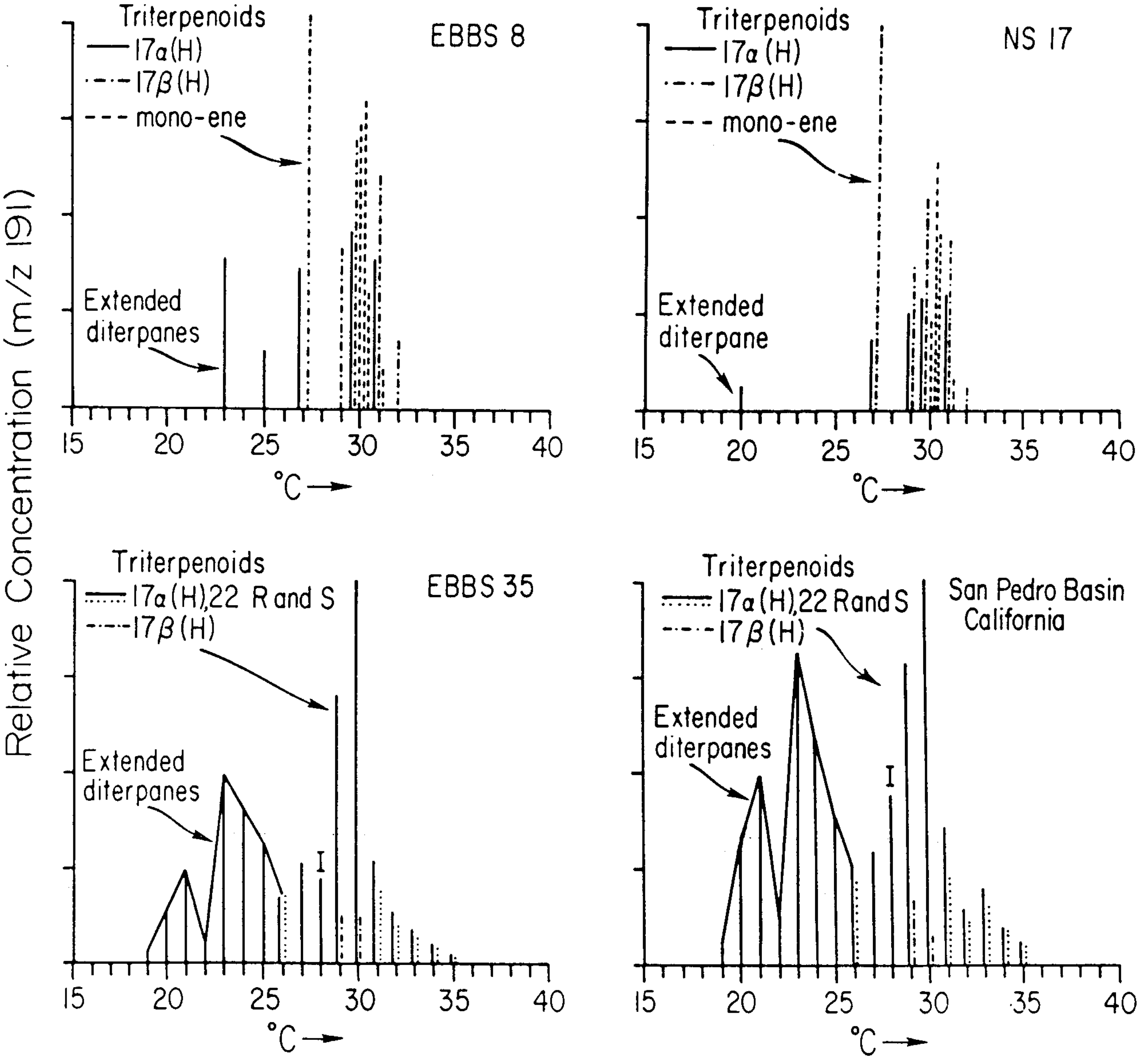

Figure 26. Diterpenoid and Triterpenoid Distributions in Sediments from the Bering Sea (from Venkatesan et al., 1981). Relative distribution histograms based upon m/z 191 mass chromatograms. EBBS = southeastern Bering Sea; NS = Norton Sound; San Pedro Basin = 20-25 mm core, Venkatesan et al., 1980. Diastereomers indicated by dotted and continuous lines. I is 17a(H), 18a(H), 21b(H)-28, 30-bisnorhopane.

It is possible that petroleum is being released from faults that occur in this area. Thermogenic gas was reported by Kvenvolden and Redden (1980) and Kvenvolden et al. (1981) from two locations near Station 35 (56°17.8'N: 168°14.28'W and 56°11.95'N: 168°20.01'W). However, there was no correlation between hydrocarbon gas and C_{15+} hydrocarbon content in those sediments from this site (Sandstrom et al., 1983).

Site 35 occurs at about the 200-m depth contour, in the Outer Shelf Domain at about the Shelfbreak Front (Kinder and Schumacher, 1981). Sediments from the area have been characterized as predominately sand (70 %) (Haflinger, 1981). Annual bottom-water temperature fluctuations are probably not as great here as occurs within the Middle Shelf and Coastal Domains due to the influence of the northwesterly flowing Bering/Alaska Stream water on the Outer Shelf Domain. Haflinger (1981) suggests that the benthic community associations in this area probably consist of stenothermal, Arctic-Boreal species. Multivariate statistical analysis of benthic species associations indicate that the area near Station 35 contains relatively small group (3-5 species) associations of ampeliscid amphipods, bivalves, and polychaetes (Haflinger, 1981). Infaunal standing biomass also appears to be relatively low (<75 g/m^2, wet weight; <4 g/m^2, infaunal organic carbon; Haflinger, 1981). If the Station 35 vicinity eventually proves to contain oil seeps, this site may prove useful in addressing the hypothesis of "organic enrichment" which is discussed in "Effects of Low Level Chronic Releases of Petroleum Hydrocarbons on Components of the Marine Ecosystem," this volume.

Based on anomalous levels of C_1 - C_2 gases measured by Cline and Holmes (1977) in Norton Sound (Figure 27), it was suspected that petroleum seepages were present south of Nome. Although of thermogenic origin, additional investigation (Venkatesan et al. 1981; Kvenvolden et al., 1979; Kvenvolden et al., 1981) indicated that the major compound in this seepage was CO_2. There was little hydrocarbon accumulation in the sediments, which was probably due to discrete gas vents piping hydrocarbons directly into the water column (Kvenvolden et al., 1981).

Several studies have been conducted on the distribution of hydrocarbons in the sediments of the Alaskan Arctic OCS (Shaw et al., 1979; Shaw, 1981; Kaplan and Venkatesan, 1981; Venkatesan and Kaplan, 1982; Venkatesan et al., 1983; Boehm et al., 1987) From these studies it is apparent that hydrocarbon concentrations in Beaufort Sea sediments are somewhat elevated over other outer continental shelf sediments. The compositions of the hydrocarbons are largely fossil derived (peat, coal and petroleum) and, therefore differ from most other shelf sediments.

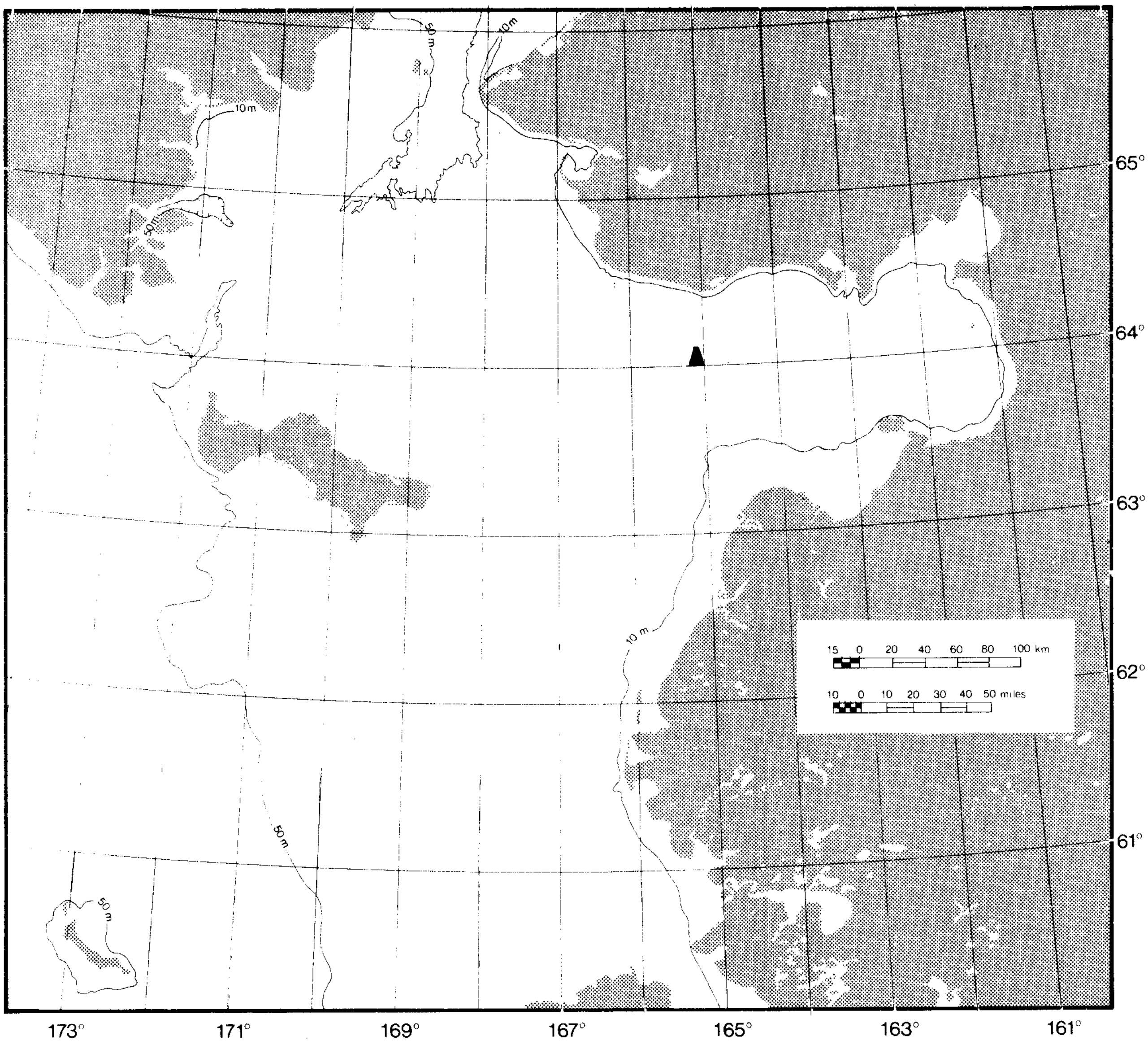

Figure 27. Location of Gas Seeps (▲) in Norton Sound (Kvenvolden, 1981).

Shaw, et al. (1979) examined the hydrocarbons in the nearshore sediments from Point Barrow to Barter Island and identified a suite of nearshore arctic sediments whose alkane composition suggested only biogenic sources. The saturated hydrocarbons were dominated by n-alkanes ranging in chain length of 23-31 C with strong odd-even preference and no UCM. Total hydrocarbon concentration in the nearshore area was 0.3-20 ug/g dry sediment. The range of total hydrocarbon concentrations in the offshore areas was reported by Kaplan and Venkatesan (1981) and Venkatesan and Kaplan (1982) to be 20-50 ug/g dry sediment. These differences in nearshore vs. offshore areas could possibly have been due to the differences in the methods used or to a greater abundance of fine-grained, organic-rich sediments in the offshore area.

In both nearshore (Shaw et al., 1979) and offshore (Kaplan and Venkatesan, 1981; Venkatesan and Kaplan, 1982) sediments, the distribution of saturated hydrocarbons indicated a prevalent biogenic input of terrigenous plant material, most likely resulting from transport of riverine materials. Some marine biogenic sources were indicated by the occurrence of pristane and n-heptadecane in the offshore sediments (Kaplan and Venkatesan, 1981; Venkatesan and Kaplan, 1982).

Measurable amounts of aromatic hydrocarbons have been found in almost all Beaufort Sea sediments examined so far. Ventkatesan and Kaplan (1982) indicated that Beaufort Sea sediments contain the highest PAH levels in the Alaskan outer continental shelf (200-300 ng/g), an order of magnitude above that of the Bering Sea and also higher than the Gulf of Alaska and Cook Inlet. Complex mixtures of aromatics (including PAH) have been found with distributions characteristic of both pyrolytic and fossil sources (Shaw, et al., 1979; Kaplan and Venkatesan, 1981; Venkatesan and Kaplan, 1982)). This was suggested by the distribution of akylated homologues determined by GC/MS.

Shaw et al. (1979) found that fossil aromatic distribution was most obvious at Smith Bay, Cape Halkett, Egg Island and Stockton Island (Figure 28). Pyrolytic signatures were most evident in the sediments of the Hulahula Delta, Anderson Point and Pitt Point. Those aromatics recognizable as of fossil origin were cadalene, retene and simonellite, products of minor diagenic alteration of terpenes. Only retene was a member of one of the homologous series investigated. It appeared in anomalous abundances in sediments of Smith Bay, Cape Halkett, Atigaru Point, Colville Delta, Oliktok, Simpson Lagoon, Egg Island, Stump Island, Cross Island, and Hulahula Delta. In their analysis, it was unclear to what extent diterpenoid aromatics were being produced from precursors supplied by

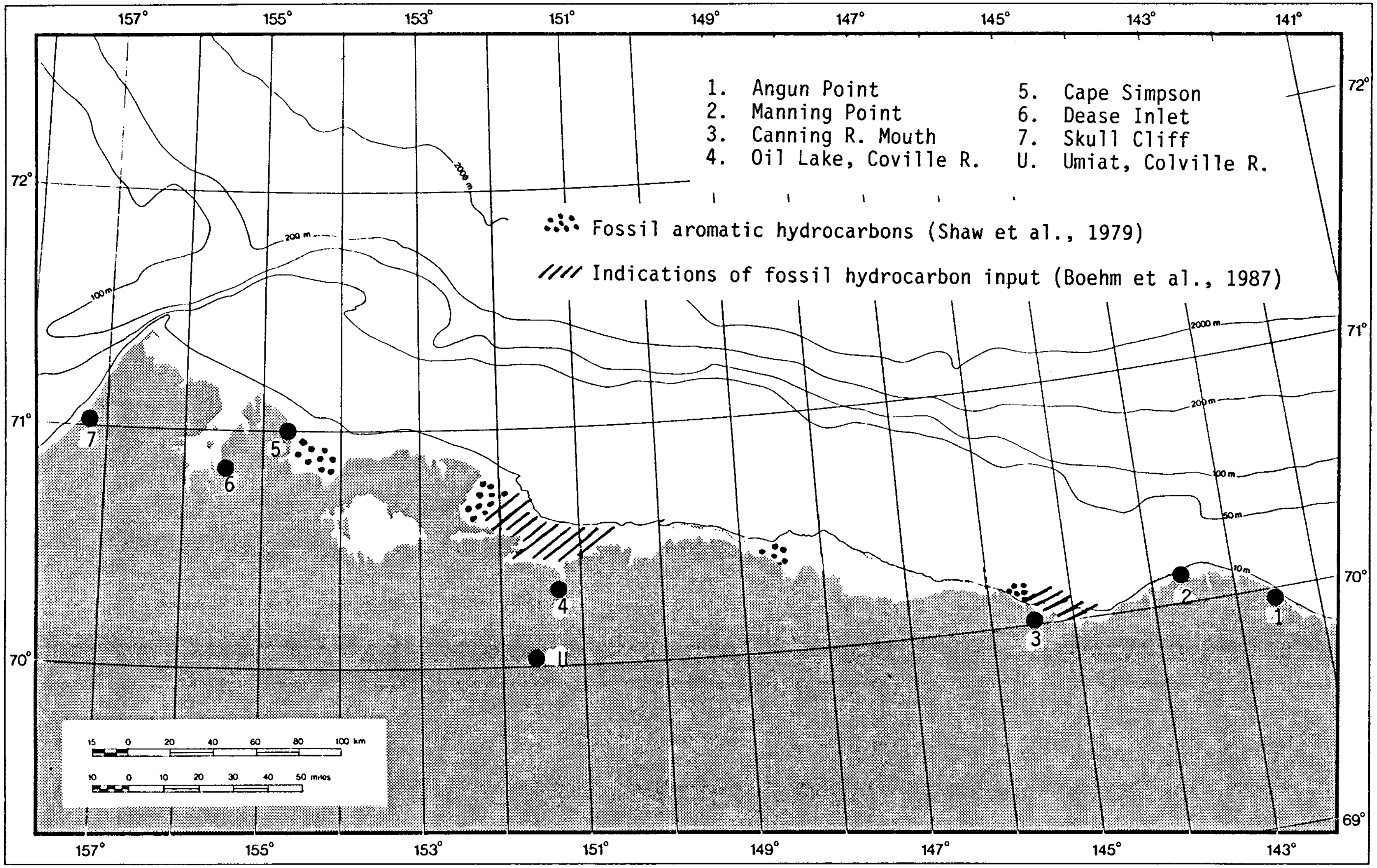

Figure 28. Coastal Seepage Areas on the Alaskan North Slope.

contemporary plants or were derived from sedimentary fossil hydrocarbons, such as peat, coal, and oil (seeps).

In a two year study of the hydrocarbons and metals of the Beaufort Sea, Boehm et al. (1987) found that the saturated hydrocarbon composition (determined by GC-FID analysis) was composed of an n-alkane distribution from n-C_{10} to n-C_{20} with no odd-to-even carbon dominance and and n-alkane distribution from n-C_{21} to n-C_{33} with a distinct odd-to-even dominance. The n-C_{10} to n-C_{20} alkanes appeared to originate in the rivers, possibly due to upstream fossil inputs, while the coastal peat samples contributed to the sediments throughout the study area and were rich in the higher molecular weight alkanes. There appeared to be no relationship between the distribution patterns of the PAH compounds and the saturated hydrocarbons.

The aromatic hydrocarbon distributions were fairly uniform with the 2- and 3-ringed naphthalene and phenanthrene series dominant (Boehm et al., 1987). In other continental shelf sediments not impacted by petroleum, the 4- and 5-ringed PAH usually dominate. It appears that this lower molecular weight PAH originates from river discharge (introducing fractions from peat, coal beds and oil seeps).

Sediment samples from Harrison Bay contained the strongest signals for fossil hydrocarbon input - PAH and lower molecular weight alkanes (Figure 8) (Boehm et al., 1987). This was attributed to input from the Colville River drainage basin, which contains numerous outcrops of coal and oil shale as well as oil seeps. For example, **Oil** Lake is located slightly west of the Colville and 5 mi from the coast (70°18'N: 151°09'W). This 1.5-mile-long lake is named for the natural seep oil that forms a slick on its surface. The organic material carried by the Colville River includes fractions of peat, coal, and oil.

Stations in the Harrison Bay region contained the greatest concentrations of hydrocarbons, with those in east Harrison Bay area, nearest the Colville River, having the highest values. This was also reflected in the PAH concentrations (2-3 ringed PAH). Unfortunately, no samples were collected in Smith Bay, therefore, indications of fossil hydrocarbon input presented by Shaw (1979) could not be confirmed with data from Boehm et al. (1987). The lower molecular weight n-alkanes characteristic of petroleum were found to be relatively high in the sediments discharged from both the Canning and the Colville rivers.

The general conclusion from this review is that the existing data base on the hydrocarbon constituents of the sediments in the Beaufort Sea can not be used to any great extent to locate areas of probable submarine seepage. This is basically due to the limitation in areal coverage of sampling stations, plus the fact that all areas of elevated fossil derived hydrocarbons which have been identified by this limited data base can be attributed to either known coastal terrestrial seepages or freshwater stream input from a variety of sources (known oil seeps in the river system, coal deposits, and peat).

DISCHARGE OF OIL FROM NATURAL SEEPS INTO THE ALASKAN MARINE ENVIRONMENT

It is difficult to estimate the volume of oil that might be entering the Alaskan marine waters via natural oil seepage. For the seepages located on the Arctic coast, only those at Skull Cliff and Manning Point appear to be directly entering the marine environment. The volumes of those discharges have not been determined.

Terrestrial erosion undoubtedly provides petroleum hydrocarbons to the Arctic marine waters through transport via freshwater streams, but no estimate of the magnitude of this input is available. Much of the oil is probably altered and oxidized during erosion and transport. It might also be difficult to distinguish petroleum hydrocarbons from coal-bed sources. Kvenvolden and Harbough (1981) estimated that, on a world-wide basis, only 10 percent of the erosional petroleum hydrocarbons actually reach the ocean.

McGee (1972) estimated the amount of natural oil seepage discharge to the marine waters of the Gulf of Alaska. His estimates for individual seeps were usually <1.0 bbl/day. His estimate of total discharge to the Gulf of Alaska from all known seeps was 7 bbl/day. This value is an order of magnitude less than the estimated 70-90 bbl/day released from the Coal Oil Point submarine seep off the California coast (Hunt, 1979).

EFFECTS OF LOW LEVEL CHRONIC RELEASES OF PETROLEUM HYDROCARBONS ON COMPONENTS OF THE MARINE ECOSYSTEM

The low level, chronic release of oil into the marine environment, such as may occur with oil and gas development and production activities, has been postulated to exert effects on the marine community ranging from organic enrichment to environmental toxicity (Spies, 1985). The resolution of this question is difficult as pertinent laboratory research requires a major long-term commitment from the researcher and the funding agency. The use of marine seeps as "natural laboratories", although replete with the problems typical of field studies, is a viable alternative to laboratory research.

A group of easily accessible, very active seeps near Coal Oil Point in the Santa Barbara Channel, California are the most extensively studied marine seeps in the world. Of this group, the Isla Vista seep, shaped like a rough oval approximately 10,000 m^2 in area, releases 50 to 100 bbl per day of petroleum into the Pacific Ocean, has been the focus of a series of long-term observations and field experiments (see Montagna et al., 1986 for references). Seepage within the oval is variable. There are many loci, ranging from approximately 0.25 - 2.0 m^2, of very active seepage. Between these loci are larger areas of less active but observable seepage. Gas bubbles are common and are often associated with the oil droplets. The seepage differs from the production oil pumped from similar formations farther offshore by virtue of its extremely low levels of n-alkanes and high levels of low-molecular-weight naphthenic compounds, suggesting bacterial degradation of the oil before it reaches the sediment-water interface (Reed and Kaplan, 1977; Figure 29).

The total extractable hydrocarbons in the sediments around the seep range from nearly 100% in source sediments to less than 1 ppt several kilometers "upstream", with an apparent median concentration (within 2 kilometers) of between 5,000 and 10,000 ppm. Total extractable hydrocarbons as well as the proportion of fresh petroleum can be quite variable in close-set samples depending on how many lumps of tar or oil droplets are included in the sample. Every core (0.019 m^2) taken at the seep station during a 28 month study of community structure by Davis & Spies (1980) contained at least a few drops of fresh oil, evidence that benthic organisms are brought into close contact with large amounts of petroleum. Most of the exposure however, appears to be to highly weathered asphaltic compounds and, except in heavy seepage areas or chance encounters with droplets in areas of moderate seepage, the exposure to the most acutely toxic and water soluble, mono- and di-aromatic petroleum compounds is in the low parts-per -billion range. The concentrations of

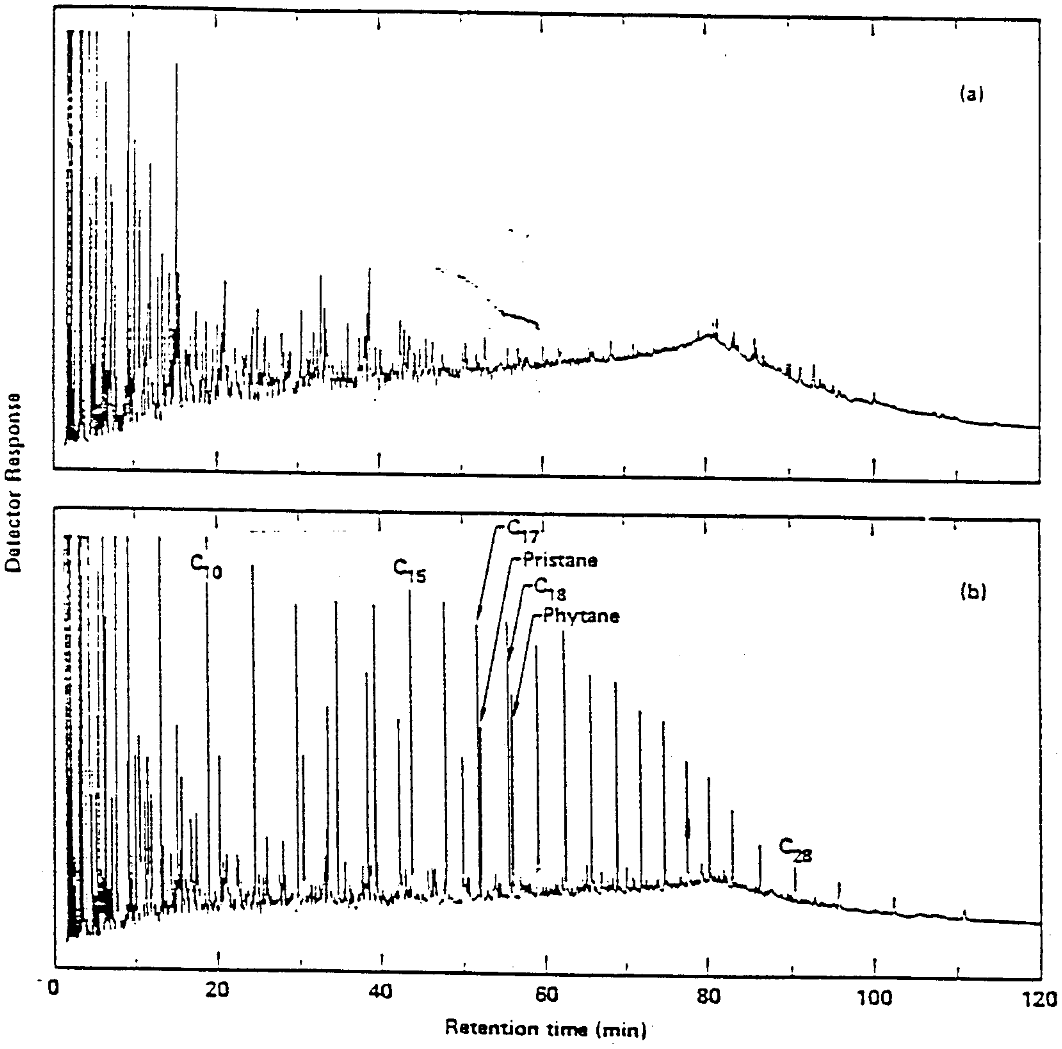

Figure 29. Gas chromatograms of crude oils: a) Isla Vista seep and b) Platform Holly, Monterey Zone. Note the large hump of the Unresolved Complex Mixture (UCM) that is indicative of microbially degraded oils in the Isla Vista seep oil. (from Spies et al. 1980)

these hydrocarbons are usually below 10 ppb in waters around the Coal Oil Point seep and are often in the <1 ppb range. The concentrations in interstitial water are more variable: in an area of intense seepage, an interstitial water sample had a concentration of 1.3 ppm (these limited areas are generally depauperate in numbers of individuals and species, Spies et al. 1980); in areas of moderate seepage, concentrations ranged from 45 to 117 ppb and in a non-seepage area, concentrations of 0.2 to 5.0 ppb have been observed (Stuermer et al. 1982).

The benthic community of the Isla Vista seep is well developed, with a typical structure and faunal composition for that region of the California coast. Comparisons of the seep community with a nearby non-seep community (Spies & Davis, 1979; Davis & Spies, 1980), however, demonstrated consistently higher numbers of individuals at the seep station than the non-seep station, even though the number of species at the seep station was only slightly higher. The dominant species, listed in Table 8, contributed a total of 58 and 52% of the individuals to the seep and comparison stations, respectively. Both sites had in common 72% of the 320 species collected, representing over 90% of the individuals. The remaining (site-specific) 28% or 90 species represented only 10% of the total number of individuals collected. Both areas had, on the average, similar values for diversity (H') although small scale fluctuations of Shannon-Weiner diversity were apparent; evenness was fairly constant and the differences seen were not consistent. Measures of skewness and kurtosis of the dominance-diversity curves were also quite similar, despite the density differences between stations and pronounced seasonal fluctuations (Davis and Spies, 1980).

Other, less striking differences between the two stations were:

1. An abundance of surface-deposit feeders at the seep station (14 of the 15 species considered). The seep station had one carnivore and 14 deposit-feeders (11 surface); the comparison station supported 3 carnivores, 1 herbivore, 6 surface-deposit feeders and 5 sub-surface feeders (Table 8).

2. The extreme dominance of oligochaetes, both individuals and populations, at the seep station.

3. Significantly fewer numbers of amphipods (5.9% of total) at the seep station as compared to the non-seep station (11.5%).

Spies et al. (1980) suggested that the differences in density and the numbers of surface deposit feeders at the

Table 8. Fifteen most abundant taxa from each station during study period (December 1975 - March 1978) near Santa Barbara, California. Abbreviations in parenthese denot A, amphipod; An, anthozoan; E, echinoderm; O, ostracod; Pe, pelecypod; Po, polychaete. (Davis and Spies, 1980)

Taxa	Density per core $(\bar{X} \pm S_{\bar{X}})$	
Seep Station:		
Oligochaetes	14.0 ± 7.3	
Tellina modesta (Pe)	12.1 ± 7.0	(1) [a]
Mediomastus californiensis (Po)	11.1 ± 7.6	(2)
Euphilomedes sp. (O)	9.4 ± 2.1	(3)
Prinospio pygmea (Po)	9.0 ± 4.2	(4)
Nematodes	8.5 ± 4.7	(5)
Chaetozone setosa (Po)	7.5 ± 4.9	(6)
Tharyx nr *tesselata* (Po)	6.7 ± 3.4	(7)
Tellina nuculoides (Pe)	4.2 ± 2.8	(8)
Nepthys caecoides (Po)	3.9 ± 3.4	(9)
Parvilucina approximata (Pe)	3.4 ± 3.3	
Ophiuroid	3.4 ± 2.6	
Edwardsia sp. (An)	2.8 ± 3.7	(10)
Neries procera (Po)	2.8 ± 1.5	
Pista disjuncta (Po)	2.6 ± 4.2	(11)
Comparison station:		
Nematodes	8.5 ± 5.4	
Euphilomedes sp. (O)	6.7 ± 1.7	
Prinospio pygmea (Po)	6.6 ± 4.7	
Chaetozone setosa (Po)	4.0 ± 3.2	
Tellina modesta (Pe)	3.4 ± 3.1	
Mediomastus acutus (Po)	3.4 ± 1.4	(15)
Paraphoxus abronius (A)	3.2 ± 2.4	
Typosyllis sp. (Po)	2.8 ± 0.8	
Mediomastus californiensis (Po)	2.7 ± 2.0	
Lytechinus pictus (E)	2.4 ± 4.2	
Thaianessa spinosa (Po)	1.9 ± 0.7	
Edwardsia sp. (An)	1.8 ± 2.9	
Exogone uniformis (Po)	1.7 ± 0.8	(13)
Megaiona piteikai (Po)	1.6 ± 1.9	
Tharyx nr *tesseilata* (Po)	1.6 ± 0.8	

---

[a] Thirteen of the 15 most abundant taxa common to both stations; not listed are No. 12, *Hemilamprops* sp. (cumacean) and No. 14, Hemicordata.

two stations were a reflection of microbially-mediated organic enrichment occurring as a result of the seepage. This hypothesis of increased microbial biomass associated with the H_2S and oil-laden seep sediments was based on gas chromatographs indicating extensive bacterial degradation of the n-alkanes in the seep oil (Reed & Kaplan, 1977) and the presence of extensive mats of the sulfide-reducing bacterium, *Beggiatoa sp.*, in areas of intense seepage. Experimental evidence for a gradient of increasing sediment ATP with increasing amounts of fresh oil also supports this hypothesis (Davis & Spies, 1980). More recent work (Montagna et al., 1986; Montagna et al., pers. comm.) has correlated bacterial abundance (as number of cells) and measurements of microbially-mediated benthic metabolism, e.g. rates of hydrocarbon degradation and sulfate reduction, with total extracted hydrocarbons (Table 9).

Evidence for the utilization of the seeping petroleum by the benthic community was provided by examination of the isotopic ratios of sulfur and carbon in the tissues of infaunal invertebrates from seep and non-seep stations (Spies & DesMarais, 1983). The seepage constituents are isotopically light with respect to carbonate: $g^{13}C = -24\%$ for whole oil and -38% for the gasses (Reed & Kaplan, 1977). Other sources of carbon in the marine environment are quite variable but generally consist of isotopically heavier carbon with less negative values of $g^{13}C$. So if the consistently denser populations in the seep truly result from trophic enrichment by petroleum that is isotopically light in carbon, then one would expect a shift in the $g^{13}C$ values of the seep organisms towards more negative values. The stable carbon-isotope abundances in *Beggiatoa sp.* and 12 infaunal invertebrates common to both the seep and comparison stations displayed $g^{13}C$ shifts ranging from - 0.22% for the cirratulid polychaete *Tharyx tesselata* to -4.5% for the maldanid polychaete *Axiothella rubrocinta* (Table 10). The mean shift for all species was -1.32% towards the petroleum $g^{13}C$ value. Interestingly, the development of a carbon budget for the maldanid polychaete, *Praxillella affinis pacifica*, indicated that the lighter hydrocarbons and gases, e.g. methane, were utilized more readily than the liquid oil (Spies & DesMarais, 1983).

Similarly, the presence of large amounts of isotopically light H_2S ($g^{34}S=1.7\%$) as compared to the heavier ($g^{34}S=20\%$) sulfur found in seawater and most marine organisms (Kaplan et al., 1960) provides a tracer of energy derived from the petroleum seepage. Sulfate reducers favor $^{32}SO_4{}^{-2}$ and low sulfur isotope ratios are indicative of biologically derived H_2S. The sulfur isotope ratios for *P. affinis pacifica* are lower at the seep station (12.27 compared to 14.11). The sulfur isotope ratio in the interstital H_2S at the seep station is lower yet (1.69) and lowest in *Beggiatoa* mat (-0.37) at this station (Spies & DesMarais, 1983).

Table 9. Grand averages of bacterial abundances, metabolic rates and total hydrocarbon concentrates in the sediments at Seep and Comparison sites in and near the Isla Vista petroleum seep in the Santa Barbara Channel. (modified from Montagna et al., 1986)

Process	Station	
	Seep	Comparison
O_2 Flux (mmol M^{-2} d^{-1})	-41	-12
Sulfate reduction[1] (mmol M^{-2} d^{-1})	4.1	0.66
Hydrocarbon mineralization[2] (%d^{-1})	10	5.1
Total hydrocarbons (mg g^{-1} sediments)	4.8	1.1
Mean cells[3] (millions cm $^{-1}$ sediment)	58	47

[1] To a depth of 5cm
[2] Average of all tests
[3] Data from Montagna et al. unpubl.

Table 10. Stable carbon isotope abundances and $\delta^{13}C$ shifts in samples of benthic organisms from petroleum seep area of Santa Barbara Channel. Numbers of samples are given in parentheses. am: amphipod; bi: bivalve; po: polychaete. nd: no data. (Spies and DesMarais, 1983)

Organism	Mean $\delta^{13}C$				$\Delta\delta^{13}C$
	Comparison		Seep		
Praxillella affinis pacifica (po)	-17.97 ± 1.12	(4)	-20.7 ± 0.58	(3)	-2.73
Axiothella rubrocinta (po)	-16.9	(1)	-21.4	(2)	-4.5
Mediomastus californiensis (po)	-16.6	(1)	-17.5	(2)	-0.9
Hemichordate	15.9	(1)	16.3	(1)	-0.4
Tellina modesta (bi)	-16.18 ± 0.49	(4)	-16.65	(2)	-0.47
Tharyx tesselata (po)	-17.05	(2)	-17.27	(1)	-0.22
Pista disjuncta (po)	-17.35	(2)	-18.13	(2)	-0.78
Nematodes	-17.4	(1)	-18.45	(2)	-1.05
Nereis procera (po)	-17.4	(1)	-19.1	(2)	-1.7
Paraphoxus spp. (am)	-14.27 ± 1.7	(3)	-13.8	(1)	-0.47
Nepthys caecoides (po)	-16.15	(2)	-18.07	(1)	-1.93
Glycera branchiopoda (po)	-16.05		-16.75	(2)	-0.7
Beggiatoa sp.	nd		-20.7		nd

Mean = - 1.32±1.24

In summary, benthic metabolism at the Isla Vista seep is similar to that described for other organically enriched systems such as salt marshes (Howarth & Teal, 1980) and abyssal hydrothermal vents (Karl et al., 1980). When the enrichment is derived from seeping petroleum, aerobic heterotrophs metabolize petroleum to supply chemoautotrophs with carbon; the energy source is H_2S, originally at least partially derived from the oxidation of petroleum (Figure 30). Meiofauna feed on both the heterotrophs and the chemoautotrophs as well as the chlorophyllous microbes (either microalagae or cyanobacteria) and are in turn fed upon by macroinfauna and larval fish.

Enrichment is not the only observed effect of the seeping petroleum. Even at low levels, oil released in the marine environment may cause changes in community structure as the result of the mortality, decreased reproduction or avoidance of sensitive or vulnerable species. Amphipods, in particular, seem to be sensitive to low levels of petroleum hydrocarbons. Davis & Spies (1980) reported significantly fewer numbers of amphipods (5.9% of total) at the seep station than at the comparison station (11.5% of total individuals). Immediate and almost total mortality of amphipods followed the Florida, Tsesis and Amoco Cadiz oil spills (Sanders et al., 1980; Elmgren et al., 1983; Gundlach et al. 1983). Also, the winter after the Tsesis spill, Elmgren et al. (1983) reported an increase in the frequency of abnormally developed eggs in Pontoporeia femorata females. Length-frequency data for P. femorata, Gammarus setosus, and Anonyx sp., from the Baffin Island Oil Spill (BIOS) Experiment also indicate possible reproductive anomalies in amphipods chronically exposed to low level petroleum contamination (Cross et al., 1987). Alternatively, the changes in population structures observed for these species may have been due to the active avoidance of the oil by the animals, such as has been reported previously (Percy, 1976; 1977). Echinoderms also seem to be sensitive water quality indicators. Decreases in the densities of the urchin, Strongylocentrotus droebachiensis, in the experimental bays following the BIOS oil releases were very probably the result of avoidance behavior (Cross et al. 1987).

Sublethal acute and chronic exposures to petroleum compounds such as aromatic hydrocarbons will induce the enzymes of the cytochrome P-450 or mixed function oxygenase (MFO) system (see review by Stegeman, 1984 for induction in marine species). These enzymes catalyze the metabolism of organic pollutants and endogenous steroids. There is increasing evidence that the induction of the enzymes of the P-450 system may adversely affect reproduction. For example, in starry flounder, Platichthys stellatus, increased maternal hepatic aryl hydrocarbon hydroxylase (AHH) activity has been

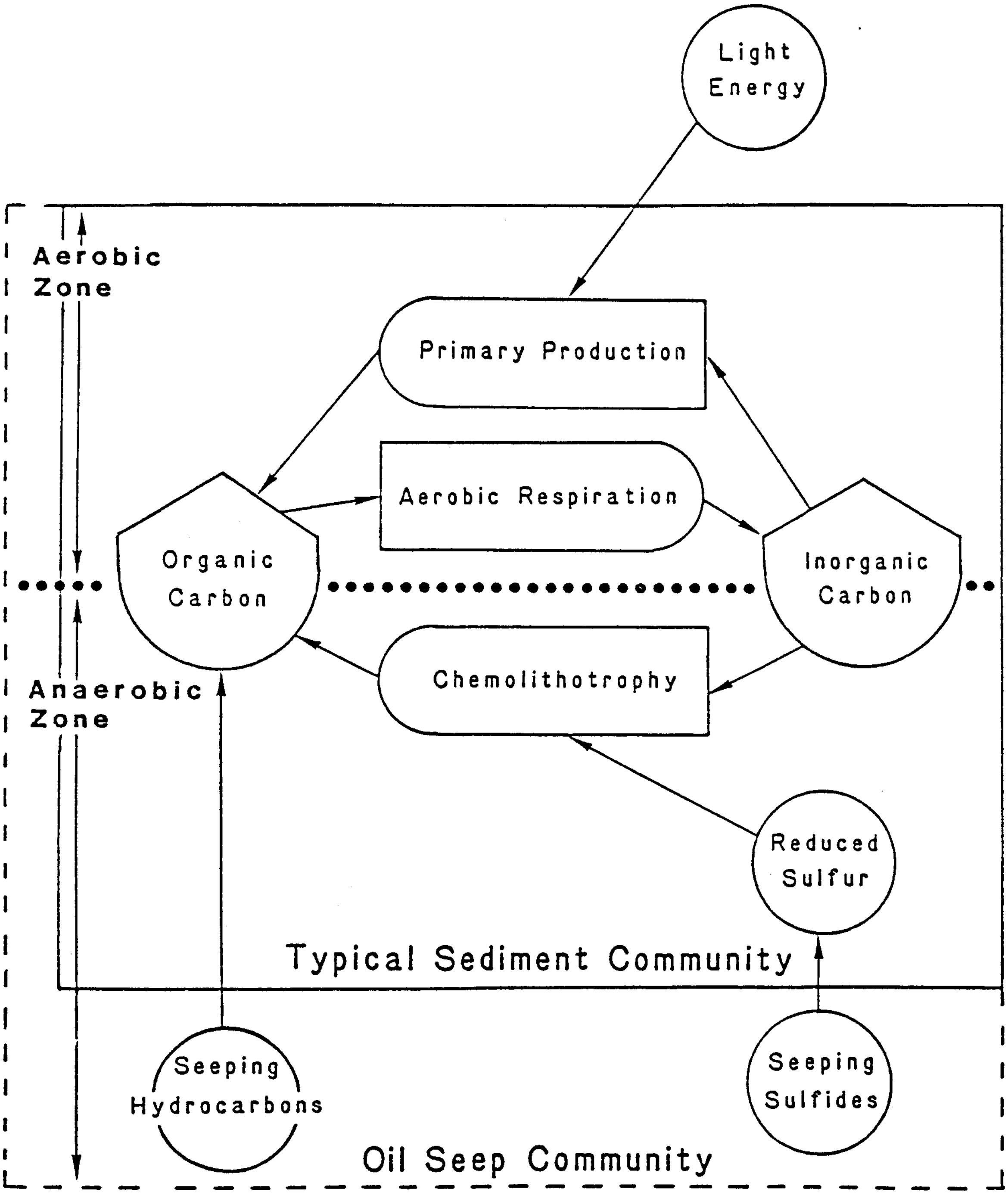

Figure 30. Model of sediment trophic-dynamics. The model demonstrates trophic enrichment by carbon and sulfide additions, via seepage, to the benthic community. The vertical zonation of oxygen and sulfide gulates decoupling of carbon and energy fdmflow in anaerobic zone. (Montagna et al., personal communication)

associated with subsequent reductions in gamete viability, fertilization success and embryo survival (Figure 31, Spies et al., 1985; 1986).

Induction of the P-450 system may have direct effects on reproduction through the catalytic activity of this system. All lipophilic organic molecules present in an animal must undergo biotransformation through the enzymes of the P-450 system to more polar derivatives before they can be excreted. Upon oxidation, however, some compounds form reactive intermediates which are capable of binding with macromolecules including deoxyribonucleic acid (DNA). Specifically, benzo(a)pyrene, a polynuclear aromatic hydrocarbon, is metabolized by AHH to a bay-region dihydrodiol-epoxide, which binds closely to available DNA (Dipple et al., 1984). If this reaction occurs in the liver or gonads of a sexually mature organism, the resulting lesion may affect either the synthesis and storage of necessary lipids or proteins, e.g. vitellogenin, or be transferred directly to the gamete (Varanasi et al., 1981, 1982). In either case, the lesion may be expressed through the abnormal development or mortality of the gamete and embryo. The potential for such toxicity is indicated in a study where female flathead sole, Hippoglossoides elassodon, fed 4 mg of benzo(a)pyrene 5 h before spawning produced eggs with significantly lower hatching success and a higher incidence of embryological abnormalities than controls (Hose et al., 1981).

Alternatively, induction of the P-450 system may have indirect effects on reproduction, through interference with the synthesis and degradation of steroid hormones. As all the steps in steroidogenesis from cholesterol to estradiol, as well as steroid metabolism, are mediated by P-450 enzymatic function, there are multiple opportunities for contaminant-induced P-450 activity to interfere in steroid balance and normal reproductive function. For example, a P-450 isozyme (P-450E) has been isolated from the hepatic microsomes of induced scup, Stenotomus chrysops, that hydroxylates both benzo(a)pyrene, for which it is the major catalyst and testosterone (Klotz et al., 1986), the immediate precursor of estradiol. Because of this surprisingly broad substrate specificity, P-450E might be expected in vivo to accelerate testosterone clearance rates in contaminant-induced fish. Indeed, a series of short-term exposures of salmon and winter flounder to petroleum did result in lower total plasma and bile titers of testosterone, 11-ketotestosterone and 17b-hydroxytestosterone in sexually mature males (Truscott et al., 1983).

Elevated levels of AHH activity have been reported in fish collected from areas with low-level chronic petroleum contamination. Spies et al. (1982) measured increased

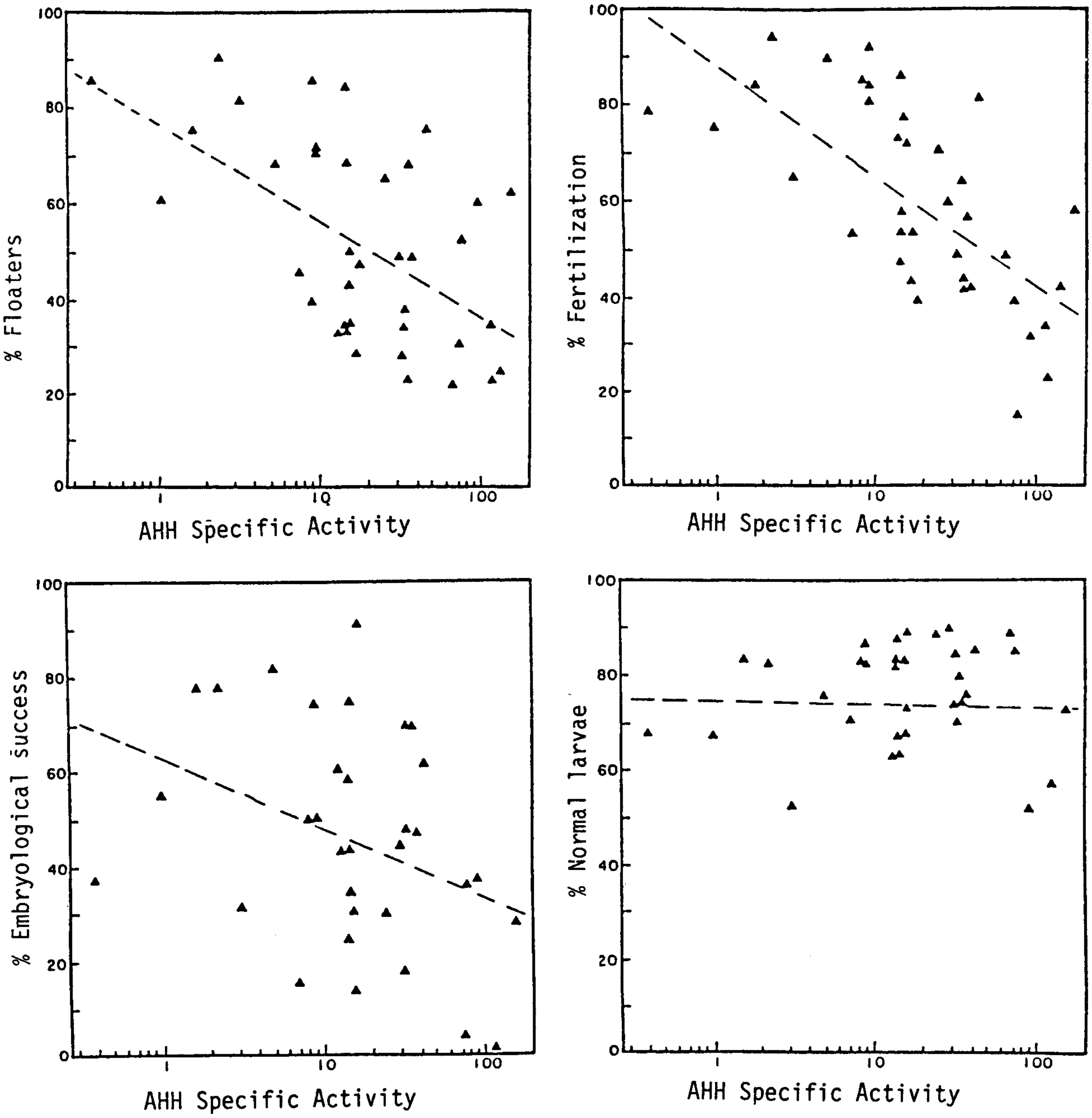

Figure 31. Relationship between hepatic Aryl hydrocarbon hydroxylase (AHH) activity and primary developmental success measures for starry flounder females collected in San Francisco Bay. (Spies et al., 1986)

levels of AHH activity in two species of sanddabs, Citharicthys sordidus and C. stigmaeus collected around the seeps in Santa Barbara Channel. Davies et al. (1984) measured increased enzyme activity in cod, whiting and haddock collected around offshore drilling platforms in the North Sea where oil-based drilling muds have been disposed. In neither case were the levels much above two-fold those of comparison fish. There were strong species-specific differences, however and in light of more recent work, e.g. Spies et al. 1986, separation of the fish by sex as well as species, might have resulted in clearer differences between fish collected in contaminated and non-contaminated areas.

The effects of low level chronic releases are not necessarily limited to the benthos. Concentrations of petroleum hydrocarbons as low as 10-90 ug/l under conditions of chronic exposure can affect the composition of planktonic communities (Lee & Takahashi, 1975; Elmgren & Frithsen, 1982). Observations of natural zooplankton after a major spill (Samain et al., 1981) or Arctic seeps (Gilfillan et al., 1986) indicate a reduction in feeding, and consequently reduced secondary productivity, resulting from exposure to low levels of petroleum hydrocarbons.

ARCTIC MARINE ECOSYSTEMS

Biological events in the Arctic are characterized by marked seasonality. Annual cycles in meteorological conditions, particularly temperature and day length, induce changes in physical factors, e.g. river flow and sea-ice conditions, and biological processes, e.g. primary production. As a result of these widely fluctuating environmental conditions, nearshore Arctic marine animals live in a very harsh environment compared to temperate species. They may experience unusually broad temperature fluctuations, salinity changes and photoperiod extremes. Daily salinity and temperature values change rapidly; changes up to 6°C and 15%. have been observed in Simpson Lagoon (Truett, 1978). Seasonal variations in the same lagoon have been reported by Craig and Haldorson (1979) as:

	spring	summer	fall	winter
temperature	0-5°C	7-10°C	0-6°C	-2-0°C
salinity	1-10%	18-25%	18-25%	26-60%

Arctic marine food webs are generally short, involving at most four or five energy transfers through herbivorous and carnivorous zooplankton and fish to seabirds and marine mammals. Furthermore the diversity at each trophic level appears to be lower than that occurring in temperate waters.

Arctic marine zooplankton populations and communities share many basic attributes with their counterparts in more temperate waters. Copepods, particularly calanoid copepods, dominate arctic zooplankton in terms of number of species, abundance and biomass. They are common prey for many other species, including fish larvae and seabirds and have a pivotal role in marine food webs. Chaetognaths, pteropods, hyperiid amphipods and several other groups may also be locally abundant and account for a significant portion of the biomass. Zooplankton assemblages frequently include hydrozoans, ctenophores, polychaetes, isopods, ostracods, mysids, decapods and benthic invertebrate larvae. Zooplankton communities differ considerably in different areas and water masses. There is considerable variation in the abundance and species composition with season as a result of reproduction and development (Grainger, 1965).

Arctic zooplankton generally have an extended life span; two years or more for species of *Calanus* and *Pseudocalanus* as, compared to four generations per year in temperate populations (Cairns, 1967). Many herbivorous zooplankton have developed reproductive cycles that coincide with the season of plant growth, whereas carnivorous species generally have a less well defined season of reproduction.

The porous crystalline matrix found on the underside of the characteristic Arctic ice cover is the substrate for a unique and very productive marine community. In the spring (April and May), a dense bloom of microalgae occurs on and in this matrix. It has been estimated that this bloom may account for as much as 25 to 30% of the total annual primary production in various Arctic areas (Horner, 1976, 1977). In addition, this bloom occurs before there is significant production by planktonic and benthic algae during the open water season; it is available to herbivores earlier in the season than is planktonic production (Dunbar, 1968). The community consists of a trophic network of microalgae, herbivores and invertebrate and vertebrate carnivores. Both infauna and epifauna are present. Small organisms such as protozoa, nematodes, polychaetes, copepods and juvenile amphipods penetrate deep into the ice in brine channels. The epifauna, the largest and most conspicuous invertebrates associated with and utilizing this complex community of ice algae and meiofauna, are gammarid amphipods. Dominant species (on the order of 105 individuals/m^2) on the undersurface of the ice have included, at various places and times, *Onisimus litoralis* or *O. glacialis*, *Gammarus setosus*, *Ischyrocerus anguipes* and *Apherusa glacialis* (Cross, 1980, 1982). The habitats of these species in the absence of landfast ice include the undersurface of pan ice, the water column and shallow sublittoral and intertidal areas. All are important food items for arctic cod (Craig et al., 1982), various marine birds (Bradstreet and Cross, 1982) and ringed seals (Finley, 1978). These data indicate that the epontic community may be a critical element of arctic marine food webs.

The nearshore benthic infauna and epifauna are extremely depauperate due to seasonal scour from bottom fast ice (Broad, 1979). Similar scouring resulting in depauperate benthic fauna may occur in the depth interval of 15 to 30 m due to ridge ice in the Stamukhi zone. These regions do contain small populations of annual species or juvenile immigrants from adjacent unscoured zones. Benthic faunal diversity increases with water depth seaward from the bottom fast ice zone, with the exception of the Stamukhi zone. Dominant taxa include polychaetes, gammarid amphipods, isopods and bivalve molluscs. The highly motile forms such as amphipods and isopods may invade the area in large numbers during the open-water season (Griffiths and Dillinger, 1981: Northern Technical Services, 1981).

The Arctic Ocean is relatively impoverished of productive fish stocks. Marine mammals and sea birds are the principal top predators in Arctic marine food webs. Low primary and secondary productivity may be "inimical to the development of truly pelagic stocks of arctic marine fishes" (Johnson, 1983). There are no endemic species of commercial importance. Stocks of Pacific herring in the Beaufort Sea and capelin, atlantic cod and Greenland halibut in the Eastern Arctic have some potential for local utilization. Most species that presently support local fisheries are anadromous; i.e. ciscoes, whitefishes and Arctic char. Although of no commercial importance, the arctic cod has been described as a "key species in the ecosystem of the Arctic Ocean" because of its abundance, widespread distribution and importance in the diets of marine mammals, birds and other fishes. Frost and Lowry (1984) calculate that Arctic cod are by far the most important consumer of secondary production in the Alaskan Beaufort Sea.

EFFECTS OF LOW LEVEL CHRONIC RELEASES OF PETROLEUM HYDROCARBONS ON ARCTIC MARINE ECOSYSTEMS

The impact of oil released into the environment, terrestrial or marine, is mediated by microorganisms, in particular the hydrocarbon utilizing bacteria, through the biodegradative removal of the oil. The "rate" of petroleum removal by biodegradation will reflect the simultaneous or sequential removal of various components of the release at various rates. These rates, in turn, are influenced by the abundance of hydrocarbon-degrading microorganisms, the composition of the oil, and environmental factors, such as temperature, dissolved oxygen levels and nutrient concentrations (see reviews by Bartha & Atlas, 1985; Atlas, 1985). No crude oil, however, is completely biodegradable, even under the most favorable conditions.

Hydrocarbon-degrading microorganisms are ubiquitous. Studies in the Canadian and US Arctic substantiate the presence of hydrocarbon-degrading microorganisms in Arctic marine ecosystems and indicate that quantitative differences in the distribution of these microorganisms are relatively unimportant over large geographic distances (Bunch & Harland, 1976; Roubal & Atlas, 1978). Population levels of these microorganisms and their proportions within the microbial community seem to be more sensitive to previous exposure to hydrocarbons than to latitude. In fact, they appear to be extremely sensitive indices of environmental exposure to hydrocarbons as the introduction of hydrocarbons into the environment results in a significant increase in the numbers and proportions of hydrocarbon-degrading microorganisms. Atlas (1981) has reported that in unpolluted ecosystems, hydrocarbon degrading bacteria generally constitute less than 0.1% of the microbial community; in oil-polluted ecosystems, they can constitute up to 100% of the viable microorganisms. This increase in hydrocarbon-degrading microorganism serves both as an index of the extent of hydrocarbon impact and as a signal of the onset of hydrocarbon biodegradation. There is evidence that this increase in hydrocarbon-degrading microorganism is slower in Arctic than Subarctic marine ecosystems (Haines & Atlas, 1982; Eimjellen et al., 1982; Bunch et al., 1983a, 1983b).

The rates of hydrocarbon biodegradation in Arctic and subarctic Alaskan seas, however, seem to bear no significant correlation to the numbers of hydrocarbon utilizers but do correlate with latitude: they are lower in the Arctic Ocean than in more southerly Alaskan regions. _In situ_ ^{14}C dodecane oxidation rates, based on $^{14}CO_2$ production, were measured by Arhelger et al. (1977) in Port Valdez (0.7 g/liter per day), Chukchi Sea (0.5 g/liter per day), and Arctic Ocean (0.001 g/liter per day). A second comparative study of biodegradation potentials in the sediments and water columns of these areas supported this conclusion and demonstrated large seasonal variations, probably due to seasonal depletion of available nutrients, in the Beaufort Sea (Roubal and Atlas, 1978).

The degradation of Prudhoe Bay crude oil in Arctic marine ice, water and sediment ecosystems has been examined by Atlas and co-workers (see Atlas 1985 for references). Degradation was slow. Loss of the light hydrocarbons was greatly restricted by ice cover and biodegradation of oil on the surface of, or under, sea ice was negligible. Hydrocarbon biodegradation potentials were lower in ice than in water or sediment. Biodegradation rates were slow and limited by temperature and concentration of available nitrogen and phosphorus. Optimal rates of hydrocarbon biodegradation typically occur at C:N and C:P ratios of 10:1 and 30:1 (Atlas and Bartha, 1972), which are several orders of magnitude higher than measured N and P concentrations in the experimental sediments. Oxygen availability also may have been a rate-limiting factor. O_2 and N are limiting factors in fine grained sediments (Gibbs & Davis, 1976) due to low rates of nutrient and oxygen exchange between the interstitial water of such sediment and the overlying water column. These exchange rates would be further decreased by the ice damping of wave action under winter conditions.

There is a large and growing data base on the effects of petroleum on arctic organisms and ecological processes (see review by Wells & Percy, 1985; Figure 32). These data show effects and threshold concentrations, measured as 96 hour LC_{50}s, that are similar to those for organisms and processes in cold temperate waters and are the basis for the hypothesis that the sensitivities of species and life stages are similar in arctic, subarctic and temperate waters (Carls & Korn, 1985; Wells & Percy, 1985; Rice et al., 1984). However, the sensitivity of an organism in a laboratory study is not the same as the vulnerability of an organism in its native habitat. Arctic organisms and habitats are more vulnerable to hydrocarbons than those of more temperate climates. As a result of the lower temperatures and slower rates of biodegradation, hydrocarbons are more persistent and stable than in warmer climates. Depending upon the vulnerability of the habitat being considered, this persistence provides the potential for long-term exposures and sub-lethal chronic effects, such as the reproductive effects discussed previously for benthic fish and reported for Spio by Cross & Thomson (1987).

The pelagic environment is the first habitat to be impacted by an oil spill. In temperate waters, this habitat recovers quickly, depending on the time of year, zooplankton life cycle stages, and the amount of contact with the oil. Most zooplankton specialists consider that major pollution incidents will not have a lasting impact on zooplankton

BIOLOGICAL RESPONSES	*ZOOPLANKTON*																	*BENTHOS*												
	HOLOPLANKTON										MEROPLANKTON																			
	PROTOZOA	HYDROZOA	SCYPHOZOA	CTENOPHORA	COPEPODA	AMPHIPODA	MYSIDACEA	OSTRACODA	EUPHAUSIACEA	CHAETOGNATHA	POLYCHAETA	GASTROPODA	CIRRIPEDIA	CUMACEA	DECAPODA	ECHINODERMATA	TELEOSTOMI	PORIFERA	BRYOZOA	POLYCHAETA	TUNICATA	GASTROPODA	PELECYPODA	ECHINODERMATA	CUMACEA	CIRRIPEDIA	AMPHIPODA	ISOPODA	MYSIDACEA	DECAPODA
LETHALITY	◪		□	●	□	●	●				○		◐		●	■	■			○		◐	◪	◐		◪	■	□	●	■
SUBLETHALITY																														
LOCOMOTION					◪	●					◐		◐		●		◐			◐		●	■	●		●	■			■
BEHAVIOR					◐								◐		●		◐			◐		●	■	●		◪	■	□		■
FEEDING					●□	□							○		●		◐			○		◐	◪	◐		◐	■	□		●
UPTAKE/METABOLISM				●	○◪	○			◐						○		◐			◪			◪	◪						◐
RESPIRATION																●	◐			◐		◐	◪	●			◪		◪	◐
BIOCHEMISTRY															◐					◐			◪							
REPRODUCTION					●	●										○				○		◐	◪				■			◐
DEVELOPMENT															●	■	■			○			◐	◪		◐				◐
GROWTH/MOLTING					●	●									●	◐	●			○			◪			◐	■	□		●
FIELD RESPONSES																														
POP./COMMUNITY				●	□	□														◐			◪	◪			◪	□		
HABITAT DISRUPTION																														
SHORT-TERM	◐ ———→———→———→										◐ ——→——→——→									○		◐	◪	◪		◐	◪			
LONG-TERM	○ ———→———→———→										○ ——→——→——→									□			□	□		○	□			

LEGEND:

EFFECTS	ARCTIC DATA	EXTRAPOLATED DATA
EXPECTED	■	●
POSSIBLE	◪	◐
UNLIKELY	□	○

Figure 32. Anticipated Effects of Spilled Oils on Arctic Marine Invertebrates. Figure based on information available to Wells and Percy (1985) through April 1984.

communities, due to the transient nature of their populations and their wide distribution, and would result in little if any significant effect (Conover, 1979; Horner, 1981). Although Arctic communities are more vulnerable than those in lower latitudes due to the persistence of the oil at lower temperatures, the longer exposure times and the longer generation times of many Arctic species, this conclusion is most probably valid for Arctic as well as temperate communities.

The epontic communities are very vulnerable to oil contamination. The potential exists for quantities of oil to accumulate under the ice cover and interact with the components of this community for relatively long periods of time. It has been speculated that the impact on this community could be severe (Milne & Smiley, 1976; 1978) although there is little direct evidence, and data from more temperate latitudes, concerning the effects of oil on components of this community, are conflicting and confusing.

The intertidal and shallow subtidal environments are also vulnerable to oil contamination. The intertidal habitat will be rapidly, severely and visibly affected by the stranding of floating oil. However, because of the impoverishment of the biological communities in this habitat the impact will be negligible. The beached oil may serve as a reservoir for the chronic input of hydrocarbons into the subtidal sediments, where they could have a biological impact (Owens et al., 1987; Cross & Thomson, 1987; Cross et al., 1987; Humphrey et al., 1987).

Low concentrations of oil in the subtidal sediments, whether the result of anthropogenic activities or not, will exert effects on the benthic communities. These effects may be most noticeably expressed as changes in populations or communities and may be the result of altered reproductive potentials or avoidance. The effects of oil on reproductive processes can be detected at the site of disturbance only for species lacking planktonic larvae. In the Arctic many benthic species develop directly, allowing this sort of determination. The objectives of the microbiological component of the Baffin Island Oil Spill (BIOS) Experiment, which was conducted at Cape Hatt in the Canadian Arctic were to assess the effects of oil and dispersed oil on the macrophytic algae, the relatively immobile benthic infauna (e.g. bivalves, polychaetes) and motile epibenthos (e.g., amphipods, urchins) in shallow arctic waters. The study design resulted in the incorporation of low levels (<10 ppm) of oil in the subtidal sediments of the two experimental bays. The subsequent long-term monitoring of biota of these bays revealed only minor effects in analyses of density, biomass or size data for 28 individual infauna and 13 epibenthic taxa. The longterm effects were in two categories, reproductive and behavior.

Reproductive effects were inferred for an infaunal polychaete, Spio sp., and the amphipod Pontoporeia femorata (Figure 33). Comparisons of the population densities in the experimental and control bays indicated that a natural population increase of Spio did not occur in the experimental bays. Assuming direct development, Cross & Thomson (1987) suggest 1) that breeding of mature adults or development of their offspring in the oiled bays was affected in the year following the spill, or 2) that juveniles released on oiled sediments the second spring or summer were unable to survive. Length-frequency data for P. femorata indicated recruitment of the second year class following the spill was reduced in one experimental bay. Again, Cross et al. (1987) suggest that oil incorporated into the sediments of this bay disrupted some aspect of reproduction. Previous studies, reported in the literature for both groups of organisms, support the hypothesis of an effect on reproduction. Rossi and Anderson (1976, 1978) reported that for the polychaete Neanthes arenaceodentata, fecundity was suppressed and hatching success was reduced upon exposure of the adults to fuel oil. Carr and Reish (1977) reported similar results in polychaetes exposed to the seawater-soluble fractions of crude oil. Elmgren et al. (1983) reported a greater frequency of abnormal eggs in P. affinis following the Tsesis spill and Gundlach et al., (1983) reported a lower frequency of egg-carrying lobsters in commercial catches after the Amoco Cadiz spill. The mechanism being developed and verified in benthic flatfish for the disruption of reproduction through induction of the P-450 system by xenobiotics, including components of petroleum, may very well be applicable to invertebrates as well as vertebrates. In any case, reduced fecundity will probably result in population decreases and must be considered an effect of serious ecological consequence. This is particularly true for benthic organisms without pelagic larvae, such as those in the Arctic, because recolonization of large disturbed areas would be slow (Chia, 1970).

The length-frequency data for the amphipod, Anonyx is difficult to interpret; two years after the releases, Anonyx juveniles emigrated to shallow water earlier in experimental bay which had the highest sediment oil concentrations than anywhere else. The suggestion that this was avoidance is based on prior data (e.g., Percy, 1976, 1977) for similar species. Changes in the densities of the urchin, Strongylocentrotus droebachiensis appeared to be the result of avoidance behavior. The urchins apparently moved rapidly away from high concentrations of dispersed oil and returned shortly thereafter, when oil concentrations in the water were much reduced. This had no obvious negative

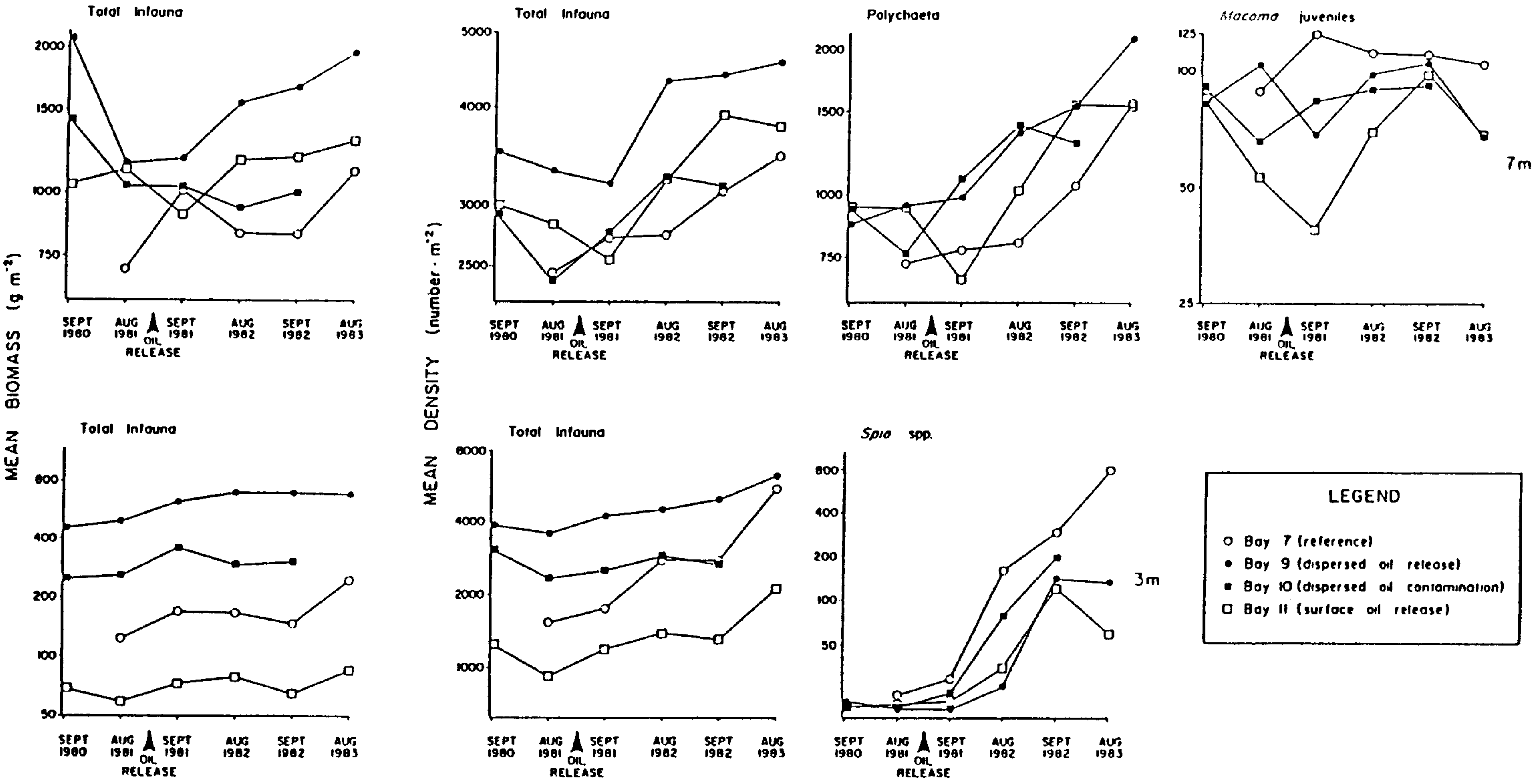

Figure 33. Mean biomass and density of total infauna and mean density of each taxon where analysis indicated possible oil effects, in four bays at Cape Hatt, northern Baffin Island, during pre- and post-spill sampling periods, September 1980-August 1983. Each symbol represents the back-transformed mean of log-transformed data from 24 replicate 0.0625 m2 airlift samples for each depth, bay and period.(from Cross & Thomson, 1987)

consequences and may in fact have prevented adverse effects. Long term avoidance of oil was indicated by decreases in urchin densities between 1982 and 1983, together with concurrent increases in oil concentrations in sediments and in the urchins themselves (Boehm et al. 1985). In contrast to the short-term avoidance of dispersed oil, long-term avoidance of oiled sediments may have had significant ecological consequences later in the summer of 1983 or in subsequent years. Elsewhere, changes in urchin densities not related to oil have caused major changes in abundance and structure of macroalgal communities (e.g., Paine and Vadas, 1969; Himmelman et al., 1983). Massive algal blooms have been attributed to oil-related depletion of other herbivores (e.g. North et al., 1965). The significance of urchin depletion in the arctic is uncertain, however, because urchin diets and feeding rates are poorly known and because urchins are much less abundant than in boreal or temperate waters.

CONCLUSIONS

1. Twenty-nine oil seepage areas have been reported to occur along the Alaskan coast; 14 of these areas have been confirmed as containing actual oil seeps while 15 are unconfirmed reports. None of the confirmed seeps are subtidal but range in distribution from just above the low tide datum on a beach face (Skull Cliff, Chukchi Sea) to inland sites that could influence the marine environment through input via freshwater streams (Yakataga, Gulf of Alaska).

2. The coastal seepage areas having the greatest amount of background data and information are the Arctic sites of: Angun Point, Manning Point, Cape Simpson, and Skull Cliff; and the Gulf of Alaska sites of Puale Bay, Iniskin Peninsula, Katalla, and Yakataga.

3. The coastal seepage potential classification proposed by Wilson et al. (1973, 1974) works fairly well when applied to the Alaskan coastline. The high potential of the central Gulf of Alaska is well reflected in the large areas of seepage that have been identified in the Yakataga and Katalla areas.

4. The evidence for submarine oil seepage in Alaska is rather limited. Shallow gas deposits are quite common in the Beaufort Sea and seem to commonly occur adjacent to high-angle faults that may act as conduits for gas migration. If petroleum seepage occurs here, such faults might also act as conduits for petroleum seepage. However, the authors of this report could locate no information confirming the presence of submarine oil seeps in the Alaskan Beaufort and Chukchi seas.

5. The existing data base on the hydrocarbon constituents of the sediments in the Beaufort Sea could not be used to located areas of probable seepage. The data base was very limited in areal coverage and the elevated fossil-derived hydrocarbons measured in some areas could be attributed to many possible sources: known coastal terrestrial seeps, unidentified submarine seeps, and freshwater stream input from oil seeps, coal deposits, oil shale deposits, and peat in the drainage basins.

6. There is some sediment geochemical evidence suggesting that an area of submarine oil seepage might occur in the southeastern Bering Sea, between the Aleutian Islands and Pribilofs. The suspected area occurs at the 200-m depth contour, in the Outer Shelf Domain at about the Shelfbreak Front. Bottom environmental

conditions are thought to be relatively constant here as compared to more shallow areas of the Bering Sea. The productivity and standing biomass of bottom communities are probably much lower than more shallow areas, which might provide an opportunity to investigate the phenomenon of "organic enrichment" if oil seepages are actually found to occur here.

7. It is difficult to estimate the volume of oil that might be entering the Alaskan marine waters via natural oil seepage. Volumes of oil that might issue from the Arctic coastal seeps have not been estimated; however, past estimates by McGee (1972) suggest that the amount of oil entering the Gulf of Alaska from known coastal seepages is rather small when compared to known seepage rates on the coast of California.

8. Any future efforts to estimate the amount of hydrocarbons entering Alaskan marine waters, from human induced and natural sources will have to consider a wide variety of natural sources, seepages being only one. Erosional sources might be significant in the Beaufort Sea. Erosional input includes: coastal erosion (peat and coastal seeps) as well as drainage basin erosion of coal and oil shale deposits, terrestrial oil seeps and peat.

9. Oil released in the Arctic would impact the pelagic, intertidal, benthic and under-ice habitats. The rates of chemical weathering and biological degradation in this environment are slow, compared to more temperate climates, and allow for the persistence of the oil in all of these habitats.

10. The under-ice habitat is the most acutely vulnerable. The potential exists for oil to interact with the components of this community for a length of time sufficient to lose that portion of the total annual productivity contributed by this community. This is offset by the probable spatial limitation of this interaction.

11. The pelagic environment is the least vulnerable. The increased persistence of the oil and the long generation times of many species of Arctic zooplankton will contribute to an increased impact, as compared to more temperate waters, but the similarities in the distributions of temperate and Arctic species indicate that the impact would not be significant.

12. The impoverishment of high latitude intertidal zones would alleviate the impact of oil on these areas.

13. The benthic habitat exhibits the potential for chronic, sublethal effects. These effects would be expressed as alterations in populations or communities as the result of organic enrichment, reduced fecundity or altered behaviour. Organic enrichment of the benthic community by seeping oil has been demonstrated in the Isla Vista seep off the coast of California. While a similar enrichment is possible for benthic communities associated with seeps in the Arctic, the slower rates of oil degradation by the Arctic hydrocarbon utilizing microorganisms and the "pauses" induced in microbial activity by environmental fluctuations such as ice cover, would indicate an effect of a much lower magnitude. Effects on reproduction, mediated by the induction of the P-450 system by petroleum hydrocarbons, has been demonstrated for benthic flatfish. This mechanism may be involved in the observed effects of oil exposure on the reproduction of marine invertebrates. For benthic organisms without pelagic larvae, e.g., many Arctic species, and the consequent potential for rapid recolonization and restoration of a disturbed area, a reduction in fecundity may be a long-term effect of major ecological consequences. The avoidance of oiled sediments has been demonstrated in echinoderms and amphipods. The significance, if any, of the avoidance of oiled sediments by these species in the Arctic is unclear.

14. Within any given environment, factors such as the structure of the hydrocarbons and the feeding strategy of the organisms and their capacity to metabolize hydrocarbons will significantly influence the uptake, accumulation and total exposure of the organisms to oil and be reflected in the sensitivity of the organisms.

15. The data do not support the hypothesis that Arctic marine organisms are more sensitive to petroleum and its components than organisms from warmer waters. The vulnerability of Arctic marine organisms, because of their long generation times and the increased persistence of oil in this environment, is greater than that of organisms from more temperate climates.

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CHUKCHI SEA COASTAL STUDIES: COASTAL GEOMORPHOLOGY, ENVIRONMENTAL SENSITIVITY, AND PERSISTENCE OF SPILLED OIL

by

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Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 644

March 1985

DEDICATION

This report is dedicated by three of the authors to the memory of our friend, colleague and fourth author, Carl Foget, who passed away before this project could be completed. Carl was a true pioneer in the art and science of oil spill containment and cleanup technology. He taught many of the present generation (including the three of us) much of what we know about oil spill countermeasures. He always brought a very practical engineering and operations-oriented perspective to the often esoteric and impractical ideas many of us had about dealing with oil spills in the real world. This perspective is reflected in this report (Section 7.0) and many others. Carl is and will be truly missed as a friend, critic, and colleague as well as an outstanding oil spill countermeasures engineer.

ACKNOWLEDGMENTS

Successful completion of the field, analytical and mapping components of the program which resulted in the Final Report, Maps, Resource Tables, and Appendices reflects the cooperation and support of many people. The authors are grateful to all, named below or not, who contributed to this program. This study was funded in part by the Minerals Management Service, Department of the Interior through an Interagency Agreement with the National Oceanic and Atmospheric Administration, Department of Commerce, as part of the Alaska Outer Continental Shelf Environmental Assessment Program.

All authors were Woodward-Clyde Consultants (WCC) employees at the beginning and for varying lengths of time in the program; however, all have since left WCC. We are grateful to WCC, especially Mr. James D. Sartor, for the continued support services (word processing, graphics, reproduction) that allowed us to complete the report. We are also grateful to our respective organizations for the continuing support that allowed us to finish the report. They are ENTRIX INC. (Dr. Gordon Robilliard), Dobrocky SEATECH (Dr. John Harper) and Jon Isaacs and Associates (Jon Isaacs).

We are grateful to a large number of individuals and organizations for their support, encouragement and patience throughout this project. Special thanks go to: Mr. Lyman Thorsteinson, NOAA Alternative COTR, and our principal NOAA contact on this project; Dr. M.J. Hameedi, NOAA COTR; Amos Agnassagga, resident of Pt. Lay and field guide; Lt. Gary Vandenberg (NOAA pilot) and Tony Accurso (NOAA flight engineer; Ben Mangina, WCC field and VTR technician; Russ Geagel, NOAA field logistics coordinator; Dr. Peter Connors, Bodega Research Associates, arctic shorebird ecologist; Mike Joyce, ENTRIX INC., arctic waterfowl, seabird and shoreline vegetation ecology; Brian Sawyer, map preparation and production. A special note of appreciation goes to Kay Rooker and her word processing staff at WCC for their patience in deciphering our handwriting and redoing this report several times. We apologize to those whom we did not explicitly identify, however, we gratefully acknowledge their support and we do not value their contribution any less.

LIST OF PARTS

CHUKCHI SEA COASTAL STUDIES: COASTAL GEOMORPHOLOGY, ENVIRONMENTAL SENSITIVITY, AND PERSISTENCE OF SPILLED OIL

PART I. FINAL REPORT

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TABLE OF CONTENTS

7.0 OIL SPILL COUNTERMEASURES

Appendices and other deliverables submitted separately
to NOAA include:

Appendix A. Aerial Videotape Manual (5 copies)

Appendix B. Original Field Data Sheets

One set of 21 20-minute ¾" Videotapes

LIST OF FIGURES

LIST OF TABLES

1.0
INTRODUCTION

1.1 NEED FOR STUDY

The Outer Continental Shelf Environmental Assessment Program (OCSEAP) was established to conduct environmental research in Alaska Outer Continental Shelf (OCS) areas targeted for potential oil and gas development. The OCSEAP is under the auspices of the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce. OCSEAP provides to agencies the scientific data and information needed to predict environmental disturbances, to resolve multiple-use conflicts associated with offshore oil and gas leasing and to make other resource management decisions in Alaska.

One of the categories of information is the relative vulnerability and sensitivity to spilled oil of Alaskan shorelines adjacent to areas proposed for offshore oil and gas development. Much of the Alaskan coastline has already been classified on this basis. Such classifications are useful in pre-development planning and decisions relating to shoreline protection and cleanup strategies in the event of an actual spill. Coastal vulnerabilities are determined by an integration of the major physical and biological features of a particular region with emphasis on the physical features. NOAA-sponsored coastal vulnerability studies have typically included analysis of coastal oceanography and geomorphology data to predict the persistence of oil in nearshore waters and beach sediments. Such information, when coupled with biological attributes, forms the basis for oil spill response decisions and environmental sensitivity assessments. Results from such studies have been portrayed on a series of maps which rank the vulnerabilities of each segment of the coastline.

The Chukchi Sea coastline has not been classified with regard to oil spill sensitivity, vulnerability, persistence, etc. Some of the specific information needs, identified by MMS for the oil and gas lease sale in the Barrows Arch of the Chukchi Sea are: (a) identification and characterization of the species and habitats at risk from and sensitive to spilled oil, (b) persistence or residence of oil on the shoreline and (c) realistic oil spill protection and cleanup strategies for the Chukchi Sea coastline. To assist in management decisions, this information should be compatible with and complement that which has already been done and has produced coastal characterization and sensitivity maps.

1.2 STUDY AREA

The study area extends from Pt. Barrow in the northern Chukchi coast southwards to Cape Thompson (Fig. 1.1), a coastline length of approximately 675 km (420 miles). The study area includes a variety of coastal environments including: barrier islands, coastal lagoons, estuaries, deltas, tundra cliffs and a few bedrock exposures. The resource description and sensitivity analyses are restricted to the zone between the lower-low water level and the upper limit of normal storm-surge action as defined by the most prominent log debris line. The astronomical tidal range is less than 0.3 m (1 ft) but storm surges commonly exceed 2.0 m (6 ft) on some sections of the coast, and coastal waters may innundate large areas of the tundra. The physical, biological, and human use characteristics of the study area are decribed in more detail in Section 2.0.

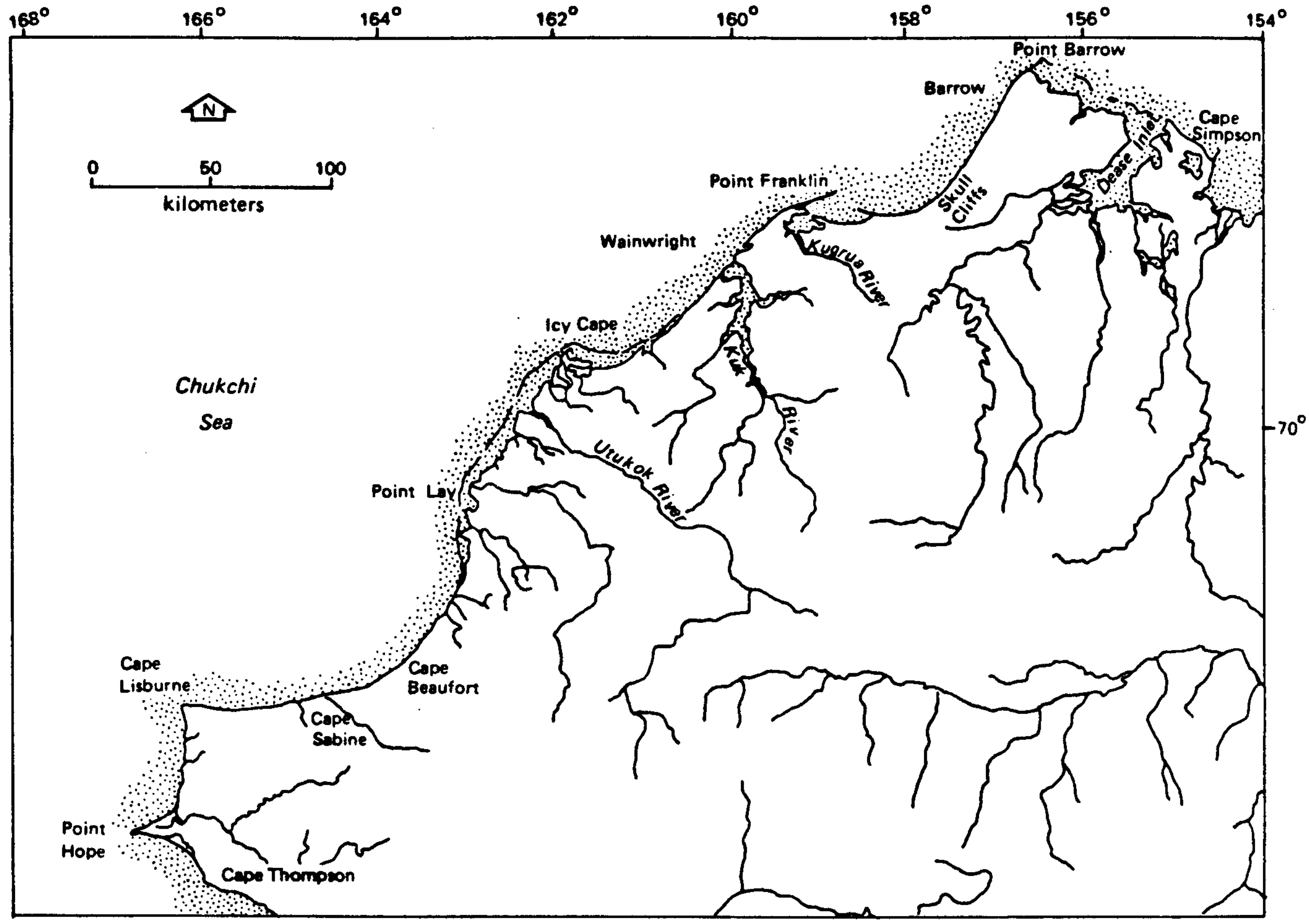


Figure 1-1. STUDY AREA EXTENDING FROM PT. BARROW TO CAPE THOMPSON

1.3 OBJECTIVES

The primary objectives of this program are:

(1) Describe the physical and biological characteristics of the northern Chukchi Sea coastline, emphasizing shore characteristics that influence the effect of oil spills or that are likely to be affected by oil spills.

(2) Describe and map the level of oil persistence along the shoreline.

(3) Describe and map the vulnerability and sensitivity of selected coastal biological resources to spilled oil.

(4) Describe and map the sensitivity of selected human uses of the shoreline to spilled oil.

(5) Describe the cleanup techniques and equipment available for use in arctic conditions and recommend appropriate shoreline countermeasures.

This report addresses each of these objectives and provides NOAA/MMS with the information required to make oil and gas leasing decisions.

1.4 BACKGROUND ON SHORE-ZONE SENSITIVITY INDICES

Prior to evaluating environmental impacts, identifying appropriate countermeasures, or pre-planning in the oil spill contingency plan, the vulnerability and sensitivity of shore-zone resources need to be described in a way that is useful for impact assessment as well as for spill countermeasure planning and implementation. Comprehensive, but simple and practical oil spill sensitivity indices are a significant aid in meeting these three needs.

Numerous indices have been proposed to represent the effect of oil on biological, physical, human, or some combination of these resources of the shore zone. However, most of the indices have been difficult to apply in realistic situations. Some are too simple in that they do not take into account essential information, especially related to temporal distribution of resources. Others are too complex in that they include all the essential information and attempt to present it as part of the index. In most cases, indices have an implied or explicit ranking mechanism built into them. The ranking system assigns fixed values (implicitly or explicitly) and is often not flexible enough to account for temporal or spatial variations in abundance, distribution, or importance of the shore-zone resources of concern.

These spill indices for shorelines have undergone a considerable evolution since Owens (1971) suggested the basic relationship between shoreline type, oil persistence, and biological sensitivity. He also defined nine shoreline types in terms of sensitivity to oil spills. Hayes et al. (1976) defined and ranked ten shoreline types in terms of an Oil Spill Susceptibility Index that was based on the physical longevity of oil in each environment in the absence of cleanup efforts. Owens (1977) described in detail the relationships between shoreline sensitivity, oil persistence, and coastal processes. Ruby (1977), Gundlach and Hayes (1978), Ruby and Hayes (1978), and Michel et al. (1978) modified the Hayes et al. (1976) approach slightly to account for persistence of oil in shoreline environments and to include some biological considerations; they termed this revised approach the Oil Spill Vulnerability Index.

Worbets (1979) added human sensitivity to the geological and biological sensitivity scale defined by Hayes et al. (1976). Worbets also introduced a weighted scale for the various shore-zone resources and developed a numberical ranking system for use in the Canadian Beaufort Sea. Nummedal (1980) defined eight shoreline types in terms of oil persistence ("retention potential") which is important in assessing the longevity of impacts.

Foget et al. (1978) presented a sensitivity ranking, modified from Hayes et al. (1976) that was based on: (a) type of oil, (b) oil penetration and burial, (c) shoreline energy level, (d) ambient temperature, (e) expected oil persistence, and (f) biological sensitivity. The biological sensitivty was a subjective evaluation based on the expected mortality levels of the dominant species, expected recolonization by the ecologically dominant species, and overall rate of recovery of the community. They then developed a matrix for sensitivity levels and oil types. Gundlach et al. (1980) incorporated important, sensitive biological resources such as marine birds and mammals into the vulnerability index of Gundlach and Hayes (1978b) and renamed the index the Environmental Sensitivity Index. They also included location and seasonal use information for each of the sensitive biological resources on the maps.

Robilliard et al. (1980) defined a combined shoreline vulnerability and sensitivity in terms of: (a) oil contamination potential, physical characteristics of oil, and persistence of oil, (b) physical processes (i.e., currents, meteorology) at the time of the spill, (c) biology, (d) geology and sediments, (e) human use of the area, (f) operational constraints (logistics, equipment performance, countermeasure, feasibility and effectiveness), and (g) cleanup impacts. This last "index" was a conceptual model developed specifically to assist both environmental managers who are concerned with environmental impacts and operations managers who are concerned with the feasibility of implementing oil spill protection or cleanup countermeasures. However, Robilliard et al. (1980) could not reduce this large amount of information to a single index (number, graphic display, narrative) that would be of practical use.

Subsequently, Woodward-Clyde Consultants (1982), Robilliard and Owens (1981), and Robilliard et al. (1983a, 1983b) developed a 2 or 3-index system with a single index for each of oil persistence, biological sensitivity, and human use sensitivity. The level of concern or sensitivity of each index is categorized as primary (or high), secondary (or moderate) and tertiary (or low) which is operationally more realistic than the multi-level ranking used for several other indices. The spatial distribution of each level of concern for each index is presented on a separate map while the temporal distribution is presented on accompanying tables.

In summary, Owens (1971) established the basic relationship between shoreline type, oil persistence, and biology; Hayes et al. (1976) established the first specific ranking scheme; Worbets (1979) added human sensitivity; and Foget et al. (1979) and Robilliard et al. (1980) added oil type and operational feasibility and effectiveness. Finally Woodward-Clyde Consultants (1982) and Robilliard et al. (1983) developed a system which presented the spatial distribution of the resource sensitivity or oil persistence on maps and the temporal distribution in tabular format.

To be realistic and useful in a practical sense to decision makers, environmental managers, and oil spill operations personnel, any oil spill sensitivity index must be flexible enough to account for the temporal and spatial variability in abundance, size, distribution, and activity of the vulnerable and sensitive coastal resources (i.e., resources that could be harmed by a potential oil spill).

This report presents a practical approach that identifies, describes and maps the concerns related to potential impacts of an oil spill on shore zone resources. The approach includes a mechanism for providing relevant information on the temporal and spatial variability of abundance and distribution of the resources. The information is provided in both map and tabular forms and is described in detail in the following chapters.

2.0
DESCRIPTION OF ENVIRONMENT

2.1 PHYSICAL ENVIRONMENT

The physical (i.e., meteorological, oceanographic, and geological) components resources of the study area are described briefly in this section. For more detailed graphic and tabular summaries of the northern Chukchi Sea coast, the reader is referred to La Belle (1975), National Petroleum Reserve of Alaska Task Force (1978) and Selkregg (1975).

2.1.1 Meteorology

The local meteorological conditions along the Chukchi Sea coast have a major influence on the potential persistence of oil on the coast and thus sensitivity of the coast to oil spills. The climate not only directly influences weathering rates of stranded oil, but also controls ice distribution patterns, seasonal migration of animals and vegetation growth patterns.

The Maritime arctic climate of the Chukchi Sea coast is characterized by subzero mean annual temperatures and little precipitation (Table 2.1). Mean monthly temperatures are less than freezing for all but June, July and August (Selkregg 1975). Low mean annual temperatures result in the formation of permafrost onshore and of sea ice offshore.

Winds are dominated by easterlies throughout the year (Table 2.1) although summer storm winds from the west are not uncommon (Natural Petroleum Reserve of Chukchi Task Force 1978).

TABLE 2.1 METEROLOGICAL PARAMETERS AT SELECTED CHUKCHI SEA COASTAL LOCALITIES (after Brower et al., 1977).

	Mean Annual Temperature (°C)	Mean Annual Precipitation (cm (in.))	Winds	
			Prevailing Direction	Mean Speed (knots)
Barrow	-12.6	12.4 (4.9)	E	11.8
Wainwright	-11.7	13.0 (5.1)	E	--
Point Lay	-10.6	17.0 (6.7)	NE	--
Cape Lisburne	-7.8	28.7 (11.3)	E	12.1

2.1.2 Oceanography

The most significant feature of the northern Chukchi Sea coast oceanographic system is the presence of ice from October to June. The sea ice limits wave exposure and in general reduces the magnitude of circulation processes. The ice also has direct effects on the shore processes as a result of shore/ice interactions.

Sea ice breakup dates for the major villages of the northern Chukchi Sea coast are listed in Table 2.2. Of particular significance is the progressively shorter open-water season as one progresses from south to north (e.g. open-water season is 30 days or 25% shorter at Wainwright than in areas to the south).

The offshore area to the south of Icy Cape is generally ice-free during August and September with open-water extending westward to the Siberian coast (La Belle 1975). However, to the north of Icy Cape, large ice floes persist throughout the summer with August and September concentrations typically in the range of 10 to 20 percent cover.

Ice cover is nearly complete for winter months (La Belle 1975) but persistent easterly winds during the winter do cause quasi-permanent shore-leads (W. Stringer, Univ. of Alaska, personal communication 1983), which serve as important migration corridors for marine mammals.

The extensive ice cover during most of the year limits wave action and most waves are less than 1 m in height. However, westerly and southwesterly storms are capable of generating waves in excess of two meters in height (Hume and Schalk 1967). Wave approach directions are predominantly from the west and southwest as a result of fetch limitations to the north. The wave approach direction drives a predominantly northward longshore drift, except in the lee of major headlands (Figure 2.1).

TABLE 2.2 ICE BREAKUP AND FREEZE-UP DATES ALONG THE NORTHERN CHUKCHI SEA COAST (after La Belle 1975)

	Break-up		Freeze-up	
	Mean	Range	Mean	Range
Barrow	22 July	15 June to 22 August	3 October	31 August to 19 December
Wainwright	29 June	7 June to 26 July	2 October	26 September to 9 October
Point Lay	24 June	1 June to 10 July	4 November	12 October to 27 November
Cape Lisburne	5 July	18 June to 16 July	29 October	13 October to 11 November
Point Hope	20 June	30 May to 8 July	11 November	6 October to 19 November

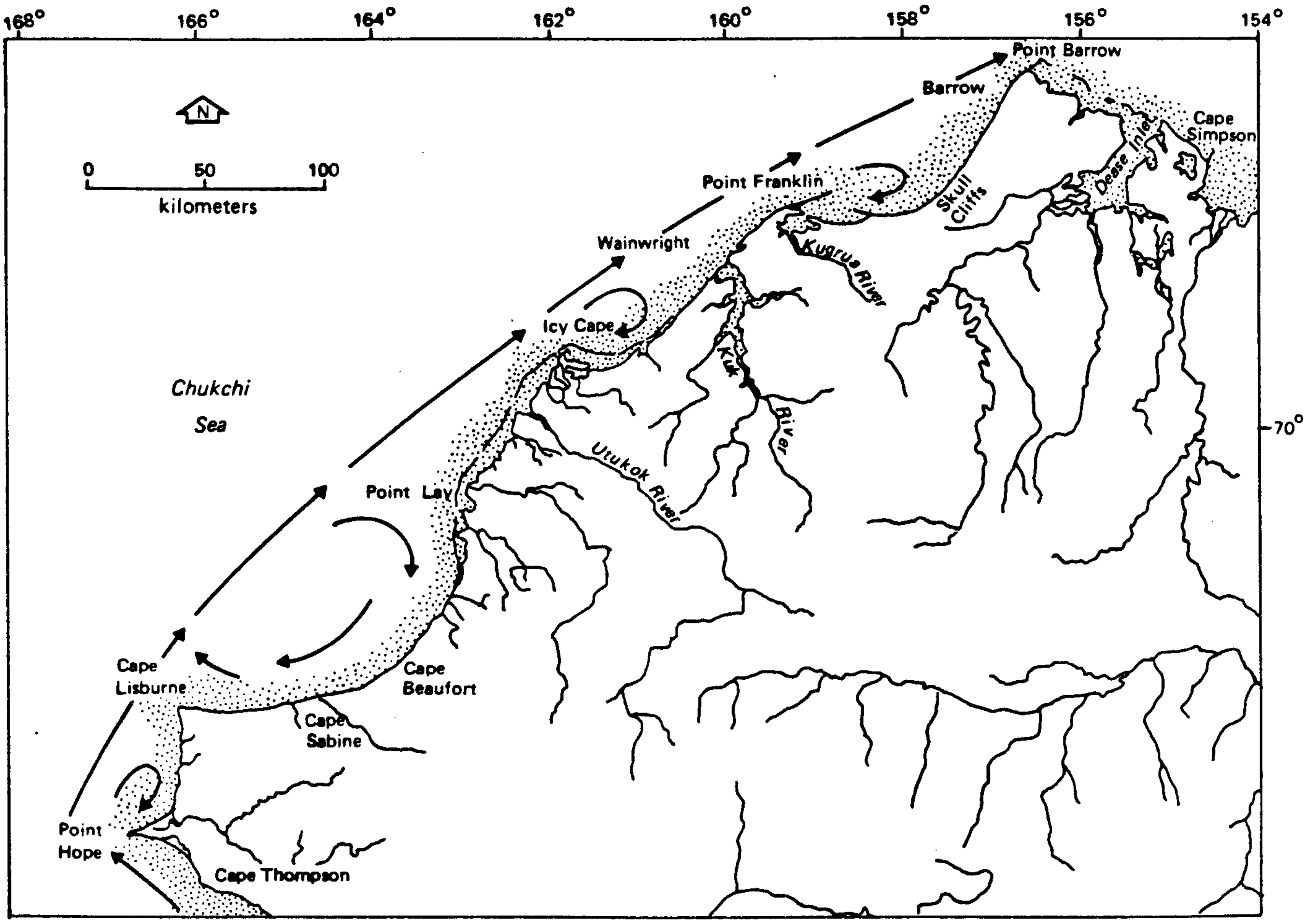


Figure 2-1. LONGSHORE DRIFT DIRECTIONS ALONG THE NORTHERN CHUKCHI SEA COAST (after Wiseman et al, 1973)

A major northward flowing current system occurs in offshore areas and is called the Alaskan Coastal Current (Paquette and Bourke 1974, Lewbel and Gallaway 1984). Current velocities are typically in the order of 10 cm/s. Winter long-term average velocities are 1-5 cm/s with summer storm-generated currents up to 200 cm/s, but more often 50-80 cm/s. Reversals in flow occur occasionally, especially in winter (L. Hochmeister, Science Applications Inc., Personal Communication 1983). In addition, a well-developed coastal jet is a dominant mode of summer coastal circulation for most of the northern Chukchi Sea coast (Wiseman and Rouse 1980). The alongshore flows in these jets may reach 70 cm/s and are commonly near 40 cm/s (Lewbel and Gallaway 1984).

2.1.3 Physiography and Geology

The Chukchi Sea coast study area extends from Pt. Barrow in the north to Pt. Hope and includes two major physiographic regions with contrasting terrain and relief conditions (Wahrhaftig 1965). The Alaskan Arctic Coast Plain which comprises much of the North Slope (Fig. 2.2) is characterized by low topographic relief, numerous thaw lakes and wetlands, and meandering streams (Black 1969; Walker 1973). Coastal relief is rarely in excess of 15 m (50 ft) and is nowhere greater than 30 m (100 ft). The Arctic Foothills Province lies between the Arctic Coastal Plain to the north and the Brooks Range to the south and extends to the coastline between Pt. Lay and Pt. Hope (Fig. 2.2). The Foothills, which include both northern and southern components (Fig. 2.2), consist generally of broad, rounded ridges (in the north) and numerous irregular buttes, mesas, and long linear ridges with intervening plains and plateaus (in the south). Topographic relief is much greater than in the Coastal Plain with elevations of 600 m (2000 ft) occurring near the coast at Cape Lisburne. Drainage is well developed and lakes are rare (Black 1969; Walker 1973).

The physiography of the study area is strongly related to the geology. The Coastal Plain is primarily a surface of deposition with unconsolidated surface sediments ranging in size from clays to gravels.

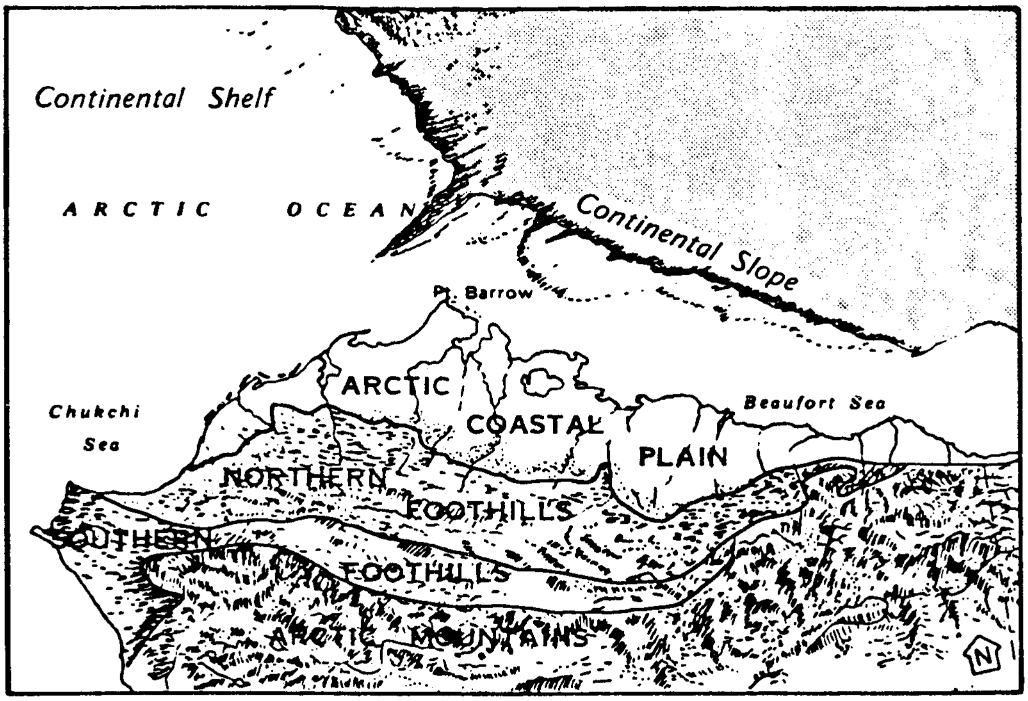


Figure 2-2. PHYSIOGRAPHIC REGIONS OF NORTHERN ALASKA (from National Petroleum Reserve of Alaska Task Force, 1978; after Wahrhaftig, 1965)

Although the Coastal Plain was unglaciated, outwash streams from the glaciers carried sand and gravel to the coast. Several recent marine transgressions over the coastal plain resulted in the redistribution of coarse stream sediments and in the extensive deposition of marine silts and clays (Black 1969; McCulloch et al. 1965; Williams et al. 1977). Consequently, a wide range of coastal deposits including beds of marine clays and silts, relict beaches, relict dunes and alluvium occur within the study area.

The Foothills Province is an area where surficial deposits are thin and resistant bedrock outcrops are common. Bedrock is comprised of resistant Mesozoic and Paleozoic sedimentary rocks (Beikman and Lathram 1976; Selkregg 1975). Resistant limestones, shales, and conglomerates crop out along the coastline near Cape Lisburne and form near-vertical coastal cliffs.

The entire study area is underlain by thick continuous permafrost (Ferrians 1965). The offshore extent of permafrost along this coast is unknown; however, permafrost does exist beneath offshore barrier islands (Owens and Harper 1977) and is probably present beneath shallow coastal lagoons. The presence of permafrost in the sediments has an important influence on the stability of coastal tundra cliffs (Harper 1978), but its influence on beach and barrier island stability is uncertain (Owens and Harper 1983).

Offshore from the coast, the shelf for the most part is mantelled by thin gravel and sand deposits although local sedimentary sandstones crop out directly on the seabed (L. Phillips. USGS, personal communication, 1983). Thick accumulations of sand occur as broad shoals near Icy Cape and Pt. Franklin. The occurrence of large-scale bedforms on the seabed and the predominance of coarse-grained sediments suggests that seabed energy levels are relatively high in these areas.

2.2 BIOLOGICAL ENVIRONMENT

2.2.1 Introduction

In the nearshore and shoreline communities of the Chukchi Sea coast, the principal biotic components of direct concern in an oil spill include beluga whales, spotted seals, several species each of seabirds, waterfowl, and shorebirds, and several species of anadromous fishes. The area hosts few winter or year-round residents so most of the concern focuses on the ice-free season.

Physical habitat factors strongly influence the distribution and abundance of many species in the near-shore zone. Ice distribution and quality dictate the distribution patterns of nearly all mammals, birds, and anadromous fishes at some time of year. The morphological configuration of coastal water bodies and substrates (e.g., existence of bays, barrier islands, lagoons and inlets) and the associated water quality affect the habitat use patterns of some mammals and most birds and anadromous fishes. Large-scale water mass movements and points of river entry affect distributions of fishes and perhaps some of their consumers (e.g., seabirds, belugas, spotted seals).

Approximately 10 coastal sites have been identified as areas where biota concentrate for specific activities and are likely to be particularly sensitive to impacts of oil and gas development (Truett 1984). These include the annually recurring Chukchi Polynya; coastal lagoons and bays and the associated barrier islands and spits; coastal cliffs and the adjacent waters; river deltas and inlets; and an area of sea cliffs that support kelp beds.

The following subsections describing the important species and habitats in the study area are based on and liberally abstracted from a recent synthesis by Truett (1984).

2.2.2 Habitat Characteristics

The nearshore habitats include include the coastal estuaries, lagoons, and semi-enclosed bays plus associated wetlands and shoreline habitats. The water mass is frequently brackish and warm. In the shallow nearshore, the consumers (spotted seal, beluga whale, Brant, oldsquaw, eiders, marsh and mudflat birds, beach birds, and anadromous and marine fishes) are with few exceptions summer and early fall inhabitants of the area. Except for terrestrial and wetland vegetation and for zooplankton transported largely from offshore, the food base is primarily benthic invertebrates.

The distribution and abundance of the important species is strongly influenced by physical attributes of the area. In the fall-spring period, the presence of shorefast sea ice plus snow cover on-land effectively eliminates most of shoreline habitat from use by birds or mammals.

In summer and fall, the important physical habitat factors include (1) the required presence of coastal cliffs and barrier islands for certain nesting and feeding birds, (2) the presence of salt marshes and mud flats for feeding brant and some shorebirds, (3) the presence of warm, semi-enclosed lagoon and bay waters for anadromous fishes, (4) the complexity of mainland and island shorelines in relation to foraging beach birds, and (5) the proximity to coastal sites of natal streams of anadromous fishes (Table 2-3).

Where and when the biota respond to these physical habitat factors have strong implications regarding the potential sensitivity of the biota to oil spills.

2.2.3 Important Species

Though a large number of species or groups of species occur in the nearshore and shoreline habitats, a limited number of marine mammals,

TABLE 2.3 PHYSICAL HABITAT FACTORS IMPORTANT TO BIOTA IN THE NEARSHORE AND SHORELINE HABITATS. (adapted from Truett 1984)

Species	Habitat Factors	Time	Place
Marine mammals			
Spotted seal	Secluded ice-free near-shore waters	Summer	River mouths, lagoons
Beluga whale	Ice-free (warm?) near-shore waters	Summer	River mouths, lagoons
Seabirds			
Alcids	Coastal cliffs	Summer	Cape Lisburne area
Kittiwakes	Open leads in ice	Spring	Cape Lisburne area
Glaucous gull	Barrier islands	Summer	Kasegaluk Lagoon, Icy Cape, Peard Bay
Waterfowl			
Eiders	Barrier islands	Summer	Kasegaluk Lagoon, Icy Cape, Peard Bay
Oldsquaw	Protected bays, lagoons	Summer	Kasegaluk Lagoon Icy Cape, Peard Bay
Black brant	Salt marshes	Summer, fall	Icy Cape, Peard Bay
Shorebirds of marshes and mud flats	Tidal flats, salt marshes	Summer	Vicinity of Icy Cape, Peard Bay
Beach birds			
Phalaropes, Sabine's gull, and arctic tern	Presence of spits and islands	Summer	Kasegaluk Lagoon, Icy Cape, Peard Bay
Anadromous fishes	Warm, brackish water	Summer	Protected lagoons and bays
	Proximity of natal streams	Summer, fall	Vicinity of mouths of large streams

birds and anadromous fish are considered important to the native groups, public and other decision makers. Most of these species are important as a subsistence resource or are protected under federal regulations. The temporal and spatial distribution, shoreline use, and importance of each species or group of species is briefly described below and in more detail in Truett (1984).

Spotted Seal

Spotted seals are relatively abundant in the northern Chukchi Sea from breakup to freeze-up (approximately July through October) when they congregate in the coastal waters. They are excluded from the area in winter by the presence of heavy ice.

Spotted seals move northward from the Bering Sea in early summer to assemble and haul out along the Chukchi coast in lagoons and bays and near river mouths. Major concentrations occur at Kasegaluk Lagoon (2000-3000 seals), at the mouth of the Kuk River near Wainwright, and at the mouth of the Kugrua River in Peard Bay. Kasegaluk Lagoon has the largest number; major haulouts here are Utokok and Akoliakakat passes. Their main uses of these coastal localities are hauling out on sand beaches and feeding.

Though their importance to subsistence hunters is low relative to that of bearded and ringed seals, spotted seals are relatively accessible in summer and any disturbance due to an oil spill could reduce their availability to hunters.

Beluga Whale

The summer belugas (2,000-3,000 individuals) congregate in Chukchi Sea coastal waters, arriving from the south in mid- to late-June and remaining until late July to mid-August. They seem to remain most of the time in shallow waters just outside lagoons and bays; occasionally they are encountered inside lagoons. They are observed most frequently in the vicinity of major passes in Kasegaluk Lagoon - Kukpowruk, Utokok, Akoliakakat - within 0.5-1.8 km of shore. They are also frequently seen near Icy Cape and occasionally at Wainwright and Peard Bay.

The summer belugas appear to use the coastal zone for calving, feeding, and perhaps for molting. Young are frequently seen with adults. The sites where they congregate are good locations for belugas to find anadromous fishes in relative abundance. The relatively warm waters of the lagoons and bays may offer a benign calving and molting environment.

Seabirds: Alcids

In summer, thousands of cliff-nesting alcids use nearshore waters of the Chukchi Sea. Of these, approximately 79 percent are thick-billed murres, 29 percent are common murres, 1 percent are tufted and horned puffins, and less than 1 percent are other species.

These seabirds arrive about mid-May and stay until approximately mid-September. Their distribution is regulated by how far they forage from nesting cliffs in the Cape Lisburne and Cape Thompson areas. In general they do not use lagoons and enclosed bays, but feed in deeper parts of the nearshore zone and in shelf areas beyond the nearshore.

Alcids use the nearshore (and offshore) waters for collecting prey for themselves and their young. Their main prey is forage fishes.

Two habitat features (in addition to the availability of coastal nesting cliffs) are important to these birds. One is the availability of open water in leads in spring when they first arrive. Years with little open water in late spring prevent the birds from readily gaining access to prey. Second, the availability of high-density concentrations of prey affects foraging efficiency.

Food availability (controlled by late spring ice conditions and prey density) appears to be a major factor regulating the annual productivity of these birds. A series of poor food years results in low reproductive success and, subsequently, lower population levels.

Seabirds: Kittiwakes and Gulls

Kittiwakes and large gulls are the most abundant surface-feeding seabirds of the northeastern Chukchi Sea. This group is dominated in number by kittiwakes.

In general, these species are present from May through October. Kittiwakes, like alcids, nest on cliffs at Cape Lisburne, Cape Lewis, and Cape Thompson, foraging up to 60 km offshore. The also congregate all summer on the deltas of the Pitmegea River and Thetis Creek to bathe and rest. Glaucous gulls nest in small coastal colonies on islands and spits, foraging coastwide throughout summer.

Habitat factors important to these birds in the coastal zone include nesting habitat (for kittiwakes and glaucous gulls), extent of open water in spring, ice conditions, and prey depth in the water column. Because all these birds feed at the top of the water column, prey must be available at the surface.

Waterfowl: Eiders and Oldsquaws

Oldsquaws and eiders (mostly common and king eiders) are the waterfowl of greatest concern in coastal habitats. These birds migrate over and feed in coastal waters (over a million eiders pass through annually); some (common eiders) find important nesting habitat in the area.

In general, oldsquaws and eiders use the nearshore zone from early May through October. The earliest use is by migrating eiders. In June, a few thousand common eiders nest on small barrier islands bordering Kasegaluk Lagoon. In July and August, post-nesting oldsquaws and eiders congregate in coastal lagoons and protected bays to molt, stage, and feed. Fall oldsquaw migrants continue to use the lagoons and bays through October.

Important habitat factors include the presence of protected bays and lagoons for molting and staging oldsquaws in summer and fall, and the presence of predator-free islands for common eiders to nest on in early summer. Islands secluded from human use may be important to molting oldsquaws.

Waterfowl: Black Brant

The coastal zone is especially important to black brant. It provides the only known fall staging area north of the Alaska Peninsula for the largest arctic Alaska nesting population of brant. Smaller numbers of locally nesting birds also use the areas.

Brant use the coastal salt marshes, particularly those in the vicinity of Icy Cape and Peard Bay, between early June and late September. They are particularly abundant there as spring migrants in June (~37,000 birds) and again in late August and September as fall migrants (70,000-80,000 birds).

In these staging habitats, they feed on salt marsh vegetation (grasses, sedges). The presence of salt marshes relatively free from human disturbance appears to be the most important habitat factor affecting brant.

Shorebirds of Marshes and Mudflats

In July and August, post-nesting shorebirds of several species congregate in saltmarsh and mudflat habitats.

The distribution of these staging shorebirds is dictated by the presence of the saltmarsh and mudflat habitats in which the birds feed.

The most extensive of these habitats are in the northern part of Kasegaluk Lagoon, especially near Icy Cape. Less extensive habitats occur on the spits and mainland shores of Peard Bay. Small areas occur near Point Hope, but the importance of these to shorebirds is not known.

Beach Birds

Representative of three groups of birds - shorebirds, gulls, and terns - concentrate their feeding activities along or very near beaches. The principal species are red and red-necked phalaropes, Sabine's gull, and arctic tern; other gull and sandpiper species are present in low numbers.

As a group these birds are found along beaches of barrier island, spits, river deltas, and the mainland from June to early October. Primary places of concentration include Point Franklin, Seahorse Island, Icy Cape, the entire length of Kasegaluk Lagoon, and perhaps Point Hope.

Habitat factors important to these birds are the local complexity of shoreline substrates and habitats, shoreline configuration (e.g., points of land appear to attract feeding birds), the presence of beach-grounded pack ice, and (for arctic terns) the presence of islands on which to nest.

Anadromous Fishes

The principal species of anadromous fishes in the coastal zone are pink and chum salmon, Arctic char, boreal smelt, small numbers of least cisco, and perhaps some whitefishes.

Temporal and spatial distributions are related to general habitat preferences and to timing of spawning runs. Specific distributions in coastal waters vary among species, though little is known about distributions of some. Juvenile salmon are found near river mouths for short periods in summer; returning adults are found coastwide in the nearshore in summer, though numbers are thought to be lower in the northerly areas. Char and especially ciscoes and whitefishes are relatively abundant in lagoons, bays,and estuaries near their natal streams during the open-water season; char are more abundant in southern parts of the study area. Boreal smelt apparently overwinter in relative abundance in Kuk Inlet prior to spring spawning.

Habitat factors that are thought to influence the abundance of anadromous fishes in coastal waters are nearness of natal streams (especially for smelt, ciscoes, and whitefishes), presence of suitable overwintering sites, and water temperature and salinity. The size, type, and availability of overwintering and spawning areas appear to limit their populations.

2.3 HUMAN RESOURCES

2.3.1 Introduction

Human resources, defined as resources (i.e., property, public facilities, subsistence resources, cultural resources), and shoreline uses (transportation, fishing sites, boat storage) are a major concern during an accidental oil spill event. Along with sensitive biological resources and shoreline types, human resources strongly influence priorities for spill countermeasures.

The study area is located within the boundaries of the North Slope Borough. Through its coastal management and comprehensive planning programs, the Borough has expressed concern about potential oil spill impacts on subsistence resources and activities. Four predominantly Inupiat Eskimo communities are located along the Chukchi Sea Coast: Barrow, Wainwright, Point Lay, and Point Hope. Human use patterns of the coastline can be identified with individual communities, although the patterns also reflect traditional uses that preceded the formation of permanent communities. Activities are intense in the immediate vicinity of each village, and include subsistence hunting and gathering, transportation (boat traffic and storage on the beach, airstrips with daily scheduled traffic) and excursions to traditional use sites.

However, local residents travel extensively outside their communities to harvest subsistence resources so village use areas extend tens of miles from the permanent communities.

Other human resources are less identifiable with individual communities. Because of its long history of human habitation, the Chukchi Sea coast is rich in cultural resources. This includes prehistoric, historic, and traditional land use sites. The general frequency of cultural resources sites is high, and density increases in areas there the distribution of subsistence resources is concentrated. Favorable topography, water supply, and other factors have contributed to human habitation of specific sites over time. Distant Early Warning (DEW) Line Sites also constitute a human resource; several are located in the study area. Active sites generate air traffic in support of their mission; inactive sites are often used to support research or resource exploration teams and can be used during emergencies.

Because the scope of this investigation is limited to the shoreline, lagoons, and estuaries, the human resource inventory addresses only these areas. It does not include offshore areas which are significant for year-round subsistence activities and can be sensitive to oil spill events. Similarly, this inventory only addresses the open water season (June, July, August, September, and October) on the assumption that an oil spill is unlikely to reach the shoreline during the rest of the year.

A brief description of each of the four communities will be presented, including the area traditionally used by community residents. This will be followed by a discussion of human resources important to this study.

2.3.2 Village Profiles

Barrow

Barrow is the regional center of the North Slope Borough; its 1982 population was 2882. Scheduled daily commercial jet service connects Barrow with Fairbanks, Anchorage, and Prudhoe Bay. The beach at Barrow is intensively used during periods in late August-early September, when the ice moves far enough offshore to offload construction supplies and general cargo. Small boats are also stored along the beach during the summer to be used for travel between communities and for subsistence activities.

Barrow has been occupied by a series of northern groups over the last 3400 years (Maynard and Partch, and Woodward-Clyde Consultants 1981). As in other areas of the North Slope, the number and proximity of subsistence resources can vary widely from year to year, and therefore a large area is utilized for harvesting resources. This is particularly true in Barrow, where the population is several times larger than other North Slope communities. Within the study area, the Barrow use zone extends from Elson Lagoon to the east and to Peard Bay and Point Franklin to the southeast. Important open-water subsistence resources harvested within the coastal strip include fish (char, cisco, and salmon), waterfowl, bird eggs, and spotted seal.

Wainwright

The village of Wainwright is located 90 miles southwest of Barrow. The 1983 population of Wainwright was 483, making it the third largest community in the North Slope Borough. As in Barrow, the shoreline in front of Wainwright is intensively used for boat storage and transportation; supplies are also brought in annually once the ice goes out.

Many of the people of Wainwright are descended from the Kuk and Utukok River peoples (Kuugmiut and Utuqaqmiut). Coastal and inland areas near Wainwright have been occupied continuously over the past 7000 years. With the exception of caribou, Wainwright's major subsistence resources derive from the marine and river environments. Fish (char, salmon, and cisco) and waterfowl are important resources harvested along the coastline, along with beluga whales and spotted seals. The coastal area used by Wainwright residents extends from Peard Bay-Point Franklin southwest to Icy Cape, and up the Kuk River past the area of tidal influence.

Point Lay

The present village of Point Lay is located near the mouth of the Kokolik River, overlooking Kasegaluk Lagoon, across from the historic village site on a barrier island. The village is approximately 188 miles southwest of Barrow. The North Slope Borough estimated the Point Lay population at 94 in 1980 and 126 in 1983 (North Slope Borough 1980, Alaska Consultants et al 1983). A DEW Line Station and its associated airstrip is located due south of the village.

During the summer, boats are pulled up onto the beach in front of the village. Residents regularly travel north and south along Kasegaluk Lagoon and up several of the rivers in pursuit of subsistence resources or traveling summer camps.

While Point Lay itself has been resettled relatively recently, most Eskimo residents are descendants of Inupiat people who traditionally inhabited the Chukchi Sea Coast between Cape Beaufort and Icy Cape (Alaska Consultants et al 1983). In a recent survey, Point Lay residents identified caribou as the most important subsistence resource. However, hunting beluga whales is extremely important, both as a communal activity and in quantity of food. Other important coastal subsistence resources include fish (salmon, char, herring, and ciscos), spotted seals, migratory birds, and bird eggs. The coastal use area of the Point Lay residents extends from Icy Cape of Cape Beaufort, but focuses on Kasegaluk Lagoon and its passes to the Chukchi Sea.

Point Hope

Point Hope is located approximately 315 miles southwest of Barrow and 140 Miles northwest of Kotzebue, near the end of a spit jutting 15 miles to the west of the Lisburne Peninsula. The second largest community in the North Slope Borough, Point Hope had a 1983 population of 570. The old village of Point Hope, abandoned due to flooding and coastal erosion, lies one mile west of the present village. The community's airstrip is located due south of the old village. During the summer, boats are hauled up on the inner shoreline of Marryat Inlet. Boats are used primarily in the Inlet, and along coastal areas to the north. Beaches on both sides of the spit are heavily used by three-wheelers.

Point Hope is a traditional whaling village and has been continually occupied for at least 2000 years (Burch 1981). The lifestyle of Point Hope people has always been strongly oriented towards utilizing marine mammals. Bowhead whales are by far the most important subsistence resource. Important shoreline resources include fish (salmon and char), beluga whale, waterfowl, seabird eggs, and spotted seal. The coastal subsistence use areas extend from Cape Lisburne south to Cape Thompson.

2.3.3 Residential Areas (Communities)

As the center of local resident activity, the concentration of private property, and presence of transportation facilities, the four Chukchi Sea communities constitute a resource that is sensitive to an oil spill event. Use of the surrounding coastal area, and hence boat and three-wheeler transportation originates from these communities. During the summer months, boats and other subsistence-related gear (such as nets) are stored along the beach in front of communities.

2.3.4 Recreation Areas (Traditional Use Areas)

Recreation is a word that is foreign to the Inupiat language. Hunting and fishing are not considered recreation, but rather as necessary for cultural and economic survival. However, many of the communities have certain areas that are traditionally used for family and group excursions not necessarily associated with subsistence activities. The popularity of these areas gives them value. For the purposes of this study, they have been labeled recreation areas, primarily to conform with a consistent system of oil spill sensitivity analysis.

In Barrow, this area includes the coastline between Point Barrow and the Wiley Post/Will Rogers monument. Many "duck shacks" are located along Point Barrow and receive frequent use. The old village sites have the same value in Point Lay and Point Hope, and are frequently visited during the summer. Other beach areas near these communities have a similar value.

2.3.5 Transportation Facilities

Two types of transportation facilities and routes are located in the study area. The first consists of specific airstrips and roads. These are concentrated at communities and at DEW Line sites. A few of these facilities, particularly roads, are located at a low enough elevation to be inundated during storm surges. Airstrips are located at Barrow, Wainwright, Point Lay, Point Hope, Icy Cape DEW Line, Cape Beaufort DEW Line, Cape Lisburne DEW Line, and at Cape Thompson.

Informal transportation routes are equally important to local residents. Beaches are heavily used by three wheelers for subsistence activities and travel to summer camps. Small boats travel along coastal waters and lagoons for the same purposes. All navigable rivers in the area are used of subsistence or summer/fall camp locations.

2.3.6 Subsistence

The value of subsistence resources and associated activities to local residents cannot be over-emphasized. It has provided the basis of the North Slope community culture and economy and continues to do so, even in the present time. Community residents range over a large area harvesting a variety of subsistence resources. Harvesting can be particularly intense during spring and summer months. The areas and species utilized can very widely, depending on their relative abundance and the individual village population.

As previously mentioned, this study focuses on resources and activities occurring in the immediate coastal strip during the open water season. Many important resources such as bowhead whale, oogrook (bearded seal), walrus, and, in some cases, beluga whale are not included. The major resources and harvest activities are described below.

Beluga Whale

They are an important resource for all four communities particularly Point Lay due to the communal effort and volume of harvest involved. However each community harvests a varying number of beluga whale within the specific study area. Beluga are considered a secondary resource by the residents of Barrow; they are hunted offshore in conjunction with the bowhead whale migration and in the waters of Elson Lagoon during the summer. Beluga are more heavily utilized by Wainwright and Point Hope. As in Barrow, some hunting takes place offshore in the spring during the bowhead whaling season. Summer hunting in the waters of Kasegaluk Lagoon and Peard Bay (Wainwright) and Marryat Inlet (Point Hope) occurs in June and July. At Point Lay, beluga provide a greater quantity of food than any other source (Alaska Consultants et al. 1983). Harvesting is concentrated in July on barrier island passes just south and north of the village. Residents use boats to drive whales through the passes into Kasegaluk Lagoon, where they are harvested. Beluga harvests at Point Lay sometimes continue into mid-August.

Spotted Seals

Spotted seals are hunted in much of the same areas and during the same time as beluga whales. In addition to their meat, spotted seals have valuable pelts. Seals are shot from the shoreline or from small boats in Elson Lagoon (Barrow), Peard Bay and Kasegaluk Lagoon (Wainwright), Kasegaluk Lagoon (Point Lay) and on the north shore of the spit and at Sinuk Pass (Point Hope). Spotted seals are less important as a subsistence resource compared to beluga whale and fish.

Fish

Salmon, char, and cisco provide a large quantity of subsistence food to communities in the study area. Fish are harvested primarily from the shoreline using set nets and beach seines. Fishing generally occurs throughout the summer season, and both boats and three-wheelers are used for access to fishing sites. Elson Lagoon is used extensively by Barrow residents, who also set nets along the coast in conjunction with other subsistence activities. However, most fishing for Barrow residents. occurs at inland camps along rivers. Fishing patterns in Wainwright are similar to Barrow. The Kuk Lagoon and River system is extremely important, although Avak Inlet and Kugrua Bay are also used, as is the general shoreline between Point Franklin and Icy Cape. Point Lay residents fish along the barrier island shorelines of Kasegaluk Lagoon during July and August. Fish camps upriver on the Kakpowruk and Utukok rivers are also important. At Point Hope, set nets and beach seines are used in late June, July, and August. Fishing occurs from the shoreline along both sides of the Point Hope spit and inside Sinuk Pass.

Migratory Birds and Eggs

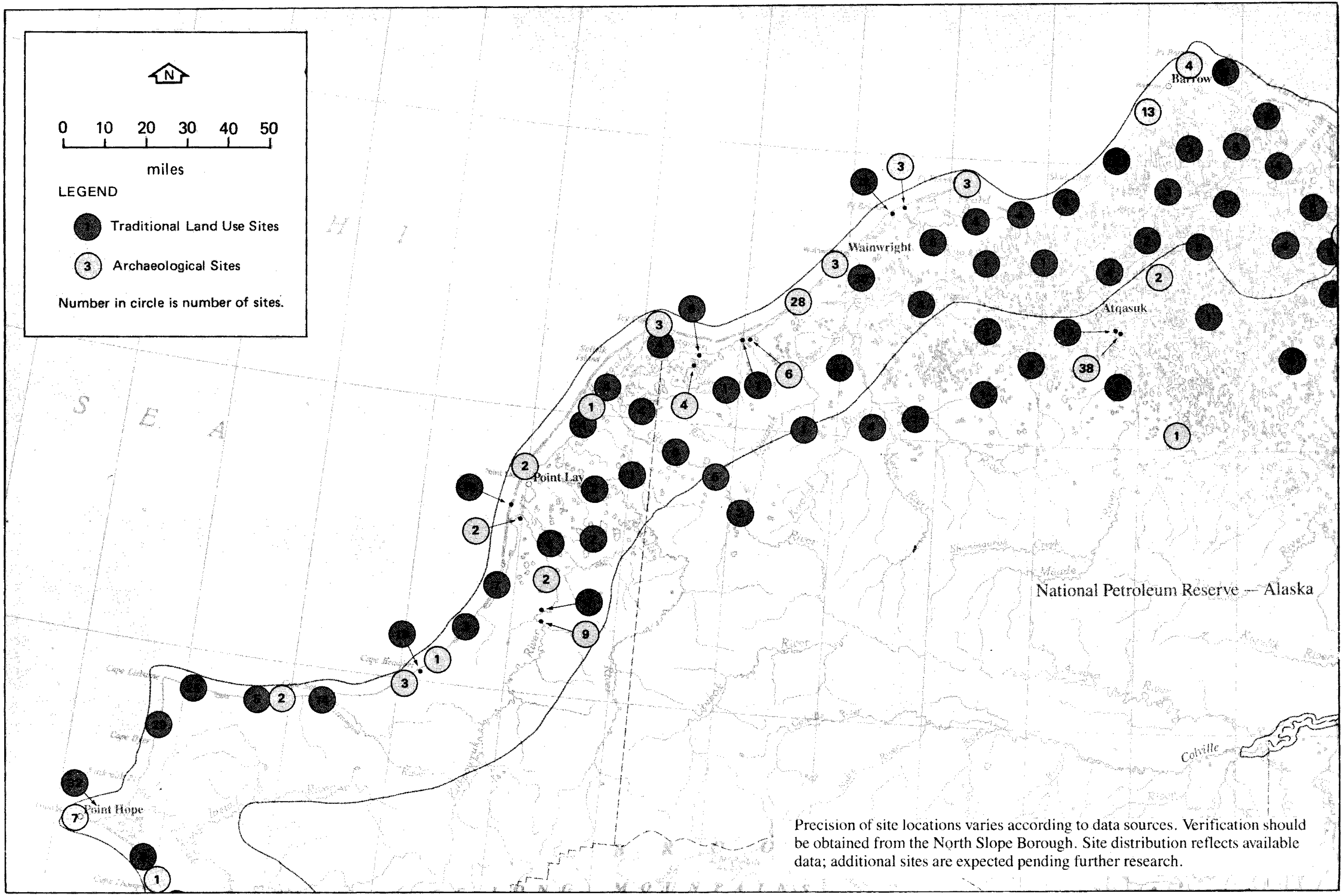
Waterfowl, migratory birds, and their eggs appear to be more important to residents of Point Hope and Point Lay. In Barrow, waterfowl harvesting increases after the bowhead whaling season, concentrating on eider ducks and geese. Waterfowl are hunted in the spring before the ice goes out and also during August and September. Point Barrow and the shoreline of Elson Lagoon are particularly important; many families have hunting cabins at Point Barrow. Collection of birds eggs are incidental to other activities. Hunting at Wainwright also occurs in late spring and late summer. While hunting takes place throughout the area, the Peard Bay/Kugrua Bay and Avak Inlet areas are important. Hunting and egg gathering areas in Point Lay are close to the village. They include the barrier from Kukpowruk and Akunik Passes and the corresponding mainland shoreline. Point Hope utilizes bird eggs more than any other village, harvesting from bird colonies between Cape Lisburne and Cape Thompson.

Brant eider and geese are harvested during late spring, often in conjunction with bowhead whaling, and also during September as they return from summer breeding grounds.

2.3.7 Cultural Resources

Cultural resources include traditional features and localities which display physical evidence of cultural activity, such as structures or artifacts. The study area is rich in cultural resource and traditional land use inventory sites. Two inventories of cultural resource and traditional use sites are maintained: the State of Alaska's Alaska Heritage Resources Survey (AHRS) and the North Slope Borough's Traditional Land Use Inventory (TLUI). The TLUI is concerned primarily with cultural resources sites directly relevant to current residents and is based on current use or oral history of past use. Sites from the AHRS inventory include historical and prehistorical sites dating back to 3000 B.C.

Figure 2.3 shows the relative density of these sites within the North Slope Borough. Tables 2.4 to 2.8 provide a listing of these sites by USGS Quadrangle (1:250,000 scale). In the tables, archaeological sites have an "X" prefix, followed by a series of two or three letters corresponding to the appropriate map. The TLUI sites have a three letter prefix based on the several master lists compiled by the North Slope Borough. In the Point Hope area, some sites are prefixed by a single letter, in which case they are not listed yet by TLUI designation but are instead correlated with sites listed by Burch (1981). An asterisk after the initial entry under the site heading indicates that the site is on or declared eligible to the National Register of Historic Places, or has been declared a National Historic Landmark.



Precision of site locations varies according to data sources. Verification should be obtained from the North Slope Borough. Site distribution reflects available data; additional sites are expected pending further research.

Source: Maynard & Partch, Woodward-Clyde Consultants, 1984.
North Slope Borough Coastal Management Program, Resource Atlas.

Figure 2-3. TRADITIONAL LAND USE AND ARCHAEOLOGICAL SITES (from Maynard & Partch, Woodward-Clyde Consultants, 1984)

Table 2-4. ARCHAEOLOGICAL SITES: POINT HOPE QUADRANGLE (1:250 000 SCALE)

SITE	LOCATION		FEATURES & ARTIFACTS	COMMENTS	REFERENCES
XPH001*, Old Tigara, PH189, E-7, PH186, PH188	68° 20' 166° 37'	N W	Burials on beach ridges 13-18; midden on beach ridges 18-28	Whale hunting site, c. 1000 A.D. to present. Western Thule Culture and Recent. Damaged by shore erosion and gravel pits.	Larson & Rainey 1948 Giddings 1962, 1967 Hosley 1972
XPH002, Jabbertown, Cooper, PH188, PH189, F-1	68° 20' 30" 166° 37' 30"	N W	Thirty large dwellings.	Whale hunting site, c. 1000 A.D. to Present. Western Thule Culture and Commercial Whaling Period. (older than Old Tigara, younger than Ipiutak).	Giddings 1962, 1967 Hosley 1972:18
XPH003* Ipiutak Site	68° 21' 10" 166° 42' 00"	N W	Eight hundred dwellings, log tomb burials.	Type site for Ipiutak Culture, 0-500 A.D.	Larson & Rainey 1948 Rainey 1962, 1971 Giddings 1967 Hosley 1972
XPH004, Ipnot, Anaaraq? PH220?, F-22?	68° 11' 166° 01'	N W	Ruins.	Reported in 1880 U.S. census.	Petroff 1884
XPH005, Initqualik, PH23, B-3	68° 52' 15" 165° 09' 00"	N W	Ruins.	Identified as relating to Tuzroyluk family in TLUI. May be actually on DeLong Mtns map.	
XPH006, Corwin Mine, PH20, B-6	68° 59' 05" 165° 08' 15"	N W	Coal mines, facilities, and ruins.	Operated commercially for early whaling ships and Point Hope and Jabbertown, 1850-1904 A.D.	Collier 1906 Burch 1981:68
XPH007, Nuna PH189, E-7	68° 21' 166° 47'	W N	Ruins.	Reported in 1880 U.S. census to have 74 people.	Petroff 1884
XPH008, Point Hope, PH190, E-7	68° 20' 166° 50'	N W	Modern village.	Present village location dates at least to 1890s; several traditional structures.	Burch 1981 Van Stone 1962
XPH009, Nammie Uyatuan House, PH 189	68° 21' 00" 166° 50' 00"	N W	Traditional sod house.	Whalebone frame & entrance, covered with planks from old whaling ship.	
XPH001, Ipiutak Arch. District	68° 21' 10" 166° 42' 00"	N W	Includes Tigara (XP001), and Ipiutak Site (XPH003), and recent structures.	Approx. 3100 acres of beach ridges showing continuous occupation for the last 2000 years.	Rainey 1941, 1942, 1962, 1971 Larson & Rainey 1948 Giddings 1962, 1967 Hosley 1972 Collins 1954 Larson 1954

Table 2-5. ARCHAEOLOGICAL SITES: DE LONG MOUNTAINS QUADRANGLE (1:250 000 SCALE)

SITE	LOCATION	FEATURES & ARTIFACTS	COMMENTS	REFERENCES
XDEL002, Akulik Creek, PHo3o? A-7?	68° 54' 34" N 164° 00' W	One circular dugout depression, stone debris.	AHRS file states that the location is not exact.	

Table 2-6. ARCHAEOLOGICAL SITES: POINT LAY QUADRANGLE (1:250 000 SCALE)

SITE	LOCATION	FEATURES & ARTIFACTS	COMMENTS	REFERENCES
XPL001, Kukpowruk	69° 36' 40" N 163° 00' 00" W	Former native village site.	Village was observed historically in 1884 and 1918.	Brower 1944:25 Stuck 1920:182
XPL002, Kokolik	69° 45' 00" N 163° 00' 00" W	Former native village site.	AHRS files are vague, map location corresponds to TLUI map location of site L26. Site was noted on 1899 USGS map.	
XPL003, Amatusuk, PL2	69° 06' 30" N 163°-37' 00" W	Ruins of five houses, scatter of recent debris.	AHRS map location corresponds to the north dot of the two map locations plotted for TLUI site PL2.	
XPL005 Kahatak Ridge	69° 03' N 163° 47' W	Scatter of chipped stone debris, stone tools.		
XPL006, Kahatak Creek	69° 03' N 163° 46' 30" W	Midden deposit containing bones of whale, dog, fox, possible human.	Some bones displayed sawn surfaces, suggesting recent origin.	
XPL036, Field #139	69° 16' 35" N 162° 37' 15" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964
XPL037, Field #145	69° 17' 00" N 162° 36' 15" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964
XPL038, Field #147	69° 20' 15" N 162° 33' 30" W	Chipped stone artifacts.	AHRS map location is within ½ mile of TLUI site PL43.	Solecki 1950:66-69 Matthews 1964
XPL039, Field #132	69° 14' 15" N 162° 42' 00" W	Chipped stone artifacts; core and blade material.		Solecki 1950:66-69 Matthews 1964
XPL040, Field #133	69° 14' 05" N 162° 43' 45" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964
XPL041, Field #134	69° 14' 45" N 162° 48' 00" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964
XPL042, Field #144	69° 16' 00" N 162° 47' 00" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964
XPL043, Field #143	69° 17' 30" N 162° 40' 45" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964
XPL044, Field #141	69° 17' 20" N 162° 38' 30" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964

Table 2-6 (concluded). ARCHAEOLOGICAL SITES: POINT LAY QUADRANGLE (1:250 000 SCALE)

SITE	LOCATION	FEATURES & ARTIFACTS	COMMENTS	REFERENCES
XPL046, Field #146	69° 18' 15" N 162° 38' 00" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964
XPL047, Field #149	69° 23' 15" N 162° 38' 10" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964
XPL048, Field #150	69° 26' 30" N 162° 40' 45" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964
XPL049, Field #151	69° 31' 45" N 162° 50' 00" W	Chipped stone artifacts.	AHRS map location is within ¼ mile of TLUI site PL40.	Solecki 1950:66-69 Matthews 1964
XPL050, Field #152	69° 35' 20" N 162° 56' 30" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964
XPL051, Field #153	69° 33' 50" N 163° 08' 00" W	Chipped stone artifacts.		Solecki 1950:66-69 Matthews 1964
XPL053, Point Lay, PL25(?)	69° 45' 28" N 163° 03' 08" W	Former native village site consisting of 20 buildings.	Site dates to 1900-1953, still seasonally occupied. TLUI site correspondance is in question.	Schneider 1980 Bland 1973

Table 2-7. ARCHAEOLOGICAL SITES: WAINWRIGHT QUADRANGLE (1:250 000 SCALE)

SITE	LOCATION	FEATURES & ARTIFACTS	COMMENTS	REFERENCES
XWAI001, Nunagiak, WAI9	70° 48' N 159° 40' W	Two historic cabins, old sod house ruins.	AHRS files say Thule Site is present.	Bandi 1969
XWAI002, Kilamitagvik, WAI82	70° 29' 30" N 160° 26' 00" W	Eight sod house pits, drying racks, 14 caches, sod cutting areas, artifacts present.	Large historic and probable prehistoric villages; pothunting and erosion have destroyed over half of the site. Observed by Lt. Zagoskin in 1800.	Orth 1967 Ford 1959 Smith & Merne 1930
XWAI003, Kuk	70° 36' N 160° 07' W	Ruins of native village.	May be correlated with TLUI sites WAI21, WAI22, or WAI23.	
XWAI004, Atanik, WAI4	70° 50' N 159° 21' W	Ruins of native village. TLUI reports cabins, sod house ruins, graves.	Observed by Lt. Zagoskin in 1847 as Atinikg, 1890 census reports 34 people.	
XWAI005, Maudheim	70° 36' N 160° 06' W		Roald Amundsen built a small camp here prior to his North Pole flight in 1925.	
XWAI006, Miliktagvik, WAI86	70° 24' 20" N 160° 37' 00" W	Nine sod houses, 7 caches, stone and historic artifacts.	Abandoned in 1930s. AHRS and TLUI map locations differ by one mile.	Ford 1949
XWAI007, Kayaasiuvɨk, Icy Cape, WAI105	70° 20' N 161° 52' W	Former native village site.	As map location indicates, site is now under water. Observed by Lt. Zagoskin in 1847. AHRS and TLUI map locations differ by three miles.	
XWAI017, Ahaliraq, WAI20	70° 37' 49" N 160° 03' 10" W	Several sod houses and caches, one drying rack.	Former residents moved to present village of Wainright. Site is severely pothunted and eroded.	
XWAI018, Tulagiak, WAI113	70° 03' 19" N 162° 27' 15" W	At least two large house ruins are present, others probable.	Possible confusion with TLUI Site WAI114.	Larson & Rainey 1948
XWAI019, Akinak, WAI91	70° 22' 18" N 160° 47' 25" W	Two sod houses, one grave.	TLUI and AHRS map locations differ by one mile.	
XWAI020, Akeonik, WAI106	70° 16' 48" N 161° 56' 35" W	Seventeen houses, 5 caches, one cabin.	Larson & Bodfish excavated in 1942, but did not report.	Smith & Merne 1930
XWAI020, Akoliakatat, WAI95	70° 18' 14" N 161° 12' 45" W	Possible midden area.	Known camp site in historic period.	

Table 2-7 (continued). ARCHAEOLOGICAL SITES: WAINWRIGHT QUADRANGLE (1:250 000 SCALE)

SITE	LOCATION	FEATURES & ARTIFACTS	COMMENTS	REFERENCES
XWAI022, Nokotlek, WAI93	70° 19' 38" N 161° 01' 09" W	Two frame houses, other misc. features, historic artifacts.	Occupied at least between 1900s and 1930s.	
XWAI023	70° 18' 28" N 161° 03' 00" W	Two sod houses ruins, others likely.	Possibly associated with TLUI site WAI94, across the river.	
XWAI025, Nevat, WAI99	70° 15' 00" N 161° 22' 00" W	Several sod houses, cabin, ice cellar.	Occupied from late 1800s to 1940s.	
XWAI026, Avak, WAI103	70° 15' 00" N 161° 34' 30" W	Many sod house ruins, most are eroded. Many stone artifacts.	Prehistoric and historic components present.	
XWAI027, Avak	70° 14" 34" N 161° 38' 55" W	One sod house ruin, cache, stone artifacts.	Note that both XWAI026 & XWAI027 are termed "Avak".	
XWAI091, Tunalik	70° 12' 05" N 160° 15' 55" W	Many lithic artifacts, including microblade material.	AHRS file states that site was destroyed by runway construction and collecting by workers.	Gal 1978, 1980 Bowers & Kunz 1980
XWAI093, Pingorarok Hill, WAI89	70° 22' 09" N 160° 43' 00" W	Stone artifacts of microblade technology, sod house ruins.	AHRS files do not note the sod house ruins, which TLUI does mention.	Hall 1978
XWAI094	70° 25' 40" N 160° 34' 30" W	Stone artifacts.		Hall 1978
XWAI095	70° 49' 22" N 159° 30' 20" W	Nine house pits, caches, drying racks, built of ship timbers. Historic artifacts.	May be correlated with TLUI sites WAI6, WAI7, or WAI8.	Hall 1978
XWAI096, Pingasagruk, WAI2	70° 52' 43" N 159° 07' 34" W	House pits, some of whale bone construction. Many artifacts.	Tested by Larson.	Hall 1978
XWAI097	(see map)	Stone artifact.	Isolated find.	Hall 1980
XWAI098	(see map)	Stone artifact.	Isolated find.	Hall 1980
XWAI099	(see map)	Stone artifacts.	Wedge-shaped cores suggest American Paleo-Arctic Tradition.	
XWAI100, Kilimintavi, WAI82	(see map)	Four sod house ruins.	Recorded by Lt. Zagoskin in 1824-1844 as Kyiyamigatvik.	Hall 1980
XWAI101	(see map)	Stone artifacts.		Hall 1980

Table 2-7 (concluded). ARCHAEOLOGICAL SITES: WAINWRIGHT QUADRANGLE (1:250 000 SCALE)

SITE	LOCATION	FEATURES & ARTIFACTS	COMMENTS	REFERENCES
XWAI102	(see map)	Stone artifact.	Isolated find.	Hall 1980
XWAI103	(see map)	Stone artifacts.	Possibly a Denbigh-related site.	Hall 1980
XWAI104	(see map)	Stone artifact.	Isolated find.	Hall 1980
XWAI105	(see map)	Stone artifacts.	Wedge-shaped cores suggest American Paleo-Arctic Tradition.	
XWAI106	(see map)	Stone artifacts.		Hall 1980
XWAI107	(see map)	Stone artifacts.	Wedge-shaped cores suggest American Paleo-Arctic Tradition.	
XWAI108	(see map)	Stone artifacts.		Hall 1980
XWAI109	(see map)	Stone artifacts.	Wedge-shaped cores suggest American Paleo-Arctic Tradition.	
XWAI110	(see map)	Stone artifacts.		Hall 1980
XWAI111	(see map)	Stone artifact.	Isolated find.	Hall 1980
XWAI029	(see map)	Stone artifacts.		Hall 1980
XWAI030	(see map)	Stone artifacts.		Hall 1980
XWAI031	(see map)	Stone artifacts.		Hall 1980

Table 2-8. ARCHAEOLOGICAL SITES: BARROW QUADRANGLE (1:250 000 SCALE)

SITE	LOCATION	FEATURES & ARTIFACTS	COMMENTS	REFERENCES
XBAR001,* Birnirk, BAR2, Pigniq	71° 20' 52" N 156° 35' 33" W	Sixteen house mounds arranged in three rows parallel to the shore. Midden deposit.	Type site for the Birnirk culture, dated to 500 A.D.	Bandi 1969 Collins 1951 Ford 1959 Taylor 1963
XBAR002,* Utkiavik, BAR6	71° 17' 25" N 156° 47' 40" W	Many stratified house mounds, midden mounds, and burial mounds.	Major site representing occupation since 3000 B.C.	Ford 1959 Stanford 1976 Yarborough 1981 Aigner and Brooks 1977 Aigner and Shinkwin 1974
XBAR003, Kugusugaruk	71° 16' 30" N 150° 50' 00" W	Burials.	Birnirk culture. Excavated in 1917-1919 by Van Valin.	Ford 1959 Bandi 1969 Yarborough 1981:13-14
XBAR004, Russian Utkaeayuk Mission Church	71° 17' 20" N 156° 49' 00" W	Historic church.		
XBAR005, Will Rogers/Wiley Post Memorial, BAR12, Walikpa	71° 09' 18" N 157° 03' 30" W	One pink granite monument, one concrete monument.	Location of fatal plane crash of Will Rogers and Wiley Post in 1935.	Brower 1942 Potter 1947
XBAR007, Browerville	71° 17' 55" N 156° 46' 15" W	Modern and historic habitations, now part of Barrow.	Named for C.D. Brower, whaling station chief and trader.	
XBAR008, Irenivio, BAR113, Igniviq	71° 07' 00" N 157° 09' 00" W			Ray 1885
XBAR009, Isutkwa, BAR005	71° 17' 20" N 156° 49' 00" W	Modern and historic habitations, now part of Barrow.	First reported in 1892 by Sgt. John Murdoch.	
XBAR010, Napawrax	71° 11' 00" N 157° 01' 00" W		AHRS map location coincides with TLUI map location for site BAR11.	Spender 1959 Ray 1885:55
XBAR011, Nuwuk, BAR1	71° 23' 10" N 156° 28' 10" W	Ruins of sod houses.	Occupied during prehistoric and historic period.	Ray 1885 Murdock 1888 Ford 1959 Mason 1928 Carter 1966 Yarborough 1981:14

Table 2-8 (concluded). ARCHAEOLOGICAL SITES: WAINWRIGHT QUADRANGLE (1:250 000 SCALE)

SITE	LOCATION	FEATURES & ARTIFACTS	COMMENTS	REFERENCES
XBAR012,* Pt. Barrow Refuge Station, BAR 6	71° 17' 34" N 156° 47' 38" W	Two-story frame building in use as a cafe in Barrow.	Built in 1893--oldest frame building in the Arctic. Was a U.S. govt. whaler refuge station, trading post.	Bockstoce 1979
XBAR013, Walakpa, BAR12	71° 09' 18" N 157° 03' 30" W	Stratified series of historic and prehistoric houses.	Cultures represented include Akmak, Norton, and Thule. Site XBAR005--the Will Rogers/Wiley Post Monument-- is located within the XBAR013 perimeter.	Stanford 1976
XBAR014, Coffin Site	71° 08' 58" N 157° 02' 35" W		Late Denbigh/Choris cultures represented.	Stanford 1976
XBAR015, BAR6	71° 17' 30" N 156° 47' 15" W	Sod house.	Dates to 1880s, shows architectural transition from sod to frame construction.	
XBAR016, Elavgak House, BAR 6	71° 17' 55" N 156° 46' 20" W	Frame house.	Believed to have been built in 1890s from lumber left over from construction of Refuge Station (XBAR012).	Brower
XBAR091, Kahraok Site	71° 08' 53" N 157° 02' 25" W	Stone artifacts.	Diverse assemblage possibly relating to Akmak assemblage.	Stanford 1976:16
XBAR093	71° 05' 18" N 154° 48' 20" W	Sod house ruin, possible cache pit.	Suffering tidal erosion.	Hall 1978
XBAR094, Brant Point (Arguqqaq), BAR4	71° 20' 02" N 156° 33' 45" W	One sod house ruin, other cultural features (mounds) being used for duck blinds now. Graves. Tent mounds.		

3.0

FIELD AND DATA ANALYSIS METHODS

3.1 INTRODUCTION

General shore-zone types were identified on the basis of existing information including hydrographic charts, topographic maps, aerial photographs and previous experience. However, additional detail was required to map the distribution of these shore-zone types in sufficient detail for oil spill sensitivity mapping. The general approach for obtaining the additional detail on the distribution of shore zone types was to conduct an aerial reconnaissance of the entire coastline and a limited ground-truth survey to verify aerial interpretations. Details of the approach are outlined in the following sections.

3.2 PRE-SURVEY PLANNING

A preliminary mapping exercise was conducted to delineate the approximate distribution of shore-zone types within the study area. This exercise provided insight into the distribution of potentially sensitive resources and therefore provided a basis for concentrating field efforts on (a) sensitive areas and (b) poorly understood areas. A set of 1:50,000 scale strip maps made up from topographic maps, were used to map existing information and for planning purposes.

Overflights were scheduled to maximize the aircraft supported survey by (a) minimizing the number of base camps and (b) minimizing non-productive traveling time. Appropriate borough and regulatory agencies were advised of preliminary scheduling.

3.3 FIELD SURVEY

3.3.1 Aerial Reconnaissance

Our aerial reconnaissance survey utilized a NOAA turbine helicopter (Bell-204) and a portable videotape recording (VTR) system plus 35mm still camera for recording coastline imagery and audio commentary. The entire shoreline was flown, including the mainland lagoon shore, at altitudes of 150 to 300 feet. The videotapes show detailed shore zone morphology and also include a biophysical description of the shore zone on the audio soundtrack. All of the outer coast, as well as the Kuk River and Peard Bay, were videotaped from the right side of the aircraft whereas the mainland shore of Kasegaluk Lagoon was videotaped from the left side of the aircraft. The color 35-mm slides provide more detail on selected locations and features.

The field crew consisted of a coastal geologist, a coastal ecologist, a VTR technician, the NOAA pilot and the NOAA flight engineer. During the overflight, a communications system was used for general communications among field crew members. This system recorded all communications onto the audio soundtrack of the VTR. These communications included real-time description of shore-zone character, biological resources, color slide locations and geographic location information.

Twenty-one videotapes were recorded during the survey. The location and time of each video tape was recorded on a video tape log sheet (Figure 3-1). The tape quality ranged from good to excellent, except over one 20 km section of coast where fog was encountered. This section was later reflown. The videotapes were reviewed in the field each evening to select exact locations for field ground-truth stations.

Detailed videotape logs and flight-line maps are included in a separate report (Appendix A: Videotape Manual of the Northern Chukchi Sea Coast).

Figure 3-1. **Chukchi Sea Coast Aerial Survey**

Videotape Log Sheet

Date ______________

Tape Number	Location Start	Location Stop	Time (ADT)	Comments

Woodward-Clyde Consultants

Sheet _____

Color 35-mm slides were obtained for certain areas or features. The location and time of each roll of film was recorded on a Color Film Log Sheet (Figure 3-2). The location of each frame was noted on the audio commentary of the VTR.

3.3.2 Ground-Truth Survey

A field ground-truth survey was conducted (a) to provide a basis for "calibrating" observations made during the aerial reconnaissance, (b) to collect topographic survey data (i.e., across-shore beach profiles) and (c) to collect specimens or samples as appropriate. The ground-truth survey was conducted using the NOAA helicopter support for transportation. In addition to the helicopter crew (pilot and engineer), a coastal geologist, coastal ecologist and field assistant comprised the field crew. The ground-truth survey was conducted at the same time as the aerial reconnaissance survey.

Ground-truth stations were selected on the basis of (a) providing an approximate uniform distribution of sample stations, (b) providing a representation of major coastal features within a geographic area and (c) maximizing field effort. During the survey, 54 ground-truth stations (Figure 3-3) were visited during seven complete survey days (two complete days were lost due to weather).

At each ground-truth station, a series of standard observations and measurements were made, and in some cases, samples were collected. Observations were recorded on a set of standardized field data sheets to assure uniformity of observations between stations. Data sheets (Figures 3-4 to 3-9) and associated observations included:

Data Sheet 1 - Location Description Sheet - geographic location information and sketches sufficient to relocate station if necessary

Figure 3-2. **Chukchi Sea Coast Aerial Survey**

Color Film Log Sheet

Date ______________

Roll Number	Location Start	Location Stop	Time (ADT)	Comments

Woodward-Clyde Consultants

Sheet _____

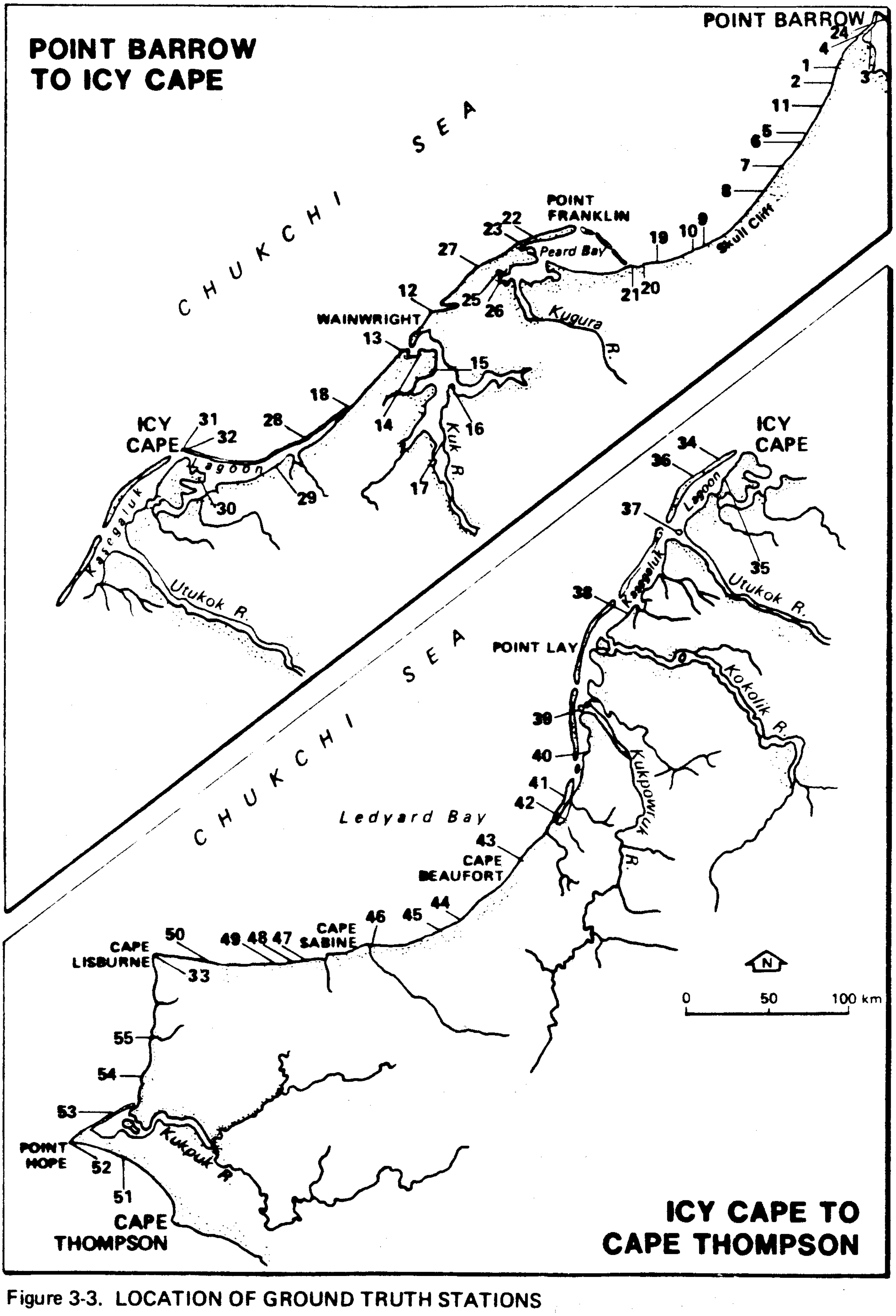


Figure 3-3. LOCATION OF GROUND TRUTH STATIONS

Figure 3-4. **NOAA CHUKCHI SEA COAST GROUND TRUTH STATION**

LOCATION DESCRIPTION SHEET

Station or Profile Number ________________ **Recorder** ________________

Date ______________ **Time** ________________

Location:

Quad Sheet # ____________

Chart # ________________

Lat. and Long. __________

Description:

Profile Bearing ____________ **(compass);** ______________ **(true)**

Bench Mark Description (if applicable)

Bench Mark Status (recovery status and date)

Topographic Control		**horizontal**	**vertical**
(TBM 1 always landward-most)	**TBM 1**	________	________
	TBM 2	________	________
	TBM 3	________	________

Miscellaneous (sketches, range set-up, etc.)

Sheet Number ____

Figure 3-5. NOAA CHUKCHI SEA COAST GROUND TRUTH STATION

SKETCH SHEET

Station Number ________ Location _____________ Date ____________

Time _________________ Tide Stage ___________ Recorder ________

Photo Numbers: Roll ___________ Frame ___________
(note locations on sketch)

Sheet Number ____________

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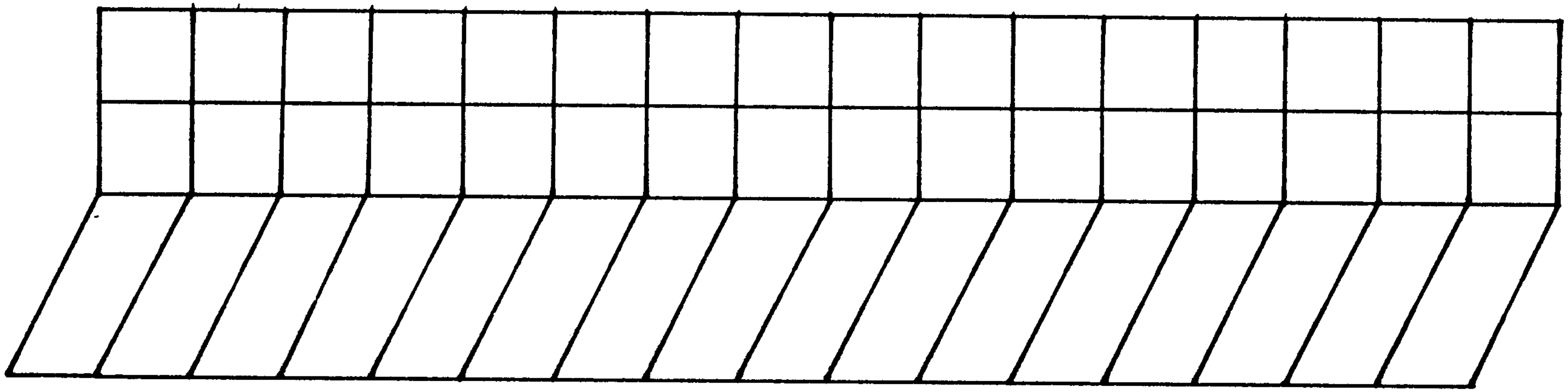
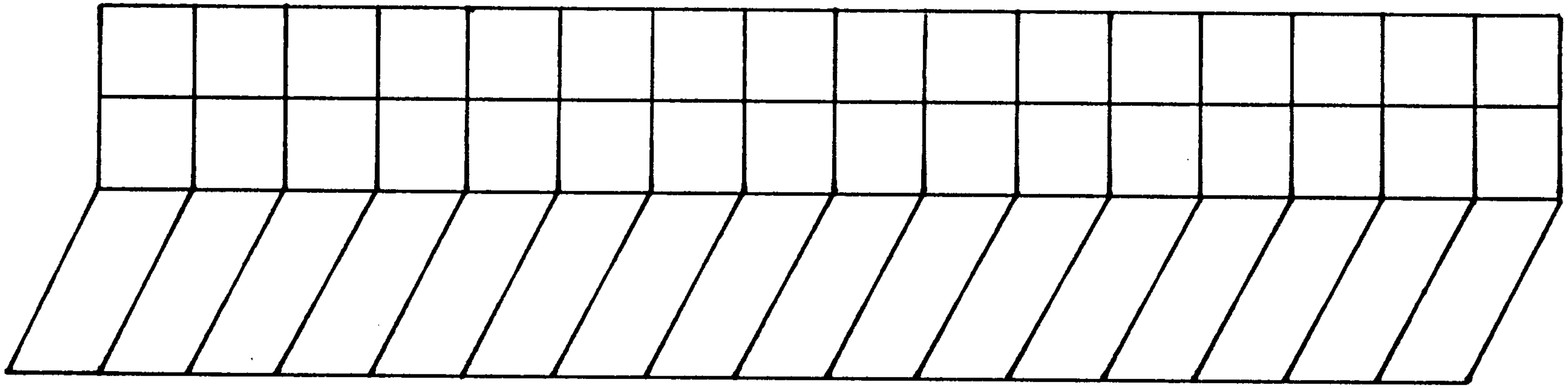
Figure 3-6. **NOAA CHUKCHI SEA COAST GROUND TRUTH SURVEY**

BEACH PROFILE

Station Number ________________ **Date** ________________ **Time** ________________

Tide Stage ________________ **Recorder** ________________ **Time Start** _______, **Finish** ______





Sheet Number __________

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Figure 3-7. NOAA CHUKCHI SEA COAST GROUND TRUTH STATION

PHYSICAL OBSERVATION CHECK LIST

Station Number ________ Date ________________ Time ________________

Recorder ______________

BEACH STABILITY

Long-term Change: Erosional ________ Accretional _______ Stable _______

Short-term Change: Erosional ________ Accretional _______ Stable _______

Mass-Wasting Features: ____

____

____

BEACH MORPHOLOGY

Storm Debris Line: Yes ____________ No ____________ Type _________

Evaluation ________________________

Rhythmic Topography or Bars ___________________________

Dominant Longshore Transport: Direction ________________________

Indicators _______________________

BIOLOGICAL FEATURES

Vegetation: Yes ___________ No _____________ Types ________

____

____

Sheet Number ____________

Figure 3.8. **NOAA CHUKCHI SEA COAST GROUND TRUTH SURVEY**

GRAIN SIZE ESTIMATES

Station Number ____________ **Date** ____________ **Time** ____________

Recorder ________________

Sample Location or Sample Number	Sediment Type (see reverse)	Mean Size (Ø or mm)	Sorting (see over)	Composition	Cone Penetrometer

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Sheet Number ________

Figure 3-9. **Chukchi Sea Coast Ground Truth Survey**

Biological Observation Checklist Sheet

Station No. ______________ **Date** ______________ **Time** ______________

Recorder: ____________________________

Wave Exposure: High ____ **Med.** ____ **Low** ____

Comments: ____

____

____

Substrate: ____

____

Profile Sketch of Significant Across-shore Features:

Disturbance: ____

____

____

Vulnerability to Crude Oil Spills: ____

____

____

Estimated Recovery Potential: ____

Photos: Color Roll No. ______ **Frames** ______ **Comment** ____________________

I.R. Roll No. ______ **Frames** ______ **Comment** ____________________

Samples: ____

____

____

Comments: ____

____

____

Sheet _____

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Data Sheet 2 - Sketch Sheet - a standardized sketch sheet for drawing oblique perspective views of shore zone at the ground-truth station

Data Sheet 3 - Beach Profile Sheet - a standardized format for recording beach survey data

Data Sheet 4 - Physical Observation Checklist - a check list that allowed important physical resource features to be evaluated at each site

Data Sheet 5 - Grain Size Estimate - a log sheet for recording sample locations (if any), sediment size, sorting, and bearing strength of each morphological across-shore component

Data Sheet 6 - Biological Observation Checklist - a checklist for evaluating existing disturbance, vulnerability to crude oil spills, recovery potential and samples of biological resources at each ground-truth station

Data sheets were completed at the ground-truth station and rechecked each evening.

Topographic beach profiles were surveyed using the Emery profile method (Emery 1960). This method provided a rapid survey technique for documenting beach slope and width characteristics and for documenting beach elevations, particularly log-debris line elevations.

Substrate character was recorded for each across-shore morphological component on a separate data sheet (Data Sheet 5). Notes on sediment character followed the terminology of Folk (1968). Both mean sediment size and an index of sorting were recorded. Sediment samples were collected at each site (locations indicated on sketch sheet) for archiving purposes.

All field data sheets were bound into a separate field data report (Appendix B: Field Data Sheets).

3.4 POST-SURVEY DATA REDUCTION

3.4.1 Mapping Techniques

Several sources of information were used to compile the physical shore-zone description that is shown on the resource maps (Volume 2). The primary information sources were (a) the oblique aerial imagery (videotapes and 35 mm color slides), (b) the field reconnaissance survey and (c) previously existing data such as maps and aerial photographs. These information sets were complementary, in that each information set provided a different perspective of the shore zone character. The aerial imagery provides a continuous record of shore-zone features with dimensions greater than 1 m; the field survey data provides a high level of detail at selected locations, and the previously collected data provide an index of temporal variations in both shore-zone morphology and sediment texture.

The aerial videotapes of the shore-zone were reviewed in our studio by a coastal geologist and the information on shore-zone character was transferred onto the 1:50,000 scale base maps (drawn from the hydrographic charts of the study area). Information on sediment size was also transferred to the maps and resource tables; recorded observations on the VTR soundtrack and ground-truth station information were most useful in estimating sediment characteristics.

The biological shore-zone information came from several sources. The VTR and slides along with ground-truth stations provided data on the distribution and size of wetland habitats, and of the major seabird colonies. The location of waterfowl and gull or tern nesting areas, small seabird colonies, and seal and beluga whale use areas was obtained from published sources.

The location and use of human resource components was based primarily on published information and unpublished data available to responsible parties from the MMS.

3.4.2 Mapping Approach

The mapping approach utilizes a progressive subdivision or heirarchy of shore-zone features, combined with a supplemental resource table (Volume 3), for the description of physical features. The mapping approach is flexible and has been applied to other oil spill risk assessment studies (Owens 1981; Woodward-Clyde Consultants 1982) as well as to land-use and recreational planning studies (Owens 1980; Owens et al. 1981; Harper 1981).

In its simplest form, the mapping method defines a series of shoreline units that are homogeneous along a section of coast (Figure 3-10). Each unit is then described in terms of a series of across-shore components. The across-shore component subdivision is based on the geomorphological and/or textural character of the intertidal zone. Thus a picture is built up of each unit, with the components as the basic building blocks from which the description of the unit is constructed.

- a unit is an association of across-shore physical components that is continuous alongshore. For this study, at a 1:50,000 map scale, the minimum unit length is approximately 0.25 km (0.5 cm on the map).

- within each unit (Figure 3.10), the across-shore physical character is described in terms of geomorphological and sedimentological components that are homogeneous both across-shore and alongshore.

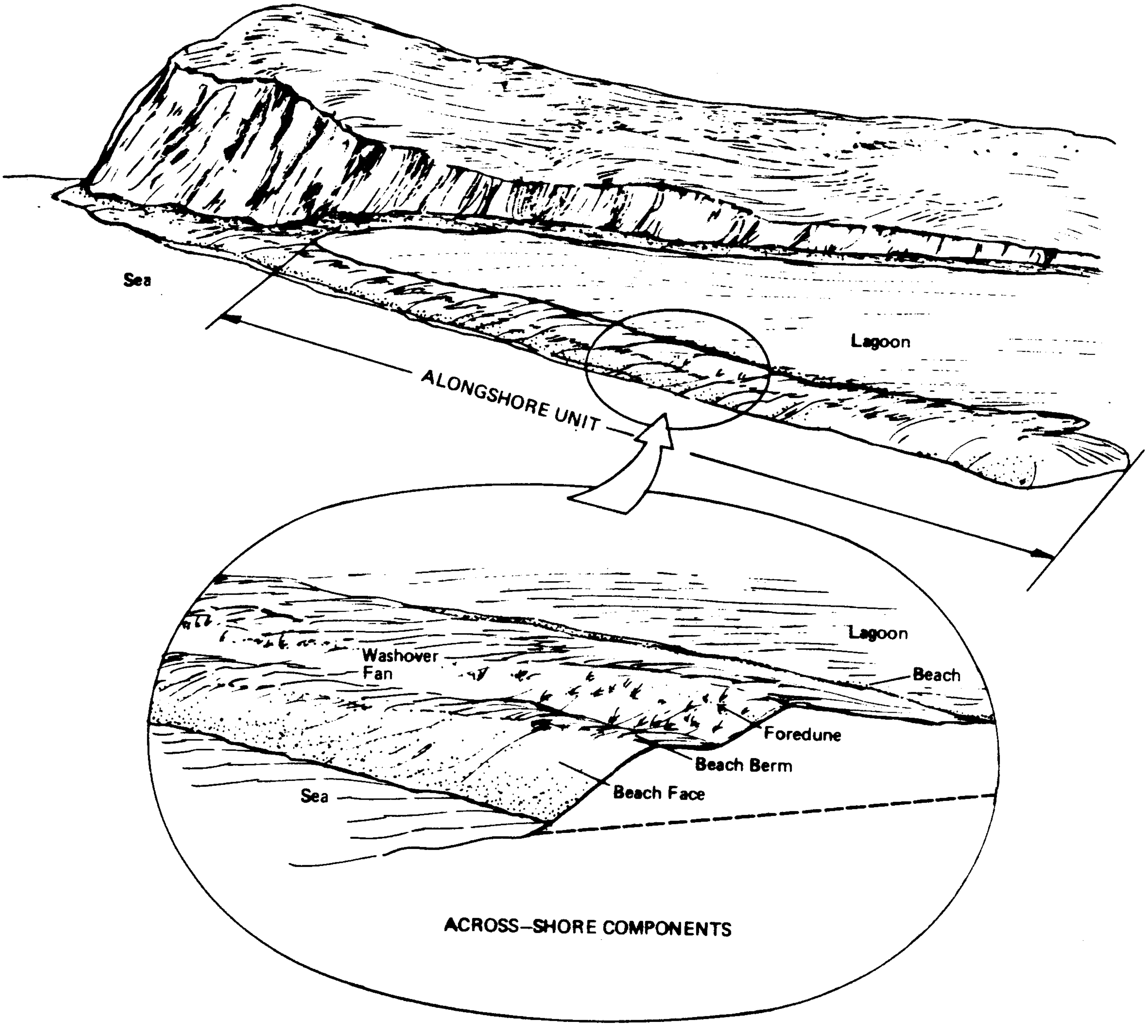

Figure 3-10. ILLUSTRATION OF THE MAPPING APPROACH

The map format identifies the boundaries of units and the shore-zone morphological and sedimentological character is illustrated using components. Each component is shown on the map by a distinctive graphic pattern (Part II).

Details on the units and components are provided on a separate resource table (Part III) which is keyed to the map by a unit identifier. The resource table provides an additional level of detail on across-shore morphological components and on substrate character. The use of a separate resource table to record shore-zone information allows a comparatively simple map format to be retained while at the same time recording a high level of detail on shore-zone character.

The location or boundaries for the biological and human use resources are displayed on the same maps as the physical features (Part II). However, the boundaries of biological and human use resources may not be the same as those of the shoreline units. The biological resources shown on the maps are primarily wetlands which are identified as a physical unit and bird nesting areas or seabird colonies. Human use resources which can be mapped as discrete sites are principally villages and industrial/military areas. Transportation corridors, subsistence and recreational areas are not as precisely defined and are shown with arrows indicating the approximate distribution.

The biological and human use resources are described in more detail in the separate resource table (Part III). For convenience, they are described within the unit identifier(s) describing the physical features of the shoreline.

4.0

OIL RESIDENCE

4.1 INTRODUCTION

The potential persistence of oil in the shore zone is of primary concern in the evaluation of sensitivity because biological and human-use impact are often related directly to oil residence periods. In other words, biological or human-use activities are more likely to be impacted in areas where oil will remain for a long period of time than in areas where oil residence is of short duration. This section of the report provides some background on (a) observations of stranded oil, (b) the Baffin Island Oil Spill Experiment and (c) previous sensitivity studies in the arctic. Development of an oil spill residence index for the study area is described and its application to the coastal environments of the study area is summarized.

4.2 PREVIOUS STUDIES ON OIL PERSISTENCE

No large-scale spills of crude oil have occurred in the arctic, and it is therefore not possible to make direct comparisons of actual spill events within the study area. It is possible, however, to make indirect inferences about the potential impact of an oil spill in the study area from review of:

- spills in temperate environments
- results from the Baffin Island Oil Spill (BIOS) experiment
- similar oil spill sensitivity studies for the arctic.

Appropriate results from studies in these disciplines are summarized in the following sections.

4.2.1 Oil Spill Case Studies

Observations from selected oil spill case studies are presented as background to the development of an oil residence index for the Chukchi Sea coast. Results from the Baffin Island Oil Spill (BIOS) program, an experimental oil spill designed to evaluate the long-term impact of an oil spill in the arctic, is presented separately in Section 4.2.2.

Selected spill studies included for discussion are: the ARROW spill in Chedabucto Bay, Nova Scotia; the METULA spill in the Straits of Magellan; the URQUIOLO spill in Spain; and the AMOCO CADIZ spill in France (Table 4.1). These spills studies provide a range of different spill types, spill volumes and coastal environments affected.

ARROW Spill

In 1970, the Tanker ARROW broke up in Chedabucto Bay, Nova Scotia, spilling a total of 18,000 tons of Bunker C fuel oil (Table 4.1). The surrounding shorelines were oiled, and an intensive cleanup effort followed. Observations of the long-term fate of the oiled beaches were made by Owens (1971, 1973, 1977, 1978), Rashid (1974), Owens and Rashid (1976), Vandermeulen et al. (1972). Of special significance are the following observations:

- oil persistence was directly related to mechanical wave energy levels; high wave energy levels promoted rapid oil dispersion and increased biodegradation rates whereas low wave energy levels resulted in little natural dispersion and slower biodegradation rates.

- burial of oil, caused by natural sedimentation processes or by cleanup activities, decreased natural dispersal of oil and retarded biodegradation of oil.

Table 4-1. SELECTED SPILL CASE STUDIES

Location	Date	Spill Type and Amount
ARROW, Chedabucto Bay, Nova Scotia	Feb. 1970	Bunker C; 18,220 tons total
METULA, Strait of Magellan, Chile	Aug. 1974	Saudi Arabia Crude; 53,000 tons total 40,000 tons onshore
URQUIOLA, La Coruna, Spain	May 1976	Persian Gulf Crude; 110,000 tons total; 25,000 to 30,000 tons onshore
AMOCO CADIZ, Brittany, France	Mar. 1978	Arabian Gulf Crude; 223,000 tons total 64,000 tons onshore

- in areas of high wave exposure, oil was stranded only in the upper parts of the intertidal zone, whereas in low exposure areas, the oil covered the entire intertidal zone.

- oil stranded above the normal limit of marine activity shows little mechanical or biological degradation over time.

Long-term observations of oil stranded on the sheltered beaches of Chedabucto Bay (e.g. Black Duck Cove) have shown little change after the first month of oiling. These beaches are very sheltered (fetch < 1 km) and are comprised of coarse gravel material (pebbles and cobbles) which promotes adhesion to the particles and penetration into the sediment.

METULA Spill

The impact of the METULA Spill (Table 4.1) on the shore-zone of the Straits of Magellan was documented by Hayes and Gundlach (1975) and Hayes et al. (1976). Oil accumulations were most common on mixed sand and gravel beaches (a) near the high water line, (b) on washover fans and (c) on gravelly low tide terraces. Penetration of oil up to 40 cm occurred on gravelly beaches. Sheltered tidal flats and salt marshes were heavily oiled and showed little change up to two years after the spill. These observations suggest that oil would remain in these types of environments for up to ten years (Hayes and Ruby 1979).

URQUIOLA Spill

Short-term impacts of the URQUIOLA spill (Table 4.1) were observed by Gundlach and Hayes (1977) and Gundlach et al. (1977). Of special significance in this spill was the burial of large quantities of oil by deposition of clean sediment over oiled sediment. If left to be removed naturally, the oil could be reintroduced into the environment and available to contaminate cleaned or previously affected areas. In addition, large amounts of material would have to be removed in a mechanical clean-up operation.

AMOCO CADIZ

Observations by Gundlach and Hayes (1978) of the AMOCO CADIZ spill in France (Table 4.1) confirmed earlier observations (e.g. Owens 1971, 1978) that wave action can be an effective natural clean-up process. Heavily oiled rocky shorelines, exposed to significant wave action, were generally cleared within one month, whereas protected shorelines such as harbors and marshes remained heavily oiled even months after contamination. Sand beaches tended to be naturally cleaned more rapidly than rocky shorelines. Gravel beaches showed significant penetration of oil and special clean-up procedures were required to flush oil from these beaches.

Coastal sedimentation processes caused local burial and removal of oil. In some locations, shorelines undergoing natural erosion were cleaned rapidly, whereas at other locations deposition of sediment in the form of berms and runnels caused rapid burial of oil.

Over the one month observations period following the spill, Hayes and Gundlach (1979) noted an approximate 80 percent reduction in oil quantities on the beaches, even though the total length of oiled shoreline increased from 72 km to 389 km. The reduction of total oil amount was a result of natural clean-up processes and clean-up activities by man.

4.2.2 Baffin Island Oil Spill (BIOS) Experiment

The Baffin Island Oil Spill was designed to valuate the impact of dispersants on arctic oil spills. Controlled experiments were conducted in experimental test bays to compare impacts associated with a non-treated crude oil spill and with a dispersant-treated crude oil spill. Controlled experiments of oil spills beaches were also conducted (Woodward-Clyde Consultants 1981; Owens et al. 1982a and b; Owens et al. 1983; Owens and Robson 1984). Observations on oil residence on beaches with different wave exposures show that mechanical wave action is the most important process controlling oil dispersal on beaches. On more exposed beaches (fetch distance approximately 100 km), 75-80 percent of the oil was removed from the test plots within the first 48 hours and, by the end of the first open-water season, no oil remained on either of the exposed test plots. On moderate exposure beaches, with limited fetch but exposed to refracted swell, all traces of oil were removed within one open-water season (approximately 30 days). On low wave-exposure shorelines (fetch less than 5 km), tidal action removed 30-90 percent of the oil from the test plots within one open-water season. After three open-water seasons, approximately 25-50 percent of the original oil volume still remains on the coarse-grained low energy test plots, whereas all oil was removed from the fine sediment beaches.

Wave exposure was of primary importance in controlling natural dispersal of oil, although substrate type and sediment transport were of secondary importance. Substate type affected oil residence, particularly on low energy beaches, as a result of (a) greater oil penetration into the coarser sediments and (b) better oil adhesion to the larger pebbles and cobbles than to the smaller sand particles. Much of the oil on silt and sand beaches was removed within a few tidal cycles even on low energy beaches due to poor adhesion properties to the fine sediments.

Sediment transport processes were locally important in controlling the residence of spilled oil. On one of the high energy test plots, oiled sediment was buried during a storm wave event by approximately 20 cm of "clean" sediment. Where storm events are infrequent and where other weathering processes are minimal, the potential for the oil to remain in the sediments is high.

The BIOS experiments generally show that oil dispersal in arctic environments is primarily controlled by wave exposure, with substrate type and sedimentation processes as secondary factors. The main difference in dispersal processes between the arctic and temperate regions is that wave action occurs only during a limited 2-3 month open-water season in the arctic as opposed to the longer (9-12 month) open-water season in temperate regions. The lack of wave action during the ice-covered season means that no natural degradation occurs during those months. For oil stranded above the limit of normal wave actions, weathering processes, principally microbial decomposition, are extremely slow.

4.2.3 Oil Spill Sensitivity Studies in the Arctic

Oil spill sensitivity analyses have been conducted for other areas of the arctic, including adjacent regions of the Chukchi Sea coast. Studies have been conducted of the Canadian Beaufort Sea coast (Worbets 1979), the Alaskan Beaufort Sea coast (Nummedal 1980) and the southern Chukchi Sea coast (Hayes and Ruby 1979).

Worbets (1979) developed an oil spill protection and clean-up strategy manual for the southern Beaufort Sea of Canada. The manual provided a combined sensitivity index for geological, biological and cultural sensitivities. The three sensitivities were combined into one index by use of weighting factors, thus providing a single arithmetic value for a given coastal segment that is easily compared with other coastal segments. Four shoreline types were mapped to provide an index of potential oil residence (Table 4.2), although no actual oil residence periods were assigned to the different shoreline types.

Nummedal (1980) mapped eight shoreline types for the Alaskan Beaufort Sea coast and developed a retention index for estimating persistence. There is no assessment of biological effects assigned by the index. The Retention Index is based on (a) the level of mechanical degradation and (b) efficiency of retaining factors. The eight-level index (Table 4.2) assigns potential residence periods from days to weeks (Retention Index 1: steep cliffs) to 10 years (Retention Index 8: marshes).

Hayes and Ruby (1979) provide a Vulnerability Index of the southern Chukchi Sea coast from Cape Prince of Wales to Point Hope (Table 4.2). Their Vulnerability Index is modified from previous studies of a similar

Table 4-2. COMPARISON OF PREVIOUSLY DEFINED SENSITIVITIES[1] AND ARCTIC SHORELINE TYPES

Canadian Beaufort Sea[2]	Alaskan Beaufort Sea[3]	South Chukchi Sea[4]
(1) Cliff; Wave-cut Platform	(1) Steep Cliffs	(1) Rocky headlands
(2) Sand Beach; Mud Flat	(2) Steep beaches and bluffs of unconsolidated sediment	(2) Wave-cut platforms
(3) Gravel Beach	(3) Exposed non-vegetated barriers	(3) Flat, fine-grained sandy beaches
(4) Estuary; Tidal Flat; Tundra Beach	(4) Vegetated low barriers	(4) Steeper, medium to coarse-grained sandy beaches
	(5) Lagoon-facing mainland shores	(5) Impermeable exposed tidal flats
	(6) Peat shores	(6) Mixed sand and gravel beaches
	(7) Sheltered tidal flats	(7) Gravel beaches
	(8) Marshes	(8) Sheltered rocky headlands
		(9) Protected estuarine tidal flats
		(10) Protected estuarine salt marshes

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[1] Sensitvity of shorelines increases from (1), least sensitive, to (4, 8, or 10), most sensitive.

[2] Worbets, 1979

[3] Nummedal, 1980

[4] Hayes and Ruby, 1979

nature (Gundlach et al. 1977; Hayes et al. 1977; Michel et al. 1978; Ruby 1977; Ruby et al. 1977, 1978). The Vulnerability Index (more recently revised as the Environmental Sensitivity Index - see Gundlach et al. 1980) uses ten repetitive shoreline types as an indirect index of potential oil persistence on shorelines of the Chukchi Sea (Table 4.2). Estimated oil persistence periods range from days to weeks (Vulnerability Index 1: Straight rocky headlands) to 10 years (Vulnerability Index 10: Protected estuarine salt marshes). The study results indicate that over 50 percent of the southern Chukchi Sea coast has high potential persistence levels (Vulnerability Indices 9-10).

4.3 DEVELOPMENT OF AN OIL RESIDENCE INDEX (ORI)

4.3.1 Background

The primary objectives of this study are to (a) provide resource managers with a regional assessment of coastal resource sensitivity to oil spills (i.e., identify sensitive resources, show where they are, and indicate when they are sensitive) and (b) provide a sensitivity evaluation which provides a rationale for development of a contingency plan (i.e., sensitivity assessment will provide a partial basis for determining oil spill counter-measure priorities). As such, the sensitivity evaluation must be necessarily general because of the regional nature of the study yet must be of sufficient detail to be of use for contingency planning. For these reasons, we developed a three level index (primary, secondary and tertiary levels) to illustrate sensitivities for (a) potential oil residence, (b) biological sensitivity and (c) human-use sensitivity (Robilliard et al. 1983).

While the use of three levels of concern for the three resource types is relatively simple, and therefore useful to resource managers, there are 27 possible combinations possible. As such, the approach provides planners with sufficient detail to develop priorities for the oil spill contingency plan. The development of the biological and human-use sensitivity indicies are discussed in Sections 5 and 6, respectively. The Oil Residence Index is discussed in the following sections.

4.3.2 Basis for Oil Residence Index Development

Observations from previous spills (Owens 1971, 1978; Owens and Rashid 1977; Vandermeulen and Gordon 1976; Owens et al. 1982; Gundlach and Hayes 1977; Gundlach et al. 1977; Hayes and Gundlach 1975) indicate that potential oil residence is determined by:

- wave exposure
- substrate type
- sedimentation processes
- oil type
- spill volume
- oil form at impact zone.

Many of these parameters cannot be determined until the time of the spill so any *a priori* index must be necessarily general. Wave exposure, substrate type and sedimentation processes can be evaluated prior to a spill, however, and provide a basis for developing an oil residence index.

Wave Exposure

The wave exposure is the primary process influencing potential residence of oil (Owens 1971; 1978). Observations and measurements from the Baffin Island Oil Spill Experiment (BIOS) support the concept that waves provide an important dispersal mechanism even in the arctic (Owens et al. 1982, 1983). Areas of low wave exposure, such as lagoons and estuaries, are likely to have lengthy oil residence periods. The relationship of wave exposure to the major shore-zone types of the study area is illustrated in Table 4.3. It should be emphasized, however, that wave exposure refers only to the open-water season. From approximately October through June, ice cover is continuous in the Chukchi Sea and there is no wave activity at the shore.

Table 4.3. RATIONALE FOR ESTIMATING POTENTIAL OIL PERSISTENCE IN THE SHORE-ZONE

Shore-zone Type	Wave Exposure[1]	Substrate Type[2]	Coastal Stability	Level of Concern
<u>Open Coast</u>				
Rock Cliffs	High	Rock	Erosional	Tertiary
Tundra Cliff	Moderate	Sandy gravel	Erosional	Tertiary
Barrier Island	High	Gravelly sand	Stable to erosional	Tertiary
Barrier Island with Vegetation	High	Gravelly sand	Stable to accretional	Secondary to tertiary
<u>Lagoon Coast</u>				
Tundra Cliff	Low	Sandy gravel	Erosional	Primary to secondary
Barrier Island	Low	Gravelly sand	Stable	Primary
Delta	Low	Muddy sand, vegetation	Accretional	Primary to secondary
Wetland	Low	Mud, peat, vegetation	Stable	Primary

[1] Exposure based on maximum open-water fetch lengths
High - fetch > 100 km
Moderate - fetch 10 to 100 km
Low - fetch <10 km

[2] Terminology of Folk, 1968

The table illustrates that most outer coast areas are comparatively exposed, with wave fetch distance exceeding 500 km during most open-water seasons. Wave exposure is lower in the northern portion of the study area, near Point Barrow, as a result of (a) the shorter open-water season and (b) shorter fetches during the open water season due to the normal proximity of pack ice.

Substrate Type

Observations of stranded oil in the shore-zone have indicated that substrate type may influence potential residence (Owens 1971; Hayes and Gundlach 1975). Coarse sediment beaches allow penetration of the oil into the substrate where it is no longer exposed to mechanical wave action. Consequently for beaches of equal wave exposure, persistence will be greater on coarse-sediment beaches than fine-sediment beaches. Similarly mud flats often have short oil residence periods because the fine sediments and the associated high water content of the sediments prevent the oil from penetrating or adhering to the substrate (Owens et al. 1982, 1983). The relationship of substrate type to shore-zone types of the study area is illustrated in Table 4.3.

Coastal Stability

Coastal stability and its effect on coastal sedimentation patterns will influence potential oil residence periods. Eroding coastal areas, by nature, will have short potential oil residence periods due to the coastal retreat, particularly since retreat rates of 1 m/yr are not uncommon (Harper 1978; Owens et al. 1980). Oil residence may be increased, however, on accretional shorelines, where there is potential for oil burial, hence removal from exposure to wave action. Such burial of oil occurred locally on exposed beaches during the BIOS experiment (Woodward-Clyde Consultants 1981). The relationship of coastal stability to the major shore-zone types is illustrated in Table 4.3.

4.3.3 Oil Residence Index (ORI)

Levels of Concern.

The levels of concern associated with the oil residence index are based on the estimated period of persistence of oil stranded in the shore-zone. As discussed above, these levels of concern are only general guidelines as to potential oil residence, as critical elements of the spill character cannot be accurately estimated until the time of a spill (e.g., spill size, oil type, oil form, etc.). Consideration of wave exposure, substrate type and coastal stability are used to develop the oil residence index for shore-zone types of the study area (Table 4.3.).

Primary Level of Concern.

Areas of primary concern are those areas where oil is likely to persist for more than a few months of open water (oil residence is discussed only in terms of open-water seasons because no natural degradation of oil is expected to occur during the winter season). In other words, oil is likely to persist in the shore zone for a period of one year or more. Areas of primary concern closely coincide with zones of low wave exposure. These zones include lagoons, ponds and estuaries with limited wave fetch lengths (< 10 km). Coastal stability and substrate type may influence residence periods, in that shorelines of mudflats and eroding shorelines are likely to have shorter residence periods than other shorelines in spite of the low wave exposure.

Secondary Level of Concern.

Areas of secondary concern coincide with shorelines of (a) primarily low to moderate wave exposure, (b) fine sediment substrates or (c) variable sedimentation patterns (Table 4.3). Estimated oil residence period in these areas is less certain and could range from a few open-water days to several open water months, depending on the nature of the spill. Types of shore-zone considered to be of secondary concern are:

- rapidly eroding tundra cliffs in lagoon areas,
- sand or mud flats in relatively exposed sections of lagoons,
- exposed barrier islands or spits where sedimentation potential exists.

Tertiary Level of Concern

Areas of tertiary level of concern generally coincide with high wave exposure shorelines where natural wave activity would promote the rapid mechanical degradation of oil (Table 4.3). Expected oil residence period is in the order of days to weeks of open water. That is, oil residence is likely to be less than one complete open-water season. Shore-zone types of tertiary concern include exposed tundra cliff and barrier island shores (Table 4.3), except where accretional sedimentation patterns could cause burial of stranded oil (e.g., near recurve spits at inlets).

4.3.4 Shore-zone Types and Oil Residence

The coastline of the study area can be categorized in terms of eight major shore-zone types. The purpose of this brief section is to describe the relationship between the major shore-zone types and the oil residence index. The two major categories of shore-zone types, open coast and lagoon coast, are determined by wave exposure, the primary process influencing potential oil persistence.

Open Coast Shorelines

Rock Cliff. Rock cliffs, with associated fringing gravel beaches, occur along the open-coast near Cape Sabine, Cape Lisburne and Cape Thompson (Fig. 4.1). The comparatively high wave exposure, and the substrate type, which prevents oil penetration, would lead to rapid removal of stranded oil and, therefore, these coastal sections are considered of tertiary concern.

Figure 4-1. Rock cliff near the abandoned Corwin Mine. Cliff height is approximately 100 meters. Note talus at cliff base.

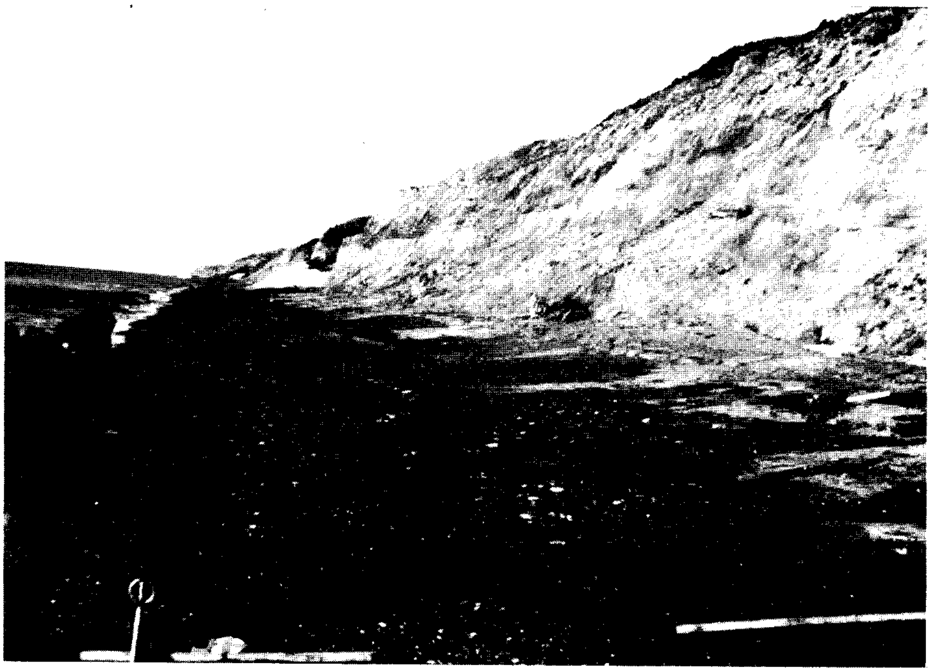

Figure 4-2. High tundra cliff to the south of Barrow (cliff height 14 m). Note gravel beach and mud from surface wash erosion on cliff face.

Tundra Cliffs. Tundra cliffs are exposed along the outer coast in the Peard Bay/Barrow area and also in the Cape Beaufort/Cape Sabine area (Fig. 4.2). Cliffs range in height from 3 to 14 meters and a narrow fringing gravel beach is usually present at the cliff base. Long-term erosion rates are approximately 0.5 m/yr (Harper 1978) although year-to-year and local variations occur.

Oil residence on these shorelines would be short duration in terms of open-water days due to the comparatively high wave exposure and because of the erosional nature of the cliffs. Consequently, these shoreline types are assigned a tertiary level of concern. Beach sediments are often coarse (gravel material consisting of granules, pebbles and cobbles), which would promote oil penetration, but the rapid coastal retreat associated with these beaches would lead to rapid exposure and removal of buried oil.

Barrier Islands. Exposed barrier island shorelines (Fig. 4.3) occur within much of the central portion of the study area (Kasegaluk Lagoon), at Point Barrow and at Point Hope. Sediments are almost always comprised of gravelly sand (> 50% sand) although in many areas a thin gravel lag lies at the surface as a result of sand removal by wind (Fig. 4.4). Extensive washover fans and channels and the lack of vegetation indicate that the islands are frequently inundated during late summer storm surges.

Oil residence on these shorelines is estimated to be of short duration in open-water days and, therefore, the shores are considered of tertiary concern. The existence of relatively long open-water fetches (> 100 km) during open-water seasons would result in rapid mechanical removal of stranded oil. The sand matrix would prevent significant oil penetration into the beach and hence promote mechanical dispersal by waves. Local sedimentation events could cause oil burial; however, because most shores are stable to erosional in nature, burial is likely to occur only locally, primarily near inlets where many of the islands have prograding recurved spits (Fig. 4.5).

Figure 4-3. Barrier spit on Ahyougutuk Lake. Note the well-developed storm berm crest (elevation approximately 2 m above MWL).

Figure 4-4. Close-up photo of barrier island sediment (near Icy Cape). Wind has blown the sand away, leaving a thin gravel lag on the surface.

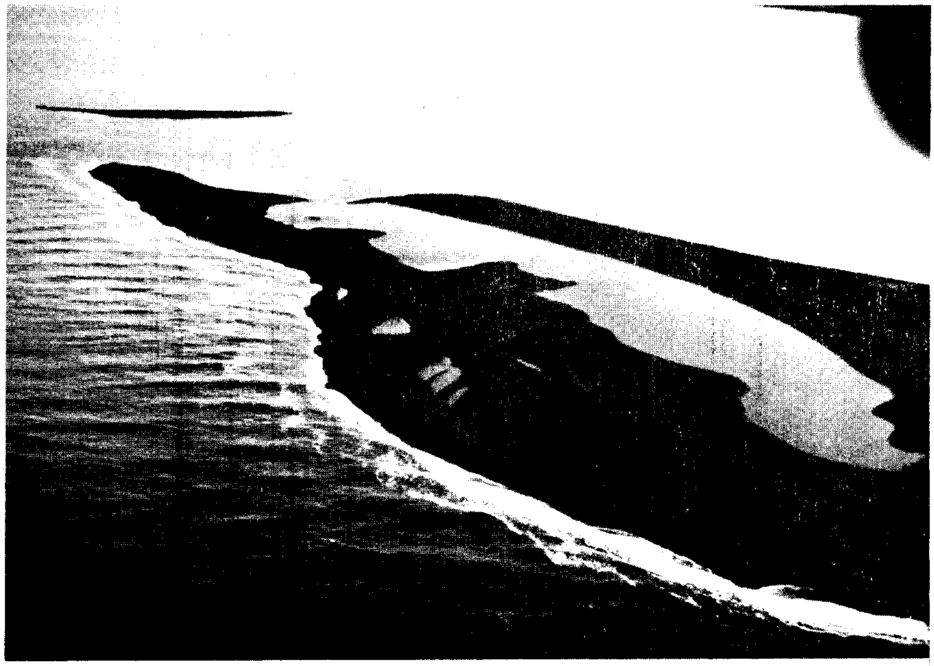

Figure 4-5. An inlet and prograding recurve spits. Longshore transport is to the north.

Figure 4-6. Wide (300 m) vegetated barrier island south of Pt. Lay. Subtle color differences in the backshore outline old recurve spits indicating a tidal pass occurred at this location.

Barrier Islands with vegetation. Many of the barrier islands along the Chukchi Sea coast are vegetated with both dune type grasses and wetland vegetation (Fig. 4.6 and 4.7). The presence of the dune vegetation allows wind-blown sand to accumulate above the upper-limit of the storm swash and, as a result, island freeboard (elevation above mean water level) is usually higher on the vegetated barrier segments. The increased freeboard is suggestive of greater coastal stability, although no coastal erosion or accretion rates have been documented for these barrier islands. A small storm-berm is often present seaward of the vegetation.

Oil residence on these shorelines is estimated to be of comparatively short duration in open-water days due to the generally exposed nature (fetch distance >100 km) of these shorelines, and, therefore, the shores are considered of tertiary concern. The significant sand component (>50%) of the barrier island beaches would prevent penetration of oil into the sediments. The stability of these barrier island segments is probably greater than the unvegetated barriers, however, there is no evidence of significant progradation, such as multiple beach ridges, except in the Point Hope area, where a wide beach plain is present. For most vegetated barrier island segments, therefore, there is no evidence of long-term accretion and it is unlikely that oil would be buried in significant quantities. The area of long-term accretion in the Point Hope area is an exception to this trend. Also the barrier island segments around inlets, particularly on the south sides of the inlets, do show evidence of progradation, and are considered of secondary concern because of the potential for oil burial within prograding recurve spits.

Lagoon Coasts

Barrier Islands. Low energy gravelly sand beaches occur along most of the lagoon shores of the barrier islands (Fig. 4.8 and 4.9). These beaches are (1) commonly narrow (<20 m in width), (2) are commonly reworked washover fans and (3) may be interspersed with wetlands and sand flats.

Figure 4-7. Thick vegetative cover on a barrier island along the south shore of the Pt. Hope cuspate foreland.

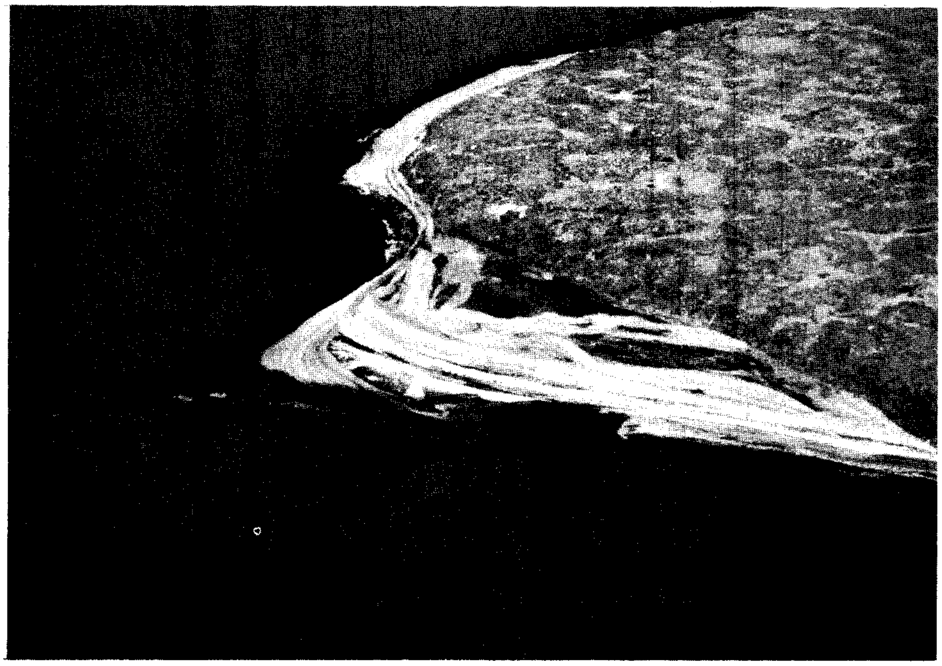

Figure 4-8. Small recurves spits in the Kuk River. The light-colored material is a sandstone shingle; the black-colored material is reworked coal.

Figure 4-9. Ground photo of small swash ridge.
Note coal and shingle-type sandstone beach sediments.

Figure 4-10. Rapidly retreating low tundra cliff in Kugrua Bay.
Note the narrowness of the beach and the reworked peat blocks on the beach surface.

Oil residence on these shores would probably be lengthy, in terms of open-water days, primarily due to the low wave exposure levels. For that reason, the lagoon barrier island shores are assigned a primary level of concern. A secondary level of concern is assigned to lagoon shorelines with greater than 10 km fetch.

Tundra Cliffs. Low tundra cliffs (Fig. 4.10) occur along much of the mainland coast of the major lagoons and estuaries (Peard Bay, Kugrua Bay, the Kuk River Inlet, Kasegulak Lagoon and Marryatt Inlet at Point Hope). Cliff heights are usually low (<3 m) and the cliff material mostly fine sand, unlike the ice-rich silty cliffs of the Beaufort Sea coast. A narrow (<10 m) gravelly sand beach typically occurs near the cliff base, although along some cliffs this may be absent or consist of thick (<1 m) reworked peat deposits. In some areas of the Kuk River Inlet, shingle-type cobble material occurs on these beaches.

Oil residence would be expected to be of long duration (i.e., of primary concern) on stable, tundra cliffs because of low wave exposure. However, where cliffs are rapidly eroding, persistence would probably be short in terms of open-water days because of the natural tendency of oil to be removed by erosion; on these coastal segments, a secondary level of concern is assigned due to the uncertainty of oil removal rates in such a low wave exposure environment.

Wetlands. Wetlands occur locally throughout the lagoons and estuaries. Along smaller estuary shorelines (Fig. 4.11), salt tolerant wetland vegetation typically rims the entire shoreline. In larger lagoons and estuaries, wetlands typically occur in low wave exposure areas of the lagoon; these areas include, swales between recurved spits, areas landward of mud flats, and coastal deltas (vegetation types are described in more detail in Section 5.0).

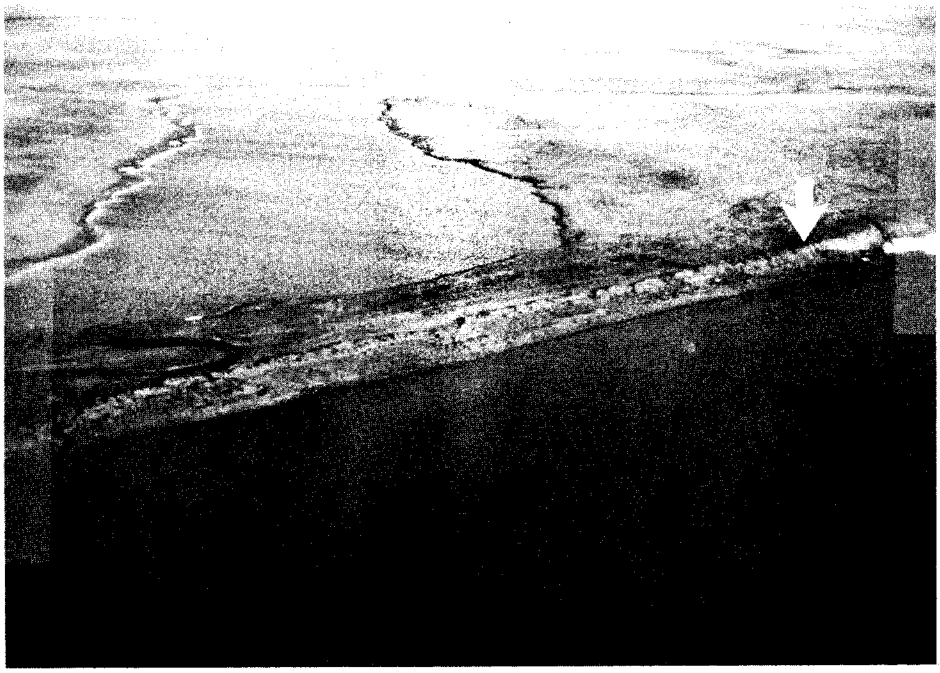

Figure 4-11. Small estuary immediately south of Barrow. Note the wetland shores, the closed ephemeral inlet and the ice-pushed sediment on the cliff edge (arrow).

Figure 4-12. Sand flats in the upper portion of the Kuk River delta.

Oil which reached wetland areas would be likely to persist for a lengthy time period and consequently wetlands are assigned a primary level of concern. The low wave exposure levels typically associated with wetlands would result in a slow rate of mechanical dispersal of oil in wetlands.

Deltas. Deltas are associated with major rivers and streams of the study area (Kugrua, Kuk, Nokotlek, Utukok, Kokolik, Kukpowruk and Kukpuk Rivers) and occur within the lagoons along the mainland coast (Fig. 4.12). The deltas have wide delta front flats grading from mud near the low water limit to sand at the normal high water limit; these flats are dissected by the river channels. Vegetation increases in density landward of the high-water mark.

The potential oil residence period would be variable due to the offsetting effects of wave exposure and substrate type. The low wave exposure would normally result in lengthy oil persistence in the shore-zone; however, the fine sediment size of the tidal flats prevents oil penetration and would promote dispersal of the oil. The deltas are therefore assigned a secondary level of concern due to the uncertainty in potential persistence of oil.

4.4 SHORE ZONE PHYSICAL CHARACTERIZATION

4.4.1 Repetitive Shore-Zone Components

Repetitive shore-zone components are used as a combined representation of morphology and substrate types in mapping the shore-zone character of the Chukchi Sea coast. Each repetitive component is indicated by a distinctive pattern (Figure 4.13) on the physical resource maps (Part II) . A detailed description of each repeatable component is provided in an expanded legend (Table 4.4) and is illustrated by a series of photographs.

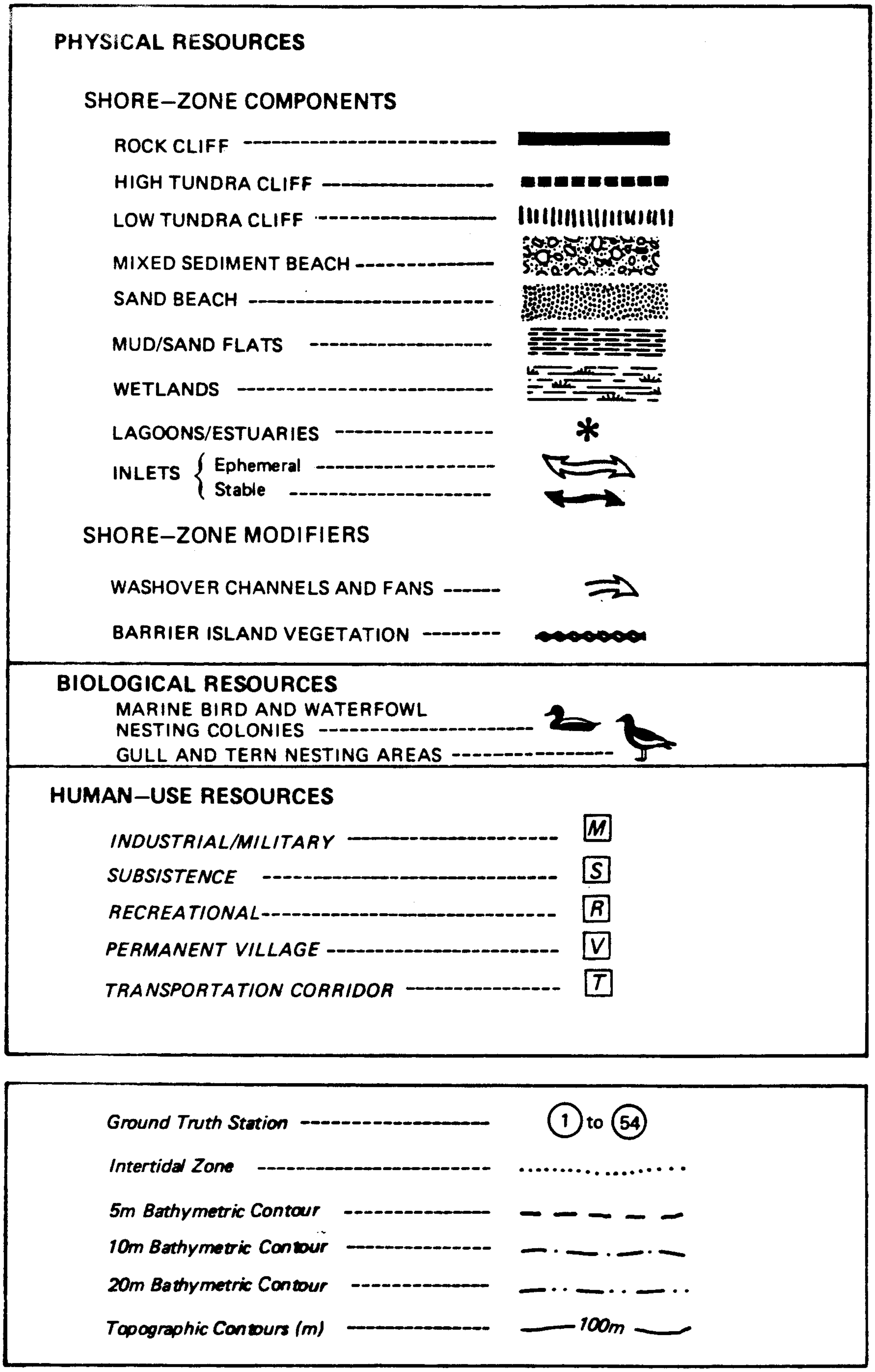

Figure 4-13. MAPPING PATTERNS USED FOR SHORE-ZONE COMPONENTS

Table 4.4. EXPANDED LEGEND OF PHYSICAL SHORE-ZONE COMPONENTS

SHORE-ZONE COMPONENTS

Rock Cliffs - primary morphology is that of a steep cliff cut by waves into the bedrock substrate. Cliff slopes are typically steep (greater than 45°) and fringing beaches are rare. Pocket beaches of gravel sized material may occur in small indentations along the base of the cliffs. Bedrock types include sedimentary sandstones in the northern portion of the study area (Skull Cliff, Peard Bay, Kuk River) to meta sedimentary and igneous in the southern portion of the study area (Cape Sabine, Cape Lisburne, Cape Thompson).

High Tundra Cliffs - wave-cut cliffs formed in unconsolidated Quaternary sediments. Relief from cliff base to cliff edge is greater than 5 m (approximately 15 ft). Cliff sediments are bonded by permafrost and are usually "ice-poor", although massive ice beds do occur locally. Slopes are usually less than 45° and are dominated by surface wash and debris slide mass-wasting processes. Coastal retreat rates, where documented, are less than 1 m/yr. Fringing gravel beaches typically occur at the cliff base.

Low Tundra Cliffs - wave-cut cliffs formed in unconsolidated Quaternary sediments. Relief from cliff base to cliff edge is less than 5 m (approximately 15 ft). Cliff sediments are bonded by permafrost and are usually "ice rich." These cliffs are most common in lagoons and near open-coast river mouths. Coastal retreat con be rapid (> 1m/yr) on some cliffs (usually steep slopes, >45°, indicate rapidly retreating cliffs), although most cliffs appeared retreating only slowly in comparison with those of the Beaufort Sea coast. Narrow fringing sand or gravel beaches are typically associated with these cliff types.

Mixed Sediment Beaches - the vast majority of beaches along the Chukchi Sea coast are comprised of a mixture of sand and gravel-sized sediment. Mixed-sediment beaches are widely distributed and are associated with both/barrier islands and tundra cliffs. Additional detail on size composition of sediment within the unit is provided in the resource tables. (Note: gravel includes sediment greater than 2 mm in diameter; sand includes sediments with diameters of 0.06 to 2.0 mm).

Sand Beaches - sand beaches occur at the distal ends of some barrier spits (the eastern Peard Bay spit, for example). Sand-sized material comprises more than 80 percent of the total sediment mass. Sand beaches may occur locally along the lagoon shores as well.

Table 4.4. EXPANDED LEGEND OF PHYSICAL SHORE-ZONE COMPONENTS (continued)

SHORE-ZONE COMPONENTS

Mud/Sand Flats - wide (>100 m or 300 ft) intertidal flats occur within the lagoon systems of the Chukchi Sea coast. These flats are typically associated with river deltas, flood-tidal deltas on the seaward side of the lagoon, with washover fans on the barrier islands and with other smaller scale coastal features along the mainland coast. Sediment texture on the flats usually grades from sand-sized material in the upper portion of the shore zone to mud-sized material in the lower shore-zone.

Wetlands - low elevation, generally flat areas with standing water for most of the snow or ice-free season. They are subject to occasional storm innundation but are generally not covered by the normal astronomical tides. Vegetation is salt-tolerant and dominated by the grass, Puccinella spp. Wetlands are low energy environments primarily on borders of small estuaries, deitas and the lagoon side of barrier islands.

Lagoons/Estuaries - protected embayments such as small lagoons or estuaries, which are too small to map separately, are delineated by a site symbol. Lagoons and estuaries typically encompass low-energy coastal features such as mudflats or wetlands, which can not be shown on the map due to the small scale of the feature. Lagoons and estuaries are necessarily connected to marine water areas by either a washover channel, or an inlet.

Inlets - inlet provide a critical water exchange link between protected lagoons, estuaries or bays. Inlet widths vary, although most are less than 1.5 km (approximately 0.25 mi) in width (with the exception of the Peard Bay inlets). Inlets which have been permanently open for the past few years are mapped as stable inlets. Inlets which are only open seasonally, such as during spring freshet or during storm-surges or which open and close on a year-to-year basis are mapped as ephemeral inlets.

SHORE-ZONE MODIFIERS

Washover Channels and Fans - washover fans and channels are activated during storm surges and provide an important water exchange conduit during storm surges. Water exchange is in only one direction, landward-directed (return flow occurs through inlets or through ground-water seepage. Washover channel and fans are found on low, usually unvegetated, barrier islands and on small baymouth bars enclosing lagoons and estuaries.

Table 4.4. EXPANDED LEGEND OF PHYSICAL SHORE-ZONE COMPONENTS (concluded)

SHORE-ZONE COMPONENTS

Barrier Island Vegetation - barrier island vegetation is mapped as a shore-zone modifier for open coast barrier islands where significant densities of vegetation occur. Vegetation on the Chukchi Sea side of the barrier islands is primarily dune grass (*Elymus arenarius mollis*). On the lagoon side, the vegetation is typically one for more species of grass, primarily *Puccinella* spp. The presence of vegetation usually indicates a greater barrier island stability (i.e., stable or accretional) and less frequent over-topping during storm surges.

More than one repetitive shore-zone component may occur within a shore-zone unit. The repetitive components are not necessarily mutually exclusive, and by combining two or more within a unit, a composite picture of the shore-zone character is established. However, not all components can be combined (e.g., rock cliffs and tundra cliffs cannot occur within the same unit). Washover fans are used as a modifying symbol within some units. These shore-zone modifiers differ from shore-zone components in that they cannot be used alone to represent a unit.

The expanded legend (Table 4.4) provides a concise summary of shore-zone components and modifiers which are used on the maps (Volume 2).

4.4.2 Repetitive Shore-Zone Types

Repetitive shore-zone types represent a set of shore-zone components that occur repeatedly in the same combination throughout the study area. Repetitive shore-zone types provide a useful means for summarizing the geomorphology of the study area. The physical shore-zone character of the study area can be summarized in terms of the seven major shore zone types (Table 4.5).

Table 4-5. RELATIONSHIP OF SHORE-ZONE TYPES AND SHORE-ZONE COMPONENTS

Shore-Zone Types	Shore-Zone Component(s)
Rock Cliffs	Rock cliffs, occasionally with mixed sediment beaches
Tundra Cliffs	High and low tundra cliffs usually with mixed sediment beaches
Barrier Islands or Spits without Vegetation	Sand and mixed sediment beaches
Barrier Islands or Spits with Vegetation	Sand and mixed sediment beaches with vegetation cover
Delta Fronts	Wetlands and/or mud flats which may occur in association with low energy beaches or wetlands
Wetlands	Salt-tolerant wetlands
Inlets	Permanent or ephemeral inlets

These repetitive shore-zone types provide a basis for summarizing the distribution of physical shore-zone character within the study area and for assigning oil residence potential.

4.5 RESULTS

4.5.1 Resource Inventory

The detailed physical shore-zone maps and the associated resource tables provide the basis for assigning appropriate shore-zone sensitivity levels. The distributions of repetitive shore-zone types, as described previously in Section 4.4 are summarized in Table 4.6. There are approximately 1,500 km of shoreline within the study area, of which

Table 4.6. PERCENT OF REPETITIVE SHORE-ZONE TYPES

	Percent of Repetitive Shore-Zone Types			
	Maps 1-32	Maps 33-58	Maps 59-84	Total
Open Coast				
Rock Cliff	0	0	4.7	4.7
Tundra Cliff	6.8	0	5.8	12.6
Barrier Island without vegetation	4.9	8.2	4.3	17.5
Barrier Island with vegetation	1.2	4.5	1.6	7.3
Inlet/Estuary	0.5	0.4	0.2	1.1
Subtotal	13.4	13.1	16.6	43.2
Lagoon Coast				
Tundra Cliff	13.5	14.1	3.3	30.9
Barriers or Spits	4.6	7.7	2.7	15.0
Delta Fronts	0.1	1.8	0.1	2.1
Mudflats	0.1	2.5	0.1	2.7
Wetlands	0.1	4.9	0	5.1
Inlets	0.4	0.4	0	0.8
Subtotals	18.8	31.4	6.2	56.8
TOTAL	32.2	44.5	22.8	100

650 km is classified as open-coast shoreline (exposed to maximum fetch distances in excess of 10 km) and 850 km is classified as lagoon or protected coast (maximum fetch distances are generally less than 10 km).

The geomorphology of the northern Chukchi Sea coast can be considered in terms of three major sections of coastline:

(1) the northern Chukchi Sea coast (maps 1-32), which lies between Pt. Barrow and Kasegaluk Lagoon and consists primarily of tundra cliffs with two major embayment-type lagoons (Peard Bay and the Kuk River Inlet)

(2) the Kasegaluk Lagoon coast (maps 33-58), which consists of 200 km (approximately 110 n mi.) of barrier island coastline in the central portion of the study area, including an extensive barrier island lagoon system with almost 500 km (approximately 275 n mi.) of shoreline

(3) the Cape Beaufort-Cape Lisburne - Point Hope coast (maps 59-84), which lies to the south of Kasegaluk Lagoon and includes a wide variety of shoreline types from rock cliffs to protected lagoons.

The northern Chukchi Sea coast is principally comprised of eroding tundra cliffs, cut into unconsolidated Quaternary deposits (Table 4.6). In a few locations Cretaceous sandstone bedrock and coal seams crop out in the cliffs. Barrier island and spit systems, consisting of gravelly sand material and mostly without vegetation, occur at Point Barrow and at Peard Bay. Two major embayment systems, Peard and Kugrua Bays and the Kuk River Inlet, occur within this coastline section and comprise a substantial segment of coastline (286 km). Shorelines of these embayments are comprised primarily of rapidly retreating low tundra cliffs, interspersed with small gravel spits (Table 4.6). Small river systems have formed deltas at the mouth of both the Kugrua and Kuk Rivers.

The central Kasegaluk Lagoon coast consists of a long (200 km), narrow barrier island lagoon system with over 475 km of lagoon shoreline (Table 4.6). Low, gravelly sand, barrier islands lie along the seaward side of the lagoon. Vegetation occurs sporadically on the barrier islands to the north of the Icy Cape suggesting that these barriers are frequently overtopped during storm surges and are, therefore, more dynamic than those to the south. Vegetation becomes increasingly common on the barrier islands to the south of Icy Cape suggesting greater stability; on many sections of the barriers, vegetation colonization particularly noticeable on old recurve spits formed by northward tidal pass migration.

The lagoon section of this coast includes a variety of coastal landforms, the most common of which is the ubiquitous low tundra cliff (Table 4.6). Gravelly sand beaches (on the lagoonal side of the barrier islands), wetlands, mudflats and delta flats are also comparatively common features of this coastline. Wetlands occur along the lagoonal shores of the barrier islands, particularly in southern Kasegaluk Lagoon and in association with the three major river deltas on the mainland shore.

The southern-most section of the study area, to the south of Kasegaluk Lagoon, includes a wide variety of coastal landforms, the most prominent of which is the resistant bedrock cliffs at Cape Lisburne (Table 4.6). Rock cliffs occur to the east and south of Cape Lisburne, as well as at Cape Thompson, and comprise approximately 70 km of shoreline. Tundra cliffs are not uncommon, however, particularly between Cape Sabine and Kasegaluk Lagoon, comprising an additional 89 km of coast (Table 4.6). Barrier islands, both with and without vegetation are extensive on the Point Hope cape-system and occur locally in association with small lagoons east of Cape Lisburne. Lagoon coasts occur primarily within the Point Hope cuspate foreland and consist of low tundra cliffs and gravelly sand beaches along the barrier islands.

The distribution and occurrence of shore-zone types provides an indirect index of important coastal processes which occur in the study area. Some important observations are:

- longshore transport is dominantly to the north, as evidenced by recurve spit orientation (see Fig. 4.5), except along north-facing coasts near Point Hope, Cape Lisburne, Icy Cape and Peard Bay. Longshore transport along these coasts is variable, with a slight southerly-directed dominance

- longshore transport along lagoonal shores is highly variable and dependent upon local coastal orientation and fetch window. In Kasegaluk Lagoon, orientation of cuspate spits along the lagoonal barrier island shore suggests a dominant southerly directed transport within the lagoons.

- measured coastal retreat rates in the Barrow-Peard Bay area indicate that cliff retreat is moderate (approximately 0.3 m/yr), with lower retreat rates in the Barrow vicinity. Wider beaches fronting the tundra cliffs near Barrow qualitatively support this observation

- observations of tundra cliffs within the lagoon systems suggests that they are comprised primarily of fine sand, rather than ice and peat, and, therefore, are probably more stable than those which occur along the Beaufort Sea coast

- ground ice slumps (Fig. 4.14), caused by massive ice beds in the surficial sediments, are common along the coast between southern Kasegaluk Lagoon and Cape Sabine, and indicate a relatively rapid retreat rate (> 1m/yr?) for this coastline

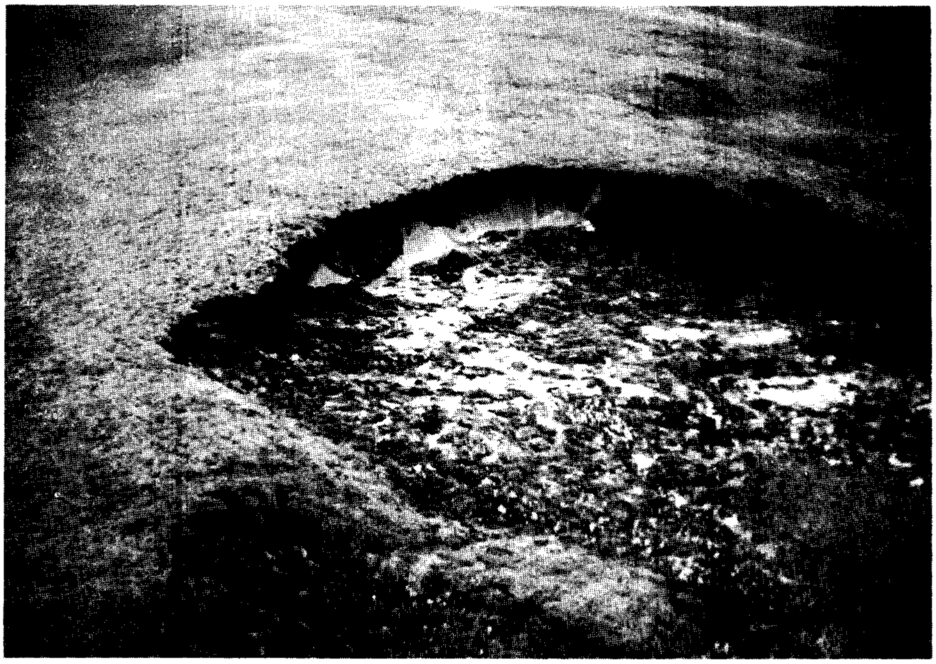

Figure 4-14. Oblique aerial photo of ground-ice slumps near Cape Beaufort. Note the massive ice in the scarp (approximately 5 m in height).

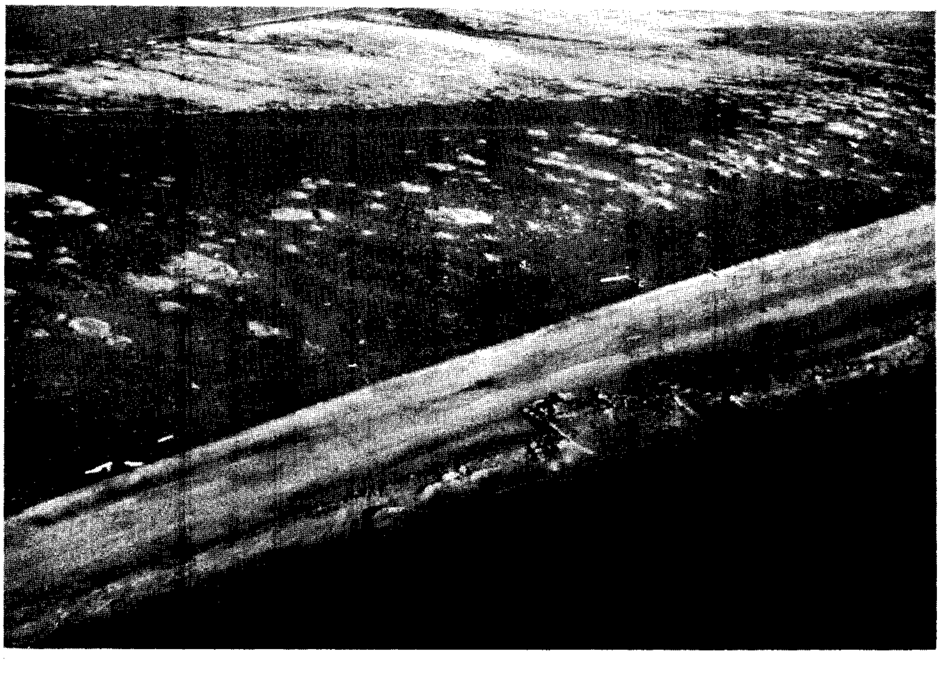

Figure 4-15. Ice push on the shore southwest of Pt. Franklin. Ice push was common near Pt. Franklin and Pt. Barrow.

- wide (and stable) barrier islands (Fig. 4.6) are most common where migrating tidal passes have produced (a) wide flood-tidal deltas seaward of the barrier islands and (b) where recurve spits increase the effective width of the barrier islands

- ice push (Fig. 4.11 and 4.15) was most notable in the Wainwright to Point Franklin area and in the Will Rogers/Wiley Post Monument to Point Barrow area, suggesting a greater intensity of ice-shore interaction in these areas

The consequences of these coastal processes in relation to potential oil residence is summarized in the following sections.

Storm surge elevations were estimated at the ground-truth stations by surveying from the waterline to the highest log line (Fig. 4.16). Logs were not always present and indirect measures, such as maximum storm-berm elevation of the barrier islands, also provided an estimate of maximum surge elevations. Measured values are listed in Table 4.7 and reliable estimates (log lines and maximum berm crest elevations) are plotted in Figure 4.17. It should be emphasized that estimates are approximate in that (a) they are referenced to a water level that was assumed to be a "mean water level" and (b) the estimates probably represent the storm-surge elevation plus wave amplitude.

Some significant variations in measured surge elevations are evident within the study area (Figure 4.17). Along the outer coast, storm-surge elevations in the Peard Bay to Barrow area are greater than 2 m with maximum values in the 2.7 to 2.9 m range. In the central barrier island coastal area, including the open-coast to Cape Lisburne, the surge elevations generally range from 2.0 to 2.5 m with a maximum barrier crest elevation of 2.7 m to the south of Pt. Lay. The highest storm-surge elevations documented in the study area occur in the Point Hope vicinity with all measurements greater than 2.5 m and a maximum measured value of 3.8 m; the greater measured elevations in this area probably reflect greater wave exposure rather than higher elevations.

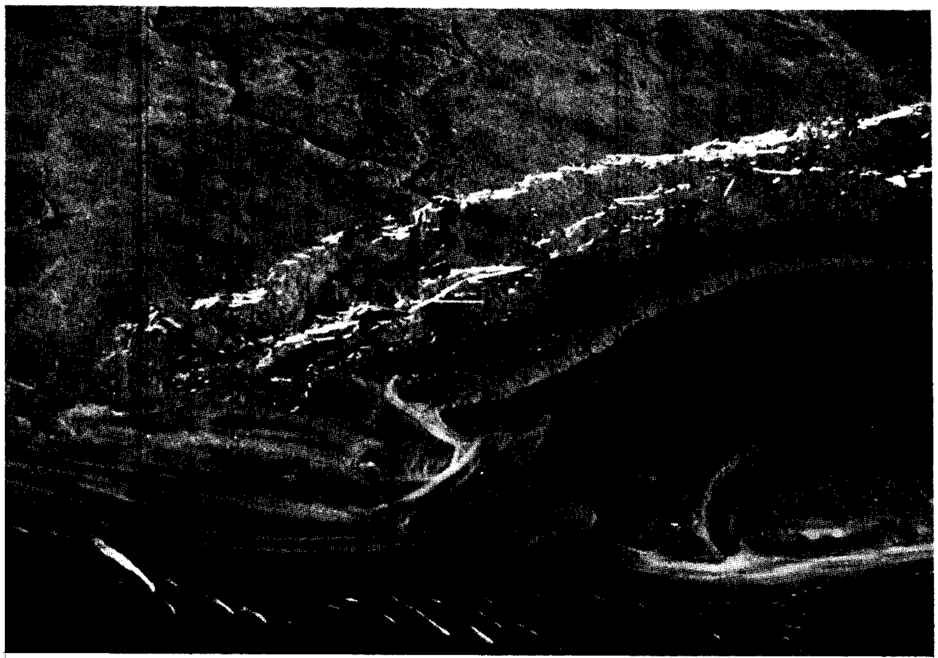

Figure 4-16. Oblique aerial photo of storm-surge log-debris lines in a small lagoon to the north of Peard Bay.

Table 4.7. STORM-SURGE ELEVATIONS - CHUKCHI SEA COAST

Ground-truth Station	Surge Indicator	Elevation Above M.W.L. (m)
CS-1	None	-
CS-2	Base Cliff	2.2
CS-3	Barrier crest	2.3
CS-4	Logs	2.0
CS-5	Cliff base	2.9
CS-6	Berm crest	2.9
CS-7	Snow	-
CS-8	Base cliff	2.1
CS-9	Berm crest	2.1
	Logs in backshore	2.4
CS-10	Base scarp	1.2
CS-11	Log line	2.7
	Base cliff with logs	3.2
CS-12	Base cliff	2.0
CS-13	Berm crest	2.3
CS-14	Log line	1.7
CS-15	Log line 1	1.3
	Log line 2	1.5
CS-16	Max swash ridge height	1.6
CS-17	None	-
CS-18	Log line	3.6
CS-19	Log line 1	1.6
	Log line 2	2.4
	Log line 3	3.1
CS-20	Log line	2.9
CS-21	Ridge crest	1.8
CS-22	Base dune, logs	1.8
CS-23	Log debris	>0.9
CS-24	Berm crest	>1.4
CS-25	Spit crest	>0.7
CS-26	Log line	>0.9
CS-27	Log line 1	1.7
	Log line 2	1.7
	Log line 3	2.3
CS-28	Barrier crest	>1.1
CS-29	Log debris	2.7
CS-30	Base cliff	>1.3
CS-31	Logs	1.8-2.1
CS-32	Barrier crest	1.7
CS-33	Cliff base	2.5
CS-34	Barrier crest	1.4 + 0.3 = 1.7*
CS-35	Logs	1.6 + 0.3 = 1.9*
CS-36	Logs	1.9 + 0.5 = 2.2*
CS-37	Logs	1.0 + 0.3 = 1.3*
CS-38	Logs	1.7 + 0.3 = 2.0*
CS-39	Logs	1.2 + 0.3 = 1.5*
CS-40	Logs	1.5 + 0.3 = 1.8*
CS-41	Logs	2.2 + 0.5 = 2.7*
CS-42	Logs	1.3 + 0.5 = 1.6*
CS-43	Logs	2.2 + 0.3 = 2.5*
CS-44	Berm	2.1
	Logs	2.0
CS-45	Logs	2.6
CS-46	Logs	1.3
CS-47	Cliff base	0.8
CS-48	Cliff base	1.0
CS-49	Logs	2.4
CS-50	Logs/berm	2.0
CS-51	Logs/berm	3.0
CS-52	Logs/berm	2.5-2.7
CS-53	Logs	3.0
CS-54	Logs	3.8
CS-55	Logs	3.5
	Berm crest	3.1

*Water levels on this day of the survey were noticeably higher than on previous survey days and an arbitrary 0.3 m was added to correct the "mean water level".

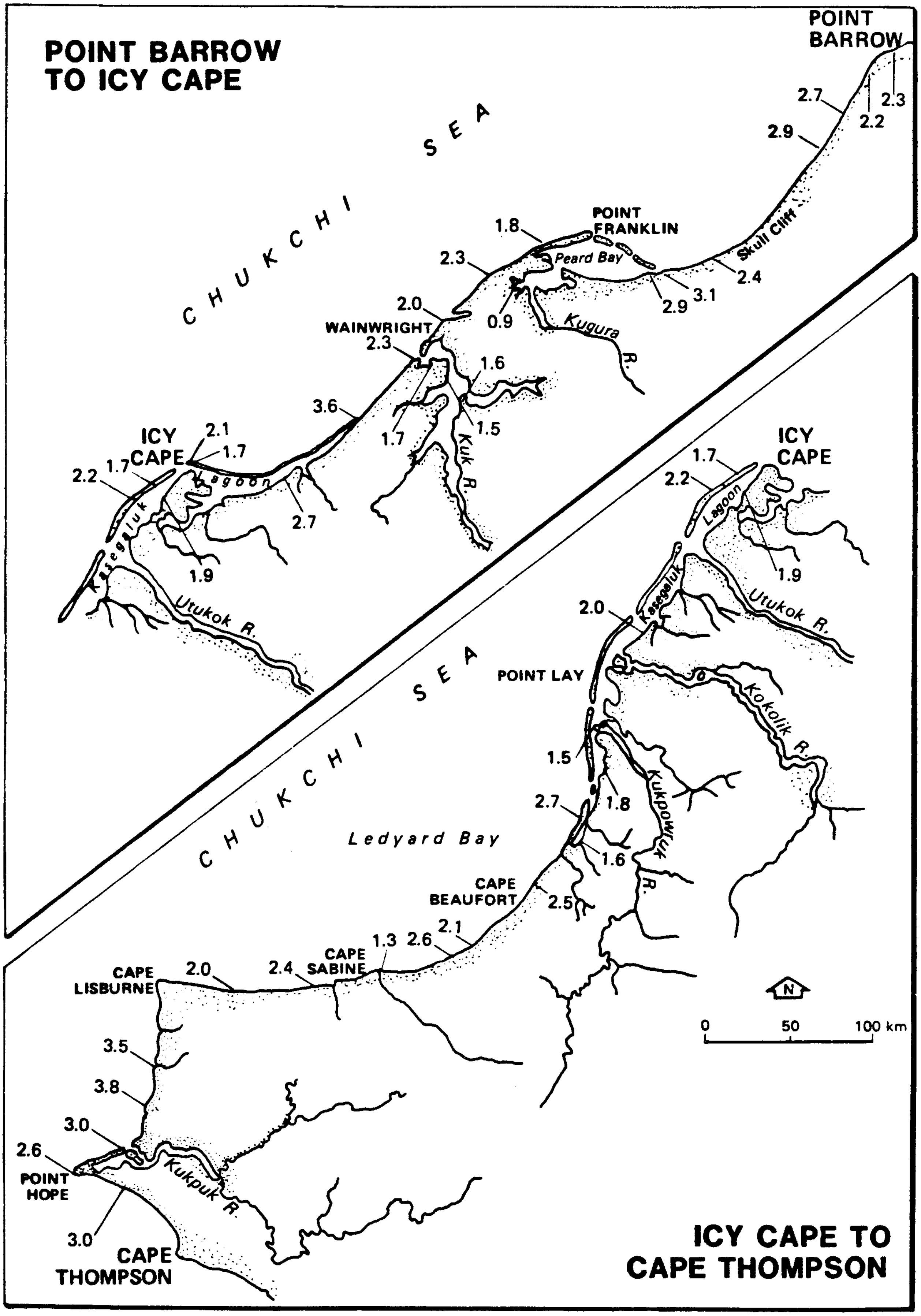

Figure 4-17. STORM SURGE ELEVATIONS (in meters) ALONG THE NORTHERN CHUKCHI SEA COAST

Significant variations also occur within the lagoons. Surge elevations within Peard Bay are notably higher in the eastern portion of the bay (~3.0 m) than in the western portion (0.9 m), suggesting that local surge anomalies similar to that of the Beaufort Sea coast (Reimintz and Mauer 1978) are generated by westerly winds. No surge anomalies are apparent in the Kuk River, as would be expected due to the north-south orientation of the lagoon and the restricted wave fetches. High storm surge elevations (2.7 to 3.6 m) in northern Kasegaluk Lagoon with decreasing elevations to the south support observations that westerly and south-westerly winds cause local surge anomalies in the shallow lagoon.

4.5.2 Oil Residence Indices

Primary, secondary and tertiary Oil Residence Indices are mapped for all segments of the northern Chukchi Sea coast, including major lagoon shorelines. The oil residence indices are graphically illustrated on the sensitivity maps (Volume 2 - Resource and Sensitivity Maps) and quantitatively summarized in Tables 4.8 and 4.9.

The results indicate that approximately 30 percent of the coastline is classified as primary concern (Table 4.8). Most of the primary concern areas are in lagoons (25 percent - Table 4.9) and include (a) low energy gravel beaches, (b) wetlands and (c) delta fronts (with associated wetlands). These areas would be expected to have oil residence periods longer than one open-water season. An additional 32 percent of the coastline is classified as secondary concern (Table 4.8). These are segments of coastline where residence time is uncertain and could range from a month to more than one complete open-water season. Shore-zone types included in this category include (a) actively eroding low tundra cliffs along much of the mainland lagoon coast (Table 4.9) and (b) recurve spits associated with barrier island tidal inlets. Potential oil residence on these shorelines would depend heavily on environmental conditions at the time of the spill and the spill characteristics. For example, if oiling levels were light, the tundra cliff shorelines would be expected to self-clean in a matter of weeks. Similarly, if oil stranding occurred during relatively quiescent wave conditions, with no

Table 4.8. DISTRIBUTION OF OIL RESIDENCE INDICES ON THE NORTHERN CHUKCHI SEA

Region	Level of Concern		
	Primary (%)	Secondary (%)	Teritiary (%)
Northern (Maps 1-32)	6.9	13.8	11.7
Central (Maps 33-58)	17.5	15.2	11.8
Southern (Maps 59-84)	5.3	3.3	14.4
Total*	29.7	32.3	38.0

*Total coastline length 1523 km

Table 4.9. DISTRIBUTION OF OIL RESIDENCE INDICES ON THE NORTHERN CHUKCHI SEA COAST AS A FUNCTION OF EXPOSURE

Region	Level of Concern					
	Primary (%)		Secondary (%)		Tertiary (%)	
	Open Coast	Lagoon	Open Coast	Lagoon	Open Coast	Lagoon
Northern (Maps 1-32)	1.8	5.1	0	13.8	11.7	0
Central (Maps 33-58)	0.8	16.7	0.5	14.7	11.8	0
Southern (Maps 59-84)	2.2	3.1	0.1	3.2	14.4	0
Total*	4.7	25.0	0.6	31.8	38	0

*Total coastline length 1523 km
Lagoon coastline length 864 km
Open coast coastline length 659 km

storm surge, shorelines around inlets would quickly self-clean (days to weeks of open-water season). If, however, oil were transported into swales between the recurve ridges during a storm surge, potential oil residence would likely be lengthy (greater than one complete open-water season).

The remaining 38 percent of the study area shoreline is classified as tertiary concern (Table 4.8). The areas of tertiary concern are restricted to open-coast areas (Table 4.9), where higher wave energy levels would likely cause natural dispersal of the oil within days to a few weeks. Areas included in the tertiary concern category are: rock cliffs, eroding tundra cliff, and gravelly-sand barrier island beaches.

It is also evident from the regional summaries (Table 4.8) that the central portion of the study area has the greatest oil persistence potential. Approximately half of the primary and secondary levels of concern occur within the central coastal segment, primarily because of the extensive lagoon systems with extensive wetland, delta front, and low-energy beach shorelines (Table 4.9). The lowest proportion of primary or secondary concern shoreline occurs within the southern segment, which consists primarily of open-exposed coastline (Table 4.9). The northern coastal segment has a comparatively small proportion of primary concern shoreline, due to the low proportion of wetlands, deltas and barrier beaches which occur within the lagoons. The higher proportion of secondary concern shoreline in the northern segment is attributable to the common occurrence of low tundra cliffs along most of the lagoon shoreline (Table 4.9).

4.6 SUMMARY

Based on a detailed inventory of coastal landforms along the Chukchi Sea and a review of oil persistence studies in other areas, approximately 30 percent of the northern Chukchi Sea coast is expected to have potentially lengthy oil residence periods (greater than one open-water season) (Table 4-8). Shore-zone types most susceptible to lengthy oil persistence are low energy beaches, wetlands and river deltas of the protected lagoon coast. An additional 32 percent is considered to have variable residence periods, which will depend significantly on environmental conditions at the time of the spill and on spill characteristics. Residence periods of oil in the shore zone may range from a few weeks to more than one open-water season. Shorelines included in this category are prograding recurve spits near barrier island inlets and eroding low tundra cliffs which occur along much of the mainland lagoon coast. The remaining 38 percent of the coast is considered to have comparatively short oil residence periods and under normal open-water conditions would probably be self-cleaned in a period of days to weeks by wave action. Experimental oil spill studies in the Canadian arctic have shown that exposed shoreline (fetch distances greater than 100 km) can be cleaned rapidly (a few days) despite heavy oiling levels. Shorelines included within this category are: rock cliff, eroding tundra shorelines along the exposed Beaufort Sea coast, and exposed barrier island shorelines.

The highest concentration of shoreline where oil persistence is likely to be high occurs in the central portion of the study area where over approximately 500 km of the lagoon shoreline is comprised of extensive wetlands, river deltas and low energy beaches.

5.0
BIOLOGICAL SENSITIVITY

5.1 INTRODUCTION

The biological sensitivity to oil spills of the Chukchi Sea coast is based on the species, habitats or other biological resources vulnerable and sensitive to an oil spill. Identification of the sensitivity and vulnerability of biological features is important for environmental impact assessment. It is especially useful for the development of oil spill countermeasure planning or implementation to protect sensitive coastal biological resources. The Biological Sensitivity Index complements the Oil Residence Index (Section 4.0) and the Human Use Index (Section 6.0).

5.2 CONCEPTUAL DEVELOPMENT OF THE BIOLOGICAL SENSITIVITY INDEX (BSI)

Important elements of evaluating oil spill impacts and planning oil spill countermeasures are (a) an estimate of the potential vulnerability and sensitivity of coastal biological resources when they come into contact with the oil and (b) the ability of the resource to recover from the effects of the oil. A Biological Sensitivity Index is one of the several separate components or indices developed to fully assess the impacts of an oil spill and to develop countermeasures (Owens and Robilliard 1981a, 1981b). Thus, the Biological Sensitivity Index is limited to "biological sensitivity and vulnerability", which is a complex enough evaluation in itself, and does not include elements of: (a) "risk" index, (i.e. probability that an oil spill will occur and contact the biological resource), (b) "persistence", "oil residence" or "oil retention" index, (c) "response and priority" index, (d) "human resource use" index, or (e) "cultural resource" index (Robilliard et al. 1980).

Most previous indices considered the biological characteristics to be largely dependent upon the geological substratum and the physical coastal processes. They largely ignored the substantial variability in, and influence of, biological features and processes. This led to the assumption that a shoreline characterization based primarily on geological features and coastal processes is sufficient to determine shoreline biological sensitivity (Owens and Robilliard 1981a). However, sensitivity indices developed on this assumption often lead to false impressions about coastal biological sensitivities and particularly about the amount of temporal or seasonal variability in these sensitivities (Owens and Robilliard 1981a).

These limitations led to the development of the Biological Sensitivity Index based upon and reflecting the temporal and spatial variability in abundance, distribution, and important activities of species, habitats or other resources of _real_ or _perceived_ concerns (Woodward-Clyde Consultants 1982, Robilliard et al. 1983a, b). The index is flexible enough to accommodate natural variability and the consequent temporal change in "importance" or "rank" of a coastal segment due to the change in the biotic components present. Most previous sensitivity indices did not explicitly take into account this temporal variation in identifying the importance or sensitivity of a coastal segment _and_ did not provide a means of including this information in the index. However Gundlach et al. (1980) modified their original approach and included the _seasonal_ importance of specific shoreline habitats to certain species directly on the maps using specific symbols.

It is also not desirable to rank or weight _a priori_ the sensitivity indices in some fixed scale as has been done previously (Hayes et al. 1976, Worbets 1979, Forget et al. 1979, Gundlach and Hayes 1978, Gundlach et al. 1980). Even though these approaches, as currently used, appear to be easier to "understand", they do not take into account the seasonal variability in the sensitivity level of the resource. The index must be presented so that it is easily understood and correctly used by the decision makers, environmental managers, and operations personnel.

Typically, this can be most readily accomplished by graphic and tabular, rather than narrative, presentations.

As a general rule, the BSI as well as a priori oil spill countermeasure planning should focus on those resources and their activities that are predictable in a spatial context; that is, they are "real-estate oriented". Therefore, only the "real-estate oriented" resources (e.g. wetlands) or activities (e.g. waterfowl nesting areas or seabird colonies) are mapped. The resources which are not spatially predictable except in a broad sense are usually mobile species like polar bears, beluga whales, spotted seals and walrus, anadromous fish, rafting or migrating waterfowl and marine birds, and most shore birds. They are not mapped because:

- putting symbols all over the map to reflect their distribution defeats the purpose of identifying sensitive areas for a priori spill countermeasure planning,
- putting symbols on a map implies that the resource is and will be present where shown,
- temporal abundance and distribution patterns at any particular location are often widely variable,
- the data on temporal or spatial distribution of the resources are generally inadequate, especially in the Arctic.

In this program, the Biological Sensitivity Index (BSI) directly reflects the biological nature, not the physical nature, of the coastal resources. The BSI displays the spatial and temporal sensitivity associated with the biotic resources of the Chukchi Sea coast at 3 levels of concern: Primary (high), Secondary (moderate) or Tertiary (low). (See Section 5.4 for details.)

Once the level of concern for a coastal resource is identified, one may compare the level of concern for that resource to the level of concern for the same resource in other coastal segments, as well as to other resources in the same or other coastal segments. This type of comparison should assist decision makers, in the event of a spill, to decide where and how to allocate resources in implementing oil spill countermeasures.

5.3 LIMITATIONS OF THE BIOLOGICAL SENSITIVITY INDEX

The Biological Sensitivity Index, as used in this report and applied on the accompanying maps, can only be used as a guideline for identifying which sections of the coast may have a high level of biological sensitivity to oil spills. Because most biological resources may vary considerably in spatial and temporal abundance, distribution, or importance on a short-term basis, it would be preferable (and may even be necessary) to verify the Biological Sensitivity Indices at the time of an oil spill. This real-time verification is easily and rapidly done. It is particularly desirable prior to any substantial implementation of shoreline protection or cleanup contermeasures This verification can minimize the time and money spent on protecting a resource that is not actually present in a particular place at the time of the spill, even if the Biological Sensitivity Index indicates that the resource is likely to be there.

5.4 DEFINITION OF TERMS

Vulnerability and sensitivity are key components in defining the level of concern for the biotic resources. For the purposes of this report, the terms are defined as follows:

- Vulnerability is the likelihood that some portion of the biotic resource of concern will come into contact with oil.

- Sensitivity is the response of the biotic resource to contact with oil.

- Level of Concern reflects a combination of the vulnerability and sensitivity levels of a particular biotic resource.

5.4.1 Vulnerability

Assessing the vulnerability of a biotic resource involves a qualitative assessment of the proportion of the population or community that could potentially come into contact with or be contracted by oil. The levels of vulnerability (low, moderate, high) represent the possibility that a substantial portion of the population/community will come into contact with oil within the study area and that the loss of this portion of the population/community could potentially affect overall population numbers of the species in the study area.

The final vulnerability level represents a composite of several factors (including abundance, distribution within the study area, and behavior) which will identify the proportion of the population/community which may come into contact with the oil. For example, clumped resources, such as some of the nesting seabirds (e.g., murres, kittiwakes), are considered more vulnerable than those with non-clumped widespread distributions, such as the cormorants and gulls. Seabirds, such as the murres, which form large social flocks on the water in the vicinity of their nesting colonies are considered more vulnerable than species, such as the terns, which do not. Birds that dive for their food (alcids) are considered more vulnerable than those that do not (gulls).

5.4.2. Sensitivity

The sensitivity of a resource is based on the expected response of that resource to contact with oil. Response is evaluated in terms of potential mortality or diminished reproductive capacity and of the resilience of the potentially affected population/community. For example, a highly sensitive resource would be one in which a large portion of the population suffered high mortalities and the population took a long time (i.e. several generations) to recover to pre-spill abundance.

5.4.3. Level of Concern

The level of concern of the BSI reflects the combination of vulnerability and sensitivity of the particular population/community being assessed.

We establish three levels of concern to oil spills and label them primary, secondary, and tertiary concern. These levels of concern are defined as follows:

- Primary (or High)
  - Major change expected in distribution, size, structure and/or function of affected biotic resource (population, community or habitat).
  - Recovery from these changes expected to required long time periods (variously defined as several years, generations, ice-free seasons, decades, etc. as appropritate for area of concern).

- Secondary (or Moderate)
  - Moderate change expected in distribution, size, structure and/or function of affected biotic resource (population, community or habitat)
  - Recovery from these changes expected to require moderate time periods (see above).

- Tertiary (or Low)
  - Little or no change expected in distribution, size, structure and/or function of affected biotic resources (population, community or habitat).
  - Recovery from any changes expected to require short time periods (see above).

In practical terms, the three levels of concern, regarding any of the components of the three resource categories, can be described in the context of an actual oil spill. The *Primary* (or High) category has high visibility with the public, government agencies, and other concerned groups. There will be considerable public and official pressure to implement protective or cleanup countermeasures with little regard to cost or practicality. The majority of knowledgeable sources will agree that there will be (or is perceived to be) a significant impact to the resource if oil contacts it. The *Tertiary* (or low) category attracts very little attention. There is little pressure from any knowledgeable source to take countermeasure actions because there is general agreement that the resources will not be affected. The *Secondary* (or moderate) category, however, includes those situations where there is considerable debate in the media and among knowledgeable sources about the importance of the resource, the cost-effectiveness of countermeasures and the likely impact of oil contacting the resource.

In most cases, decisions about the need to take countermeasure actions in areas assigned Primary or Tertiary Levels of Concern will be straight-forward (although the actual implementation may not be) and can be planned for on an *a priori* basis. However, decisions in areas assigned a Secondary Level of Concern are probably best made *at the time of the spill* though some planning can take place on an *a priori* basis.

Not uncommonly, the level of concern is influenced or even established by policy makers, government regulatory bodies, or the public on the basis of *perceived* sensitivity of the biological or human use to oil spills. This perceived sensitivity and usually high level of concern may not reflect the real ecological or human use sensitivity. That is, the species, habitat or human activities may not be substantially affected by the oil, and on a strictly ecological or economic basis, should be assigned a lower level of concern. For example, there is very little evidence from past oil spills that pinnipeds or whales in open water situations are adversely affected by oil spills, so long as the pinnipeds or whales are allowed to move about on their own accord. Yet pinnipeds and their haulout or shoreline rookery areas and whale intensive-use areas are often assigned a high level of concern by decision-makers and the lay public based on a perceived sensitivity.

Estimation of the level of concern is necessarily subjective due to the large amount of uncertainty about the likely physical, biological and human use conditions at the time of an actual spill and about the characteristics of the spill itself. The indices or levels of concern do not include an estimate of the likelihood of an oil spill occurring. The levels of concern presented on the maps are based on the experience and professional judgment of the authors and on the pertinent literature on the short and long-term effects of spilled oil on shore-zone resources. More accurate estimates of the level of concern, especially for Secondary categories, can be made at the time of the spill when the numerous variables affecting the level of impact can be evaluated in real time.

5.5 HABITATS AND BIOLOGICAL RESOURCES OF CONCERN

5.5.1 Habitats

There are five major shore zone habitats, from a biological perspective, on the northern Chukchi Sea coast. The are:

- rock cliffs (Figures 4.1, 5.1)
- wetlands (Figure 4.11, 5.2, 5.3)
- barrier islands and spits (Figures 4.3, 4.5, 4.6, 4.7, 4.15, 5.2)
- tundra cliffs (Figures 4.2, 4.10)
- deltas (Figure 4.12)

Figure 5-1.
Rock cliffs, east of Cape Lisburne. Arrow indicates beginning of the major seabird (kittiwake and murre) nesting colony.

Figure 5-2. Barrier Island at Akoviknak Lagoon, east of Point Hope. Open coast at lower left and lagoon coast at top of picture with brackish wetlands in direct communication with lagoon (large arrow) and fresh wetlands protected from lagoon waters (small arrow)

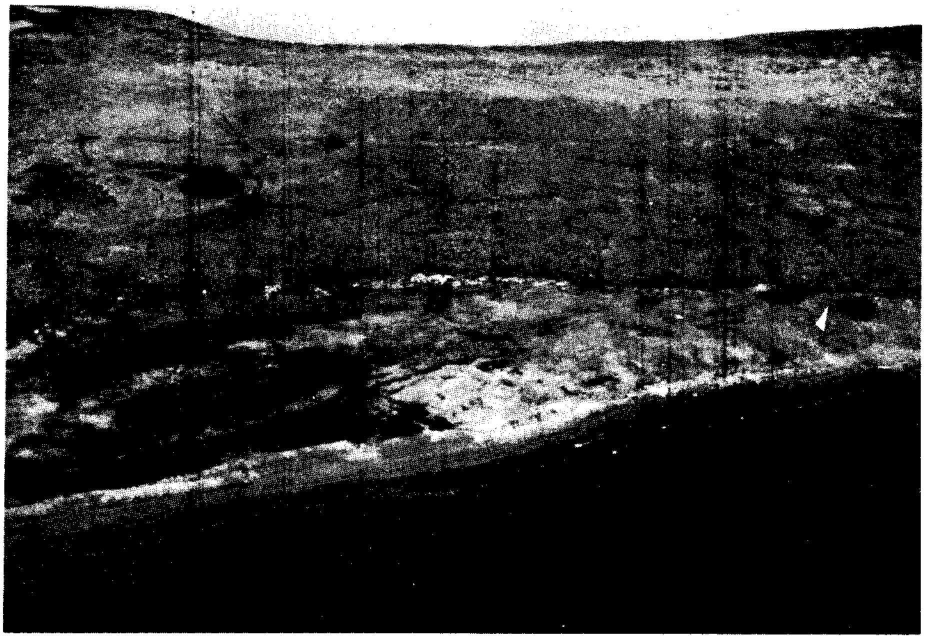

Figure 5-3. Wetlands on mainland shore in southern Kasegaluk Lagoon. River mouth is at top of picture and lagoon shore at bottom.

The physical characteristics of each type are described in Section 4.3.4.

Rock cliffs are important from a biological standpoint in the BSI because at least some provide nesting habitat for seabirds, often in large numbers. THe largest colonies are at Cape Lisburne (Figure 5.1) and Point Thompson. Other rock cliff areas similar to those at Corwin Bluff (Figure 4.1) support smaller seabird colonies. However cliffs like those at Skull Cliffs (see cover) as not stable enough to provide much seabird nesting habitat nor are they close enough to adequate concentrations of food.

Wetlands in the study area can be classified as two principal types in the shore zone. First are the salt or brackish ones which are usually in direct communication with the marine or estuarine waters, usually on the protected lagoon or bay shorelines (Figure 5.2, 4.11). The second, more extensive, type of wetland are "fresh" ones which are above the usual high water mark and are not usually directly affected by marine or estuarine waters (Figure 5.2, 5.3). A third type, the freshwater tundra ponds and lakes, are not included here because they are above the highest storm surge lines and will not be directly effected by the oil spill (although people and equipment involved in countermeasures may have an impact). The important wetlands are primarily found along Peard Bay, Kasegaluk Lagoon, Wainwright Inlet and adjacent water bodies.

The brackish wetlands are directly vulnerable to spilled oil being transported by lagoon or bay waters at normal water levels, i.e., without the influence of significant storm surges. The "fresh" wetlands that are in the shore zone below the primary storm surge elevation (about 2m above high water; see Figure 4.17) are vulnerable to oil being deposited there during storms, where it would remain for long periods (i.e, the Oil Residence Index is primary or high).

Wetlands, especially the larger ones such as at Icy Cape, are a biologically important and sensitive habitat for several reasons. They are biologically important because marsh vegetation such as Puccinellia phryganodes and P. langeana, Carex subpathacea and other species, algae, and other aquatic higher plants are the principal food of Black Brant and a few other species of waterfowl. Several species of shorebirds feed on organisms in the water, on the bottom, or in the vegetation along the shoreline. These are vulnerable as described above and because the oil is likely to have a high residence time, the oil could have a long-lasting effect on the vegetation as well as on the benthic or planktonic organisms in the water. These impacts in turn could have substantial effects on the waterfowl, shorebirds, and, possibly indirectly some fish species which ultimately may effect the human uses of subsistence hunting and fishing.

Barrier islands and spits range from low, narrow exposed ones that are frequently overwashed by storm surges and ice to high, wide, protected ones that are seldom directly affected by marine waters or ice. The former are typically barren of animals or plants (Figures 4.3, 4.5) and generally do not support resting areas for gulls or waterfowl.

However, we did observe a pair of terns nesting on the spit shown in Figure 4.3. On the other end of the spectrum are vegetated islands and spits. Figures 4.15, 5.2, 4.6, 4.7 and 5.3 show a continuum from sparsely vegetated (Figure 4.15) to densely vegetated (Figure 5.3) as a function of exposure and elevation.

There is a general vegetation zonation pattern on all these vegetated barrier islands and spits (Wiggins and Thomas, 1962) (Figure 5.4). Nearest the waterline, especially on the open coast shore are scattered patches of *Honkenya peploides* and possibly *Mertensia maritima*. Above that is the dune grass, *Elymus arenarius*, often in dense mats (Figure 4.7). From the barrier island crest toward the protected shore there may be a variety of grasses (*Poa* spp.), willows (*Salix* spp.) and other forbs or herbs, depending on the elevation and horizontal extent of the area. Toward the lagoon shore the wetlands begin to dominate and *Carex* spp., *Puccinellia* spp. and other wetland species dominate the vegetation down to the waterline.

Figure 5-4. Zonation of vegetated shoreline. Mainland side of South Kasegaluk Lagoon.

For this study, the primary importance of the barrier island and barrier spit habitats is for waterfowl and gull or tern nesting habitat. The wetlands are considered separately. The isolated, vegetated barrier islands generally support more nesting birds than barren or less isolated islands and spits. The islands and spits themselves are not identified as biologically sensitive habitats; instead the BSI is applied only for areas where the nests have been reported and it was classified as secondary or moderate.

Tundra cliffs, high (Figure 4.2) or low (Figure 4.10), do not support important biological resources. In general the tundra community is above even the storm surge line though tundra behind very low tundra cliffs (e.g. <2m) may be innundated during the major storm surges.

Deltas (Figure 4.12) in the study area are generally not important biological shore-zone habitats because most are not vegetated and they do not support large infauna populations. The various river channels through the deltas may be important however to anadromous fish, especially as overwintering areas or juvenile rearing areas.

In summary, wetlands were the only habitat on the Chukchi Sea coast classified biologically sensitive on a blanket basis. The level of concern for the BSI applied to each wetland was based on the size, type, abundance of vegetation and known or probable use by waterfowl and shorebirds. The rock cliffs and barrier islands or spits, by themselves, were not classified biologically sensitive; however, those sections used by nesting birds were classified as such and appropriate level of concern for the BSI was applied (see Section 5.5.2).

5.5.2 Species

There are several species or groups of species present in the Chukchi Sea coastal zone that are generally considered important, most of them because they are subsistence species. The principal list of species which are considered vulnerable and sensitive to an oil spill and thus classified as biologically sensitive is small. The rationale for applying the BSI to these few species and not others is presented in this section.

Anadromous fish may use the lagoons, bays, estuaries, deltas and small river mouths as well as the nearshore zone for various of their life history activities (Craig 1984). However, based on the few data available, the populations of most species appear to be small and scattered in time and space and they do not appear to comprise a major biological resource in the northern Chukchi Sea. Therefore, the anadromous fish population and habitats were not included in the BSI (although the subsistence use of fish is included in the HUI; Section 6.0).

Spotted seals, walrus, and beluga whale are the most important marine mammals on or near the shore zone in the ice free season. The few walrus haul out near Cape Lisburne while seals haul out on numerous beaches, especially on barrier islands of Peard Bay and Kasegaluk Lagoon (Frost et al. 1983). There are no pinniped rockeries on land in the study area, so only juveniles and adults may be affected within the shore zone. Beluga whales are abundant in the ice free season in passes and the mouths of major rivers. All these marine mammals would be highly vulnerable to oil on or near the shore zone or in the lagoons. However, pinnipeds and whales are not considered very sensitive to oil (Geraci and St. Aubin 1980 1982, Geraci and Smith 1976 1977, Geraci et al. 1983, Davis and Thomson 1954, St. Aubin et al 1985) except under restrictive (and unrealistic) scenarios or experimental conditions. Therefore, they were assigned a BSI with a tertiary level of concern and not identified except in the Coastal Resource Tables (Part III).

Shorebirds, except for phalaropes, spend most of their time wading or on the shoreline and therefore are not likely to become oiled sufficiently to cause mortality. However, they do feed in the intertidal areas as well as the coastal wetlands and may ingest tainted prey. Shorebirds are only considered moderately vulnerable or sensitive to oil at the most. The likelihood of a major decline in population numbers of shorebirds subjected to an oil spill is low, due to the large numbers of birds and their wide distribution in the study area. Local phalarope populations may suffer substantial mortality at the oil spill site but the species is abundant and widely distributed so regional populations are not likely to be substantially affected (Roseneau and Herter 1984). Shorebirds were not included directly in the BSI, however the importance of many wetlands was influenced by their expected importance to the shorebirds (Peter Connors, Bodega Research Associates, personal communication).

Several species of seabirds (alcids, kittiwakes, gulls, terns) and waterfowl (e.g. eiders, brant, oldsquaw) spend much to most of their time on or in the marine and lagoon waters of the study area, and are thus vulnerable to nearshore spilled oil. Most are also considered moderately to highly sensitive to oil.

The vulnerability and sensitivity of seabirds and waterfowl are determined by the following characteristics:

Vulnerability

- resting behavior
- feeding behavior
- flocking behavior
- nesting behavior
- breeding distribution

Sensitivity

- individual response to oil
- life history characteristics
- population size

Vulnerability of Seabirds

The vulnerability of seabirds such as Common and Thick-billed Murres, which spend a large amount of time resting on the water within the study area are potentially more vulnerable to oil than those, such as the

Glaucous Gull, which rests on land. Some seabirds, such as the Black-legged Kittiwakes, often feed offshore outside the study area and are less likely to encounter oil than species, such as the cormorants, which forage nearer the coast or oldsquaw which molt in protected lagoons and bays. Another consideration with respect to feeding behavior is the mode of feeding. Diving birds (e.g. puffins and murres) are more likely to become completely oiled compared to terns or gulls which do not dive for food, feeding instead on the surface or on land as predators. Some species, such as the alcids, typically form large flocks in the vicinity of their nesting colonies, thus increasing the likelihood that a large number of birds would be impacted by an oil spill reaching the study area. Brant and oldsquaw, when they are migrating and molting also congregate in large flocks thereby making a substantial portion of the population vulnerable to nearshore spilled oil. Nesting eiders, cormorants, and gulls tend not to form large flocks and are broadly distributed, decreasing their vulnerability.

Sensitivity of Seabirds

The sensitivity of marine birds to oil has been amply documented in the literature and information relevent to aquatic birds is summarized by Roseneau Herter (1984). The effects of oiled plumage on marine birds will vary depending upon the type of oil, degree of contamination, quantity of oil absorbed, environmental conditions, and condition of the bird (Ohlendorf et al. 1978). Most of the immediate mortality of marine birds upon contact with oil results from contamination of the feathers. Oiling of a bird's plumage leads to an increase in metabolism and to potentially fatal hypothermia due to increased loss of body heat to the surrounding water. Oiling of the plumage can also lead to mechanical inability to fly or to forage underwater. Ingestion of oil during preening of contaminated feathers can result in inflammation and hemorrhaging of the intestine, impairment of the liver and kidney, interference with ion transport and water balance, and decrease in growth and reproductive potential.

Reproductive success may be lowered because adult birds may not replace eggs that have died as a result of petroleum products, as they normally do when clutch losses follow natural causes (Patten and Patten 1978). The main loss in reproduction probably occurs as a result of oil contamination of the eggs. Oil that adheres to the feet or feathers of adult birds may be transferred to eggs during the process of egg laying and/or incubation (Szaro et al. 1976, Holmes and Cronshaw 1978, Coon et al. 1979, Patten and Patten 1978, Eastin and Hoffman 1978).

In addition to the sensitivity of individual birds to oil, life history characteristics are important in determining the level of sensitivity of birds, especially at the population level. Seabirds generally have long lifespans, low adult mortality rates, relatively late sexual maturity, and small clutch sizes (Sowls et al. 1980). Loss of a substantial number of breeding adults could affect the breeding population of a particular species for decades. Wiens et al (1979) modeled the short- and long-term effects of oil to seabirds in Alaska and determined that adult mortality was most critical to the seabirds studied. Recovery time of the populations studied to pre-impact levels was estimated to be on the order of decades. This can be attributed to the life history traits of seabirds, which are not particularly conducive to rapid recovery from catastrophic events affecting breeding age adults. This is less of a problem for waterfowl.

For this study, the waterfowl nesting areas and seabird colonies were included in the BSI. Colonies reported to be larger than or equal to 50 nesting pairs of birds of all species were arbitrarily assigned a primary level of concern while all smaller colonies were assigned a secondary level of concern. We recognize there may be large year-to-year fluctuations in numbers of nesting birds (which supports our concern that the BSI be used for a priori planning but that the actual conditions should be checked at the time of the spill. The seabird colonies on rocky cliffs near and south of Cape Lisburne and waterfowl nesting areas on barrier spits and islands were selected for the BSI because they are reasonably predictable in space; i.e., they are "real-estate oriented".

Large concentrations of oldsquaw, brant, eiders or seabirds feeding, or molting and staging in lagoon or offshore waters were not included in the BSI, even though they are highly vulnerable and sensitive. It is simply not practical to predict the temporal or spatial distribution of these flocks except in very broad terms, which is not useful for a priori countermeasure planning.

5.6 RESULTS

The primary, secondary and tertiary Bological Sensitivity Index is mapped for the northern Chukchi Sea Coast, including major lagoon, bay and inlet shorelines. About 5 percent of the shoreline is classified primary concern in an oil spill (Table 5.1) and most of this (3.8 percent) is on the Kasegaluk Lagoon coast of the central region (Table 5.2). The areas of primary concern in the central region are the major wetlands, especially in the Icy Cape region, and the larger bird nesting areas, espcially for eiders or terns. In the southern region, the main areas of primary concern are the seabird colonies on rocky cliffs, particularly Cape Lewis, Cape Lisburne and Point Thompson as well as several smaller colonies. In the northern region, no areas of primary concern were identified (Table 5.1) because there are few wetlands and no significant seabird colonies or waterfowl nesting areas.

The secondary level of concern was applied to 11.3 percent of the shoreline. The majority (5.8 percent) is in the southern region and associated with the bird use of Marryatt Inlet (4.2 percent; Table 5.2). The rest (1.6 percent) in the southern region is associated with small seabird colonies and lagoons or estuaries. Similar proportions of the northern and central regions are classified as secondary level of concern (2.8 and 2.7 percent, respectively) primarily for smaller wetlands and smaller bird nesting areas. The reader should note that the BSI secondary level of concern shown on area water areas of Peard Bay, Kugura Bay, Wainwright Lagoon, Kasegaluk Lagoon and Marryatt Inlet is not included in Tables 5.1 or 5.2.

Table 5.1. DISTRIBUTION OF BIOLOGICAL SENSITIVIY INDICES ON THE NORTHERN CHUKCHI SEA COAST

	Level of Concern		
Region	Primary (%)	Secondary (%)	Ter tiary (%)
Northern (Maps 1-32)	0	2.8	29.5
Central (Maps 33-58)	4.0	2.7	38.0
Southern (Maps 59-84)	1.0	5.8	16.2
Total*	5.0	11.3	83.7

*Total coastline length 1523 km

Table 5.2. DISTRIBUTION OF BIOLOGICAL SENSITIVITY INDICES ON THE NORTHERN CHUKCHI SEA COAST AS A FUNCTION OF EXPOSURE

	Level of Concern					
	Primary (%)		Secondary (%)		Tertiary (%)	
Region	Open Coast	Lagoon	Open Coast	Lagoon	Open Coast	Lagoon
Northern (Maps 1-32)	0	0	1.0	1.8	12.5	17.0
Central (Maps 33-58)	0.2	3.8	0.8	1.9	12.1	25.9
Southern (Maps 59-84)	0.8	0.2	1.6	4.2	14.3	1.9
Total*	1.0	4.0	3.4	7.9	39.0	44.7

*Total coastline length 1523 km
Lagoon coastline length 864 km
Open coast coastline length 659 km

Most (83.7 percent) of the shoreline is classified as tertiary or low level of concern (Table 5.1). This reflects the general lack of suitable habitat for most species and probably the general low abundance of food resources in the area for waterfowl, seabirds, fish, or marine mammals.

5.7 SUMMARY

Oil spill impacts in the open water season are likely to be high for about 5 percent of the shoreline. Most of these areas are wetlands in Kasegaluk Lagoon or adjacent water bodies where the ORI is primary or secondary; i.e., any oil that gets to these biologically sensitive areas is likely to persist for several seasons. The other areas are waterfowl nesting areas or seabird colonies which are not directly vulnerable (although the nesting areas on barrier islands could be directly affected if the oil spill occurred during a significant positive storm surge that overwashed the island or spit).

Over 11 percent of the shoreline is classified as secondary concern, primarily on the basis of smaller wetlands and smaller bird nesting or seabird colonies. Any one of these areas may be as vulnerable or sensitive as those classfied as primary level of concern, but on an individual basis they are considered less important to the success of the population.

That nearly 84 percent of the shoreline is classified tertiary level of concern supports the general notion that most of the northern Chukchi Sea coast is not particularly productive especially when compared to the adjacent Beaufort and Bering Seas (Truett, 1984).

6.0

HUMAN USE SENSITIVITY

6.1 BACKGROUND ON HUMAN USE SENSITIVITY

The sensitivity of human resources to an oil spill is a function of (a) spill characteristics, (b) vulnerability or risk that the resource will be impacted and (c) the importance of the resource. The human use sensitivity evaluation is similar in many ways to the biological sensitivity evaluation because many of the human uses of the Chukchi Sea shoreline are directly or indirectly based on biological resources. The major difference is that human use sensitivity explicitly includes peoples' perceptions and importance values in the level of concern applied to each coastal resource or area.

While large areas associated with each village are utilized, certain areas are more important than others. "Importance" depends on proximity to the village(s), use or harvest levels, and uniqueness of the human resources. In areas close to communities or of importance to local residents, perceptions of potential impact may actually exceed real impact. However, the concern over potential impact is very real and has been often the principal criterion in responding to an oil spill event.

The impact on certain human resources, such as subsistence species, may be closely related to biological sensitivity and oil persistence in shoreline types. The human use sensitivity analysis does not directly incorporate those analyses. However, when using resource and sensitivity maps, areas of high subsistence sensitivity often coincide with areas of high biological sensitivity and oil persistence. In addition, the human use analysis does not include the effectiveness of oil spill counter-measures or cleanup techniques.

6.2 DEVELOPMENT OF THE HUMAN USE SENSITIVITY INDEX (HUI)

The human use sensitivity index (HUI) has been developed for the following human resources of the Chukchi Sea coastal environment: (a) residential (communities), (b) transportations, (c) recreation (special use), (d) subsistence, and (e) cultural resources. The first three resources are relatively fixed in location, and, once established, the levels of concern or sensitivity values for these uses (e.g. presence of a house) should not vary much over time or on a seasonal basis.

However, the location and harvest of subsistence resources and the importance of their contribution to the community varies significantly on a month-to-month basis and from year to year. This variation and limitations to available data require some subjectivity in developing sensitivity classifications. Cultural resources are also fixed at specific areas. However, the importance of the same resource in different areas can vary widely, and the specific location can influence sensitivity to spill persistence and cleanup activities.

The vulnerability of resources and uses to oil spill impact is an important aspect of sensitivity. Some of the human uses are directly vulnerable to oil spill impacts; i.e., spilled oil could directly contact the resource or interfere with the activities of interest to people. These uses include most of the subsistence hunting and fishing activities, recreation where it depends on shoreline use or access, and transportation. The recreation and transportation uses are most likely to be affected during the containment and cleanup which may involve an increase in people and vehicle activities and thus interference with these uses. The subsistence hunting and fishing activity may be directly affected because oil could ruin nets, foul boats, and generally be unpleasant to work around; however, few of the resources except waterfowl themselves are likely to be directly affected. Increased activity associated with spill cleanup may also cause subsistence resources to avoid the area.

Some human uses are not likely to be directly affected (vulnerable); i.e., oil on the water or shoreline is not likely to directly contact villages, military operations, most cultural resources, or even many recreation or transportation uses. However, the oil spill cleanup operations may have a major impact on these human uses, especially if large amounts of equipment and number of people are moved into the area.

Development of the human use sensitivity index incorporates the following human use criteria:

- frequency of human use and presence
- relative distribution and abundance of the resource
- proximity of the resource to communities
- importance of the resource to local residents (cultural significance, contribution to diet)
- characteristics of the oil spill (e.g., size, type of oil, location of spill, etc.)

As with the ORI and BSI, the human use sensitivity index is categorized in three levels of concern. They are defined as follows:

- Primary Concern - Important or intensive human-use activities likely to be disrupted for one or more open-water seasons.

- Secondary Concern - Moderate impact of some human-use activities for some portion of one open-water season.

- Tertiary Concern - Non-intensive human-use activities unlikely to be impacted for more than a short period of one open-water season.

Each explicitly identified human use resource is displayed on the coastal resource maps. It has one of the three levels of concern associated with it. If it is a primary or secondary level of concern, then the seasonal characteristics are shown on the "Seasonal Variability of Indices" table for each map (Part II). Finally, in Part III, there is additional site-specific information regarding the type, distribution, and seasonal use of each explicitly identified human use resource

6.3 APPLICATION OF THE HUMAN USE SENSITIVITY INDEX

6.3.1 Residential Areas (Villages)

All four villages in the study area are classified as primary level of concern or primary sensitivity areas. The villages are the centers of permanent population and the sub-regional transportation hubs. The residences border on the shoreline and the residents use the shoreline for boat and gear storage.

Potential impacts from an oil spill event include property damage (land, boats, gear), aesthetic impacts, increased human and machinery activity related to oil spill cleanup, and constraints to boat and shoreline transportation. Relevant sensitivity factors include high levels of human presence and use activities, and limited distribution of habitation and boat storage sites.

6.3.2 Transportation Sites

Areas of primary, secondary, and tertiary levels of sensitivity have been classified within the study area.

Of primary concern are boat storage areas, and three-wheeler subsistence access routes in immediate proximity to a village. Of secondary concern are the less-frequently used three-wheeler subsistence access routes. The airports and barge landing areas transportation sites are of tertiary concern to an oil spill event.

Potential impacts on transportation sites from an oil spill event include fouling (short-term and long-term) of equipment and increased traffic interference caused by containment and cleanup actions. Oil fouling can affect boats stored on beaches or moving through spill contaminated waters, and three-wheeler traffic on spill-contaminated beaches. These impacts would tend to be short-term (under one open water season and until cleanup activities are completed), except in areas where a shoreline type results in increased oil persistence. Interference with transportation activities can result from spill mobilization and actual containment and cleanup actions (boom deployment, oil recovery from a shoreline). Interference activities are likely to be short-term in nature, i.e., for the duration of containment/cleanup activities and less than one open water season.

6.3.3 Recreation Areas

The "recreation" or special use areas have been classified as of primary and secondary sensitivity. Primary concern areas are those (a) intensively used for specific activities in close proximity to a village, (b) limited in abundance and distribution, or (c) of great importance to village residents from traditional use. The secondary concern areas are less intensively used, further from villages, and more widely distributed (i.e., encompassing a large stretch of coastline).

Potential impacts include fouling and interference with use from containment and cleanup activities. Fouling can affect shorelines, structures, and stored equipment in these areas. Containment and cleanup activities may interfere with or prevent use of these areas. Both categories of impact may also be aesthetic in nature, diminishing value of the use areas. However, all impacts are likely to be short-term (less than open water season and/or the duration of containment/cleanup activities).

6.3.4 Subsistence Resources

Subsistence resources and harvest areas are classified as primary, secondary, and tertiary concern. Primary concern is designated for areas of intensive use, areas in close proximity to villages, resources of importance to village residents, and resources of limited distribution and abundance. Secondary concern is assigned to resources which are of importance to local residents but are more widely distributed and are more abundant, or which are further away from villages. Tertiary concern is assigned to resources/harvest areas that are relatively abundant or widely distributed or to resources of lesser importance to specific villages.

This system accounts for differences in harvest patterns and reliance on resources by individual villages. Potential impacts include fouling of resource habitat, toxicity to subsistence resources, interference with subsistence activities, and avoidance of the spill area by subsistence resources. Oil fouling of subsistence resource habitat, especially wetlands, can occur; these impacts are discussed under the Biological Sensitivity Analysis (Section 5.0). Fouling can result in contamination and/or destruction of subsistence resource habitat, toxicity to organisms, and cause organisms to avoid the spill area. The duration of contamination effects to waterfowl and shorebird nesting habitat and fish spawning and rearing areas would depend on the size, age, or life history stage of the organisms affected and the persistence of oil in the habitat. Avoidance of the areas contaminated would depend on how long oil is present, a function of cleanup by man (Section 6.0) and the natural persistence of oil (Section 4.0).

Spill containment and cleanup activities can interfere with access to and harvest of subsistence resources, depending on location. Fouling of gear (boats and nets) needed for subsistence activities is also a possibility. Activity associated with spill containment and cleanup could also cause subsistence resources (i.e., whales, birds) to avoid the area of activity.

6.3.5 Cultural Resources

All cultural resources listed in the State of Alaska's Alaska Heritage Resource Survey (AHRS) and the North Slope Borough's Traditional Land Use Inventory (TLUI) have been classified as of primary sensitivity. There has not been an intensive inventory of cultural resource sites in the study area, and additional undiscovered sites most likely exist. These sites are equally protected by legislation.

Potential impacts to cultural resources include site contamination by oil and damage resulting from containment and cleanup activities. Oil contamination of artifacts and structures will vary in impact depending on their nature and value. Natural removal of oil may mitigate impact. Containment and cleanup activities with their associated vehicle and foot traffic, represent the greatest potential for impact. Disturbance of the site can impact the ability to understand site significance. Traffic and removal of contaminated soil can damage or destroy artifacts and structures. Unauthorized removal of artifacts and cultural resources can also result during spill containment and cleanup activities.

6.4 METHODS

6.4.1 Literature Survey

Unlike the Oil Persistence and Biological Sensitivity Indices, the Human Use Sensitivity index was prepared using existing literature and related study programs being sponsored by the Minerals Management Service. Recent studies include Alaska Consultants et al. (1983), Maynard-Partch et al. (1982), Nelson (1981), Lowenstein (1981), and Pedersen (1976). Reports were reviewed to obtain the following data:

- distribution and abundance of uses and resources
- timing and frequency of uses and resource harvests
- importance of resources and uses to village residents
- regulatory requirements

Data obtained were summarized is Section 2.3, displayed on the Resource Maps (Part II), and presented on the Coastal Resource Tables (Part III).

6.4.2 Map Development

Two sets of Human Use maps have been developed much as described for the ORI and BSI. The resource maps portray the information from Section 2.3, under the categories of Residential (V), Transportation (T), Recreational (R), and Subsistence (S) (Part II). The nature of the resource and seasonal characteristics are presented in the accompanying resource tables (Part III). The Human Use Sensitivity Map (Part II) displays the sensitivity index developed in Section 6.2 and applied in Section 6.3.

6.5 RESULTS

The primary, secondary and tertiary Human Use Index is mapped for all sections of the northern Chukchi Sea coast, including major lagoon shorelines. The results show that only about 7 percent of the coastline is considered of primary concern in an oil spill (Table 6.1). Most of the areas of primary concern are along the open coast (5.4 percent) (Table 6.2). Most are associated with the major villages and nearby subsistence areas especially those used for waterfowl hunting and egg gathering. The high recreational use of the shoreline near Barrow, the largest village accounts for some of the increased primary level of concern in the northern region compared to the central or southern regions (Table 6.1).

The secondary level of concern accounts for only about 1 percent more of the coastline (Tale 6.1). The majority is on the open coast and

Table 6.1. DISTRIBUTION OF HUMAN USE INDICES ON THE NORTHERN CHUKCHI SEA COAST

Region	Level of Concern Primary (%)	Secondary (%)	Tertiary (%)
Northern (Maps 1-32)	3.4	1.5	27.6
Central (Maps 33-58)	1.6	5.6	37.5
Southern (Maps 59-84)	1.6	3.4	17.4
Total*	6.5	10.5	83.0

* Total coastline length 1523 km

Table 6.2. DISTRIBUTION OF HUMAN USE INDICES ON THE NORTHERN CHUKCHI SEA COAST AS A FUNCTION OF EXPOSURE

	Level of Concern					
	Primary (%)		Secondary (%)		Tertiary (%)	
Region	Open Coast	Lagoon	Open Coast	Lagoon	Open Coast	Lagoon
Northern (Maps 1-32)	2.4	1.0	1.0	0.5	10.2	17.4
Central (Maps 33-58)	1.3	0.3	2.0	3.6	10.0	27.5
Southern (Maps 59-84)	1.6	0	3.4	0	11.6	6.3
Total*	5.4	1.4	6.4	4.1	31.8	51.2

* Total coastline length 1523 km
Lagoon coastline length 864 km
Open Coast coastline length 659 km

related to subsistence access and subsistence hunting and fishing. However, the reader should note that the HUI secondary level of concern shown in the open water areas on the maps covering Peard Bay, Kugrua Bay (Maps 11-19), Wainwright Lagoon (Maps 23-30), Kasegaluk Lagoon-Avak Inlet (Maps 33-54) and Marryatt Inlet (Map 79) is not included in the data presented in Tables 6.1 or 6.2.

The remaining 83 percent of the shoreline is classified as tertiary or low level of concern (Table 6.1). This reflects the sparse population, the small number of communities present in a long (1523 km) coastline, and the difficulty of travelling long distances from these communities on a regular basis.

6.6 SUMMARY

The oil spill impacts on the human uses of the Chukchi Sea coastline during the open water season are likely to be high in only about 7 percent of the area. Most of these areas are along the open coast where oil residence is typically low (Table 4.9). The major human uses in these areas classified primary concern are villages, access to nearby subsistence areas, and some subsistence fishing or hunting, especially for waterfowl. Depending upon the circumstances of the spill, the oil residence may be very short and the level of concern may be less than predicted.

Oil residence is typically higher on the lagoon shorelines (Table 4.9), but the human uses of most of the lagoon shores is typically less important (Table 6.2) except in the immediate vicinity of villages and a few of the major passes.

7.0
OIL SPILL COUNTERMEASURES

7.1 INTRODUCTION

The primary objectives of this study are to identify (a) what coastal resources are sensitive to an offshore oil spill, (b) where they are located and (c) when they are sensitive. This study does not evaluate the risk that oil spill will occur and the probability that the sensitive resources will be oiled. In addition to the vulnerability and sensitivity analyses described in previous chapters, a complete risk analysis would also require assessment of: (a) the probability of an offshore oil spill occurring, (b) the probability that oil would be transported to the shore, (c) the probability that oil would reach sensitive environments and/or the probability that the resource would be present, and (d) the effectiveness of oil spill countermeasures.

This section provides an overview of oil spill risks and impacts and a review of potential spill countermeasures for the various shoreline types along the Chukchi Sea coastline.

7.2 OVERVIEW OF OIL SPILL IMPACTS

An indication of the potential for spilled oil to reach sensitive environments, most of which are located behind barrier beaches, can be estimated by evaluating the storm surge elevations along the Chukchi Sea coast.

Storm surge measurements indicate that the upper storm surge elevations are almost all two meters or more above high tide (Figure 4.17) even though the normal astronomical tidal range is less than 20 cm. Observations of surges along the coast indicate that these surges are associated with strong westerly or southwesterly wind events which drive an onshore transport (Wiseman et al., 1973). Coastal currents are primarily to the north during these wind events. Our field observations suggest that storm surges are greatest in the northern and eastern portions of the lagoons during these wind conditions.

Given the fact that storm surges occur in association with net onshore (westward) transport, there appears to be a strong potential for oiling of the shoreline to occur concurrently with a storm surge event. Furthermore, potential for oiling of the biologically sensitive environments such as wetlands, which are primarily confined to the lagoons, would be greater in the north and eastern portions of lagoons. Many of the wetlands, which are the most sensitive resource in terms of impact potential, occur approximately 1 m above mean water level and would require a 1 m plus surge event to be oiled.

Further observations of Kasegaluk Lagoon during a storm surge event suggest that water inflow during storms is primarily through southern inlets whereas outflow is through northern inlets (Wiseman et al., 1973). These observations suggest that oil would have to enter through the southern inlets of Kasegaluk Lagoon to reach the sensitive wetland areas around Icy Cape or at the northern end of the lagoon.

Major storms which may cause storm surge events during the open water season are relatively rare. Wind data from the Chukchi Sea - Beaufort Sea Climatological Atlas (Brower, et al 1977) indicate that winds in excess of 34 knots occur less than 1 percent of the time between January and October and 1 to 3 percent of the time in November.

Therefore, in the unlikely event of a major oil spill (>1,000 barrels), there is a strong possibility that oil would not reach the coastline and even a stronger possibility that oil would not reach the sensitive environments, even without mitigation.

7.3 SEASONAL INFLUENCE ON OIL SPILL COUNTERMEASURES

When an offshore oil spill threatens to contaminate a nearby shoreline, a typical sequence of response actions is:

- containment of oil at the spill site using booms and cleanup of contained and uncontained oil using skimmers and/or dispersents,
- protection of sensitive shoreline area using booms, berms, dikes etc.,
- cleanup of contaminated shorelines,
- disposal of recovered oil and of the oily debris and sediment mixture,
- restoration of disturbed shoreline areas.

The three seasons in the Chukchi sea would have a major influence on this sequence. In the winter sea ice season, the sea is covered by ice floes and the shoreline is covered with land-fast ice. In the transitional season sea ice and land-fast ice is breaking up (Spring) or forming (Fall). In the open water season (summer), little or no sea ice is present. The typical response sequence listed above would only occur during the open water season.

In the winter sea ice season, an offshore oil spill, especially from blowout, would initially tend to spread out under the ice sheet with some oil concentrating in ice fissures, and the remainder pooling in depressions under the ice. Response actions under winter sea ice conditions would usually be limited to recovery via pumping of oil from fissures and holes cut into oil pools under the ice.

In the transitional season, an oil spill from a blowout would be even more difficult to deal with because of the dynamic nature of ice movement. Spilled oil will tend to concentrate in open leads in the ice, and the use of conventional booms and skimmers to control and cleanup oil would be limited to large open leads where oil has collected. In situ burning of thick slicks in open leads may also be effective. Dispersants also may be useful on oil slicks depending upon the nature of the oil.

If a major oil spill occurs during winter sea ice or transitional seasons, the majority of the spilled oil would probably remain under the surrounding ice and would have to be cleaned up during the following open water season. Therefore, the following sections discuss the effectiveness of cleanup and protection techniques in the open-water season of the Chukchi Sea.

7.4 OPEN WATER CONTAINMENT AND CLEANUP

In the event of an oil spill from an offshore source in the Chukchi Sea, the initial response would involve deployment of booms and a skimmer to contain the spill at its source and to initiate cleanup. Additional response actions would involve transportation to the site and deployment of spill containment and cleanup equipment from the industry cooperative Alaska Clean Seas. It may be practical to disperse the oil slick using vessel or aircraft dispersant spraying techniques. The effectiveness of these response actions to contain and cleanup oil on the open sea depends on the volume of oil spilled, prevailing weather conditions, proximity of the shoreline to the spill, proximity of sensitive biological or human use resources, and the time required to mobilize, transport and deploy oil spill equipment at the spill site. If a major spill occurs during adverse weather conditions and onshore winds, it is probable that the spill would contaminate nearby shorelines before the oil could be contained or dispersed.

7.5 SHORELINE PROTECTION

7.5.1 Methods

The protection of sensitive shoreline areas along the Chukchi Sea would primarily involve exclusion booming or blocking of lagoon inlets and estuaries, and dispersing of oil slicks in the vicinity of sea bird colonies. Almost fifty percent of the Chukchi sea shoreline is comprised of barrier islands backed by shallow lagoons. The lagoons can be protected from oil contamination by placing exclusion booms across the lagoon entrances. The effectiveness of this technique is primarily dependent on access to the lagoon entrances and the time required to deploy booms across the entrances.

Rapid access to the lagoon entrances and quick deployment of exclusion booms could be accomplished using helicopters for both boom transport and placement. Protection of sea bird colonies from oil slicks could be achieved by chemically dispersing a threatening oil slick before it reached the vicinity of the colony. The use of chemicals to disperse a slick on open water will also serve to protect a shoreline from oil contamination although most of the shorelines in the vicinity of bird colonies have low oil persistence levels. Tests in the BIOS experiment have shown that dispersal of an oil slick with chemical dispersents did not significantly contaminant an adjacent shoreline while an untreated oil slick heavily contaminated the shoreline (Owens et al. 1982).

7.5.2 Open Water Season

An extensive section of the northern Chukchi Sea coast has lengthy estimated oil residence periods (62% of the coastline is a primary or secondary concern oil residence index). During a spill event, this large area would receive a high priority in terms of protection. Most of the high sensitivity shoreline is located inside the major lagoon systems of the coast, and there is a strong potential for protection of these sensitive resources. Exclusion booming or diversion booming of tidal inlets during the open-water season could prevent oil from reaching the lagoon shorelines. Table 7-1 provides a summary of tidal pass widths and lagoon shoreline length of major lagoon systems. The data indicate that with a minimal amount of booming, or in some cases diking, oil could be excluded from most of the lagoon systems during the open-water season. Only the entrance to Peard Bay would be difficult to boom because of its width. Diversion booming, however, would be effective in reducing oil contamination to Kugrua Bay. Therefore, 77% (732 km) of the Chukchi Sea shoreline rated either primary or secondary concern in terms of oil residence time could be protected by exclusion or diversion booming or diking of the inlets.

Since it is unlikely that an oil spill would impact the entire coastline simultaneously, only a small number of inlets would have to be blocked to prevent oil reaching the lagoon shores. The significant point is that it is possible to prevent oil from reaching a significant proportion of the "sensitive" shorelines in the northern Chukchi Sea area during the open water season.

7.5.3 Transition Season

The effectiveness of booming operations during broken ice seasons (break-up and freeze-up) may be reduced, due to the presence of moving ice pieces which could damage booms. However, during break up periods there is a net flow of water seaward through most inlets due to river runoff. This outward flow which would keep oil from entering the inlets negating the need for booms. Where landward directed flows do occur, much of the sea ice grounds on ebb-tidal deltas seaward of the inlets forming a fairly effective natural barrier to oil intrusion.

7.5.4 Winter Season

Oil transport into the lagoons could occur during the winter but is considered unlikely. Oil exploration programs are likely to be distant

Table 7-1. RELATIONSHIP OF LAGOON SHORELINE LENGTH AND TIDAL PASS WIDTHS

Lagoon System	Shoreline Length (km)	Tidal Pass Width (km)	Number of Tidal Passes
Peard Bay/Kugrua Bay	115	8.4	2
Kuk River	160	0.3	1
Kasegaluk Lagoon	481	5.8	13
Marryatt Inlet	94	0.2	1
TOTAL	850	14.7	17

from the coast and in the event of an oil spill under ice, oil would not be transported as far as during the open-water season. Also spill movement is most likely to move alongshore rather than towards the shore.

Additionally, most of the lagoons are shallow and shorefast ice, frozen almost to the bottom in many of the passes, would tend to keep oil from entering the lagoons.

7.6 SHORELINE CLEANUP FACTORS

Factors influencing the methods used for cleaning oil contaminated shorelines are:

- Type of shoreline substrate (i.e. sand, gravel, rock platform etc.,)
- Degree of shoreline oil contamination (i.e. light or heavy),
- Availability of access to the shoreline,
- Availability of cleanup equipment and manpower,
- Impacts of shoreline cleanup techniques, and
- Options available for disposal of oil-contaminated material.

These factors all have to be considered in order to select the proper cleanup technique for an oil contaminated shoreline.

7.7 SHORELINE CLEANUP TECHNIQUES

Cleanup techniques applicable to the shorelines of the Chukchi sea can be classified into six categories:

- Manual cleanup

- Heavy equipment cleanup
- Light equipment cleanup
- Chemical cleanup
- Insitu burning
- Natural Processes.

Logistical support associated with each technique are summarized in Table 7-2. Each technique is described briefly below.

7.7.1 Manual Cleanup

Manual cleanup includes removal of oiled sediments using shovels and rakes, manual cutting of oiled vegetation and manual application and removal of sorbents. The use of manual cleanup techniques is usually limited to areas of light oil contamination or small areas of heavy oil contamination. The major limitation of manual cleanup is the availability of adequate manpower especially in remote areas such as the Chukchi Sea Coast. Manual cleanup can be effective on all types of shorelines but is time consuming and requires a major logistal effort (housing, food, etc.) to support the large work crews in the field.

7.7.2 Heavy Equipment Cleanup

Earthmoving equipment is used to either remove oil sediments or to disc or rototill oiled sediments beneath the beach surface. The use of earthmoving equipment to cleanup oil contaminated sediment beaches can be very effective. The major limitations to the use of heavy equipment are (a) accessability by land or water, (b) availability of heavy equipment, and (c) the trafficability of the shoreline (trafficability refers to whether equipment can operate on a beach without getting stuck). Additionally, if heavy equipment is used to remove sediment from a shoreline rather than to disc contaminated material below the beach surface, then proper disposal of the oiled sediments will be required.

Table 7-2. APPLICABILITY OF CLEANUP TECHNIQUES

	Access Requirements	Equipment Requirements	Manpower Requirements	Disposal Requirements	Degree of Oil Contamination
Manual Cleanup	Road, vessel, air, or foot	Small hand tools(shovels, rakes, etc.), cutting tools, sorbents	Large crews and logistic support organization	Portable incineration or small landfill site	Light or small areas of heavy contamination
Heavy Equipment Cleanup	Road or vessel	Earthmoving equipment	Several trained equipment operators	Large landfill site	Heavy contamination
Light Equipment Cleanup	Road, vessel or air	Pumps, hoses, hydroblasters small booms, and skimmers; storage equipment	Small crews; 2-3 men per cleanup site	Portable incineration	Light to heavy contamination
Chemical Cleanup	Road, vessel or air	Spray equipped planes, truck equipped sprayers or backpack sprayers	5-10 persons	None	Light to heavy contamination
Insitu Burning	Road, vessel, Air, or foot	Propane weed burners	3-5 persons	None	Heavy contamination
Natural Cleanup	None	None	None	None	Light to heavy contamination

7.7.3 Light Equipment Cleanup

This includes the use of pumps and hoses for low pressure flushing, and hydroblast equipment for high pressure water cleaning. The use of low pressure water flushing on vegetated shorelines and on rock is effective if the oil is not highly viscous and weathered. High pressure water blasting equipment should only be used on rock substrates, where it is effective in removing oil but is time consuming. Both these cleanup techniques require the use of small booms and skimmers or sorbents to contain and collect the oil flushed from vegetation or rock surfaces.

7.7.4 Chemical Cleanup

Dispersants may be applied manually, by vehicle or by aircraft on an oil contaminated shoreline. The use of dispersants on oiled shorelines (sediment or rock) can be very effective for both light and heavy oil contamination if sufficient wave energy is present to mix the dispersants and oil. This technique would be particularly effective in remote areas with limited access as dispersants could be applied to shoreline using aircraft. The major concern of dispersant use is the direct impact on the nearshore benthic community and the indirect impact on fish, birds, and mammals.

7.7.5 In-situ Burning

In-situ burning, the ignition and combustion of oil in place, should be used only on heavily oil-contaminated, vegetation-covered shorelines, where oil has already caused damage to the plants. If the oil has not weathered severely, this technique can be effective. The major limitation is the potential long-term damage to the plant communities, however, if the burning is conducted when sufficient water is present to cover the plant root systems, long-term damage may be minimized.

7.7.6 Natural Cleaning

Leaving oil in place and allowing natural degradation to remove the oil can be effective in both light and heavy contamination cases if the shoreline is exposed to mechanical wave action (i.e. open coast) or if erosion is a major physical process. Natural cleaning would probably be ineffective on most of the low energy shorelines such as those found inside lagoons along the Chukchi coast. The major limitation to this technique is that even on high energy shorelines, natural cleaning may require weeks to several months to remove most of the contamination. If the human or animal usage of the shoreline is high, the time required for natural recovery may be unacceptable.

7.8 EFFECTIVENESS OF CLEANUP TECHNIQUES ON THE SHORE ZONE

Not all of the various cleanup techniques (Table 7.2) are appropriate in all cases for treatment of shorelines in the study area due to the uniquely arctic nature of many of the coastal landforms. Appropriate cleanup techniques for the various shore-zone types that occur on the northern Chukchi-Sea coast are summarized in Table 7.3 and are discussed below.

7.8.1 Rock Cliffs

The high wave exposure that occurs along the rocky sections of the northern Chukchi coast would result in relatively rapid removal of stranded oil, making the natural cleaning the preferred cleanup alternative. Light equipment cleanup with high and low pressure water flushing could be used locally to remove high concentrations of oil. Chemical treatment could also be used, however, the effectiveness of natural cleaning and the uncertain biological effects of the dispersant use make this the least preferred clean-up technique.

7.8.2 Tundra Cliffs

The erosional nature of tundra cliffs make natural cleaning the preferred technique for treating most tundra cliff shorelines. High concentrations of stranded oil could occur locally in the gravel and gravelly sand beaches fronting tundra cliffs, but the high cliff retreat rate would result in rapid removal of oil from the sediments as the beach retreats with the cliffs. In general, beaches fronting tundra cliffs are

Table 7-3. SHORELINE CLEANUP METHODS APPLICABLE TO THE CHUKCHI SEA COAST.

Shore Zone Type	Manual Cleanup	Heavy Equipment Cleanup	Light Equipment Cleanup	Chemical Cleanup	Insitu Burning	Natural Cleaning
Rock Cliffs	+	-	+	+	-	✓
Tundra Cliffs	+	-	+	+	-	✓
Sediment Beaches	+	✓	+	+	-	✓
Barrier Islands w/o vegetatation	+	+	+	+	-	✓
Barrier Islands w/o vegetation	+	+	+	+	+	✓
Wetlands	+	X	+	X	+	+
Delta Fronts	+	+	+	+	-	✓

✓ Recommended
+ Applicable and Possibly Useful
X Not Recommended
- Not Applicable

too narrow for use of heavy equipment. However, in the Barrow area, the greater availability of equipment and wider beaches would allow surface oil concentrations to be scraped by heavy equipment into the surf zone where natural cleaning by wave action would be more effective. Manual cleanup may be useful where high concentrations of oil occur or where rapid oil removal is desirable (e.g., in areas used for recreation or subsistence access areas around major villages).

7.8.3 Barrier Islands Without Vegetation

Much of the barrier island coastline is exposed to comparatively high levels of wave exposure and therefore natural clearing would be most appropriate. If areas above the normal high water line are oiled, additional cleanup may be required using heavy equipment or manual techniques. Access to the islands and disposal of contaminated material pose potential logistical problems. One means of alleviating disposal problems is to push contaminated material into the surf zone where mechanical wave action could disperse the oil naturally.

7.8.4 Barrier Islands With Vegetation

Techniques appropriate to unvegetated barrier islands may also be used on vegetated barrier islands, although additional care must be used to prevent damage to the vegetation. Vegetation damage is most likely to occur with use of heavy equipment. In situ burning would be of limited usefulness in most dune-like vegetation because of the low vegetation density.

7.8.5 Wetlands

Wetland areas of the Chukchi Sea coast occur in protected lagoons and therefore have potentially lengthy oil residence periods. Cleanup in marsh areas is traditionally difficult, even with manual labor, as extensive foot traffic can severely damage a wetland. If oil reaches the wetland areas of the Chukchi coast, low pressure flushing is potentially the most useful cleaning technique, however, even with this technique vegetation damage may be a problem.

7.8.6 Delta Fronts

A number of river deltas occur in the lagoons of the Chukchi coast and consist of sand/mud flats backed by vegetated flats. Natural cleaning of the sand/mud flats may occur quickly even in areas of low wave energy as a result of poor oil-to-sediment adhesion. Oil is likely to concentrate at the high water line along the delta fronts and could be cleaned using manual techniques or heavy equipment, although because of poor access to these areas, and low bearing strength of some of the sediment, aerial deployment of light-weight equipment may be required. Low vegetation densities in the upper shore zone would probably reduce effectivity of in situ burning.

7.9 DISPOSAL OF CONTAMINATED MATERIALS

The two primary options for disposal of oil-contaminated materials are:

- Burial of oil-contaminated material in a landfill or in the backshore of the contaminated beach, or

- Burning oil-contaminated material in an incinerator or in place.

There are limitations and problems associated with each of the disposal options. Burial of contaminated material in a landfill would involve special construction of a landfill site to isolate the oil-contaminated material from leaking and causing thermoklast (melting and erosion of permafrost). It would also require a means of transporting the contaminated material from the shoreline to the landfill site, which is usually accomplished by trucks for any significant amount of contaminated material. Burial of oil-contaminated material in the backshore of beach is easier to accomplish, however, normal beach erosion may uncover the oil at a later date and leaking of oil from the buried sediments to the beach groundwater system could occur.

Burning of oil-contaminated material in an incinerator is technically feasible but is severely limited by the throughput of most portable incinerators, which is in the range of approximately 1 ton/hr. In-situ burning of oil contaminated shorelines is effective only for oil contaminated vegetation and is not feasible for oil contaminated sediments (Owens et al. 1982).

7.10 SUMMARY

Oil is most likely to enter the lagoons and affect wetlands or other sensitive habitats on the positive storm surges caused by the relatively rare major storms in the ice-free season.

Most of the effective oil spill countermeasures will be limited to the open water season. During the winter, most of the spilled oil would remain offshore under the ice. Though open water containment and cleanup countermeasures may be practical from a technological standpoint, there may not be enough time to mobilize, transport and deploy the personnel and equipment to the spill site before the oil reaches the shoreline. Therefore, we focussed on shoreline protection methods.

Shoreline cleanup techniques that could be employed during the open water season include use of manual labor, light or heavy equipment, chemicals, in situ burning and natural processes. Each has its advantages and limitations, depending upon the shore-zone type. However, in many if not most cases, letting natural processes "clean up" the shorelines may be the most environmentally, if not socially or politically, effective and acceptable method.

8.0

SUMMARY

Minerals Management Service (MMS) requires information on possible environmental impacts and mitigation of offshore oil and gas leasing actions in order to resolve multiple-use conflicts and make other resource management decisions. Specific needs include (a) characterization of the physical, biological, and human use resources of the shore zone that influence the effect of or are affected by oil spills, (b) evaluation of the sensitivity of these resources to an oil spill, and (c) description of oil spill protection or cleanup countermeasures.

In this 3-part report, we provide this information for the northern Chukchi Sea coastline between Pt. Barrow and Cape Thomson (Figure 1-1), a distance of about 675 km (420 miles). The actual shoreline length is about 1523 km (945 mi), comprised of about 864 km (536 mi) of protected lagoons, bay, deltas, and estuaries and about 659 km (409 mi) of exposed open coast (i.e., wind fetch distances are > 10 km). The resource description and oil spill sensitivity analyses covered the zone between the lower low water level and the higher storm surge elevations as defined by the prominent log debris line (> 2.0 m above normal water levels) (Table 4-7, Figures 4-16 and 4-17).

The physical resources, based on geomorphology, are considered in terms of three major sections of coastline:

(1) The northern Chukchi Sea coast (Maps 1-32), which lies between Pt. Barrow and Kasegaluk Lagoon and consists primarily of tundra cliffs with two major embayment-type lagoons (Peard Bay and the Kuk River Inlet)

(2) The Kasegaluk Lagoon coast (Maps 33-58), which consists of 200 km (approximately 110 n mi) of barrier island coastline in the central portion of the study area, including an extensive barrier island lagoon system with almost 500 km (approximately 275 n mi) of shoreline

(3) The Cape Beaufort-Cape Lisburne - Point Hope coast (Maps 59-84), which lies to the south of Kasegaluk Lagoon and includes a wide variety of shoreline types from rock cliffs to protected lagoons

The northern Chukchi Sea coast is principally comprised of eroding tundra cliffs, cut into unconsolidated Quaternary deposits (Table 4-6). In a few locations Cretaceous sandstone bedrock and coal seams crop out in the cliffs. Barrier island and spit systems, consisting of gravelly sand material and mostly without vegetation, occur at Point Barrow and at Peard Bay. Two major embayment systems, Peard and Kugrua bays and the Kuk River Inlet, occur within this coastline section and comprise a substantial segment of coastline (286 km). Shorelines of these embayments are comprised primarily of rapidly retreating low tundra cliffs, interspersed with small gravel spits (Table 4-6). Small river systems have formed deltas at the mouth of both the Kugrua and Kuk rivers.

The central Kasegaluk Lagoon coast consists of a long (200 km), narrow barrier island lagoon system with over 475 km of lagoon shoreline (Table 4-6). Low, gravelly sand, barrier islands lie along the seaward side of the lagoon. Vegetation occurs sporadically on the barrier islands to the north of the Icy Cape, suggesting that these barriers are frequently overtopped during storm surges and are, therefore, more dynamic than those to the south. Vegetation becomes increasingly common on the barrier islands to the south of Icy Cape, suggesting greater stability; on many sections of the barriers, vegetation colonization is particularly noticeable on old recurve spits formed by northward tidal pass migration.

The lagoon section of this coast includes a variety of coastal landforms, the most common of which is the ubiquitous low tundra cliff (Table 4-6). Gravelly sand beaches (on the lagoonal side of the barrier islands), wetlands, mudflats, and delta flats are also comparatively common features of this coastline. Wetlands occur along the lagoonal shores of the barrier islands, particularly in southern Kasegaluk Lagoon and in association with the three major river deltas on the mainland shore.

The southernmost section of the study area, to the south of Kasegaluk Lagoon, includes a wide variety of coastal landforms, the most prominent of which is the resistant bedrock cliffs at Cape Lisburne (Table 4-6). Rock cliffs occur to the east and south of Cape Lisburne, as well as at Cape Thompson, and comprise approximately 70 km of shoreline. Tundra cliffs are not uncommon, however, particularly between Cape Sabine and Kasegaluk Lagoon, comprising an additional 89 km of coast (Table 4-6). Barrier islands, both with and without vegetation, are extensive on the Point Hope cape-system and occur locally in association with small lagoons east of Cape Lisburne. Lagoon coasts occur primarily within the Point Hope cuspate foreland and consist of low tundra cliffs and gravelly sand beaches along the barrier islands.

The biological resources can be classified in two non-mutually exclusive categories--habitats and species. The principal habitat types are coastal estuaries and lagoons, wetlands, sand beaches, and rock cliffs. In summer and fall, the important physical habitat factors include (1) the required presence of coastal cliffs and barrier islands for certain nesting and feeding birds, (2) the presence of salt marshes and mud flats for feeding brant and some shorebirds, (3) the presence of warm, semi-enclosed lagoon and bay waters for anadromous fishes, (4) the complexity of mainland and island shorelines in relation to foraging beach birds, and (5) the proximity to coastal sites of natal streams of anadromous fishes (Table 2-3).

Though a large number of species or groups of species occur in the nearshore and shoreline habitats of the study area, a limited number of birds, marine mammals, and anadromous fish are considered important by the native groups, public, or decision makers because the species are protected by regulations or are subsistence species. An even smaller number are included in the biological sensitivity analysis and include primarily nesting waterfowl, gulls and terns, and seabird colonies. These are "real-estate oriented" species' activities which could be threatened and protected in oil spill *a priori* planning.

Human resources, defined as resources (i.e., property, public facilities, subsistence resources, cultural resources), and shoreline uses (transportation, fishing sites, boat storage) are a major concern during an accidental oil spill event. Along with sensitive biological resources and shoreline types, human resources strongly influence priorities for spill countermeasures.

The study area is located within the boundaries of the North Slope Borough. Through its coastal management and comprehensive planning programs, the Borough has expressed concern about potential oil spill impacts on subsistence resources and activities. Four predominantly Inupiat Eskimo communities are located along the Chukchi Sea Coast: Barrow, Wainwright, Point Lay, and Point Hope. Human use patterns of the coastline can be identified with individual communities, although the patterns also reflect traditional uses that preceded the formation of permanent communities. Activities are intense in the immediate vicinity of each village, and include subsistence hunting and gathering, transportation (boat traffic and storage on the beach, airstrips with daily scheduled traffic) and excursions to traditional use sites. However, local residents travel extensively outside their communities to harvest subsistence resources, so village use areas extend tens of miles from the permanent communities.

Other human resources are less identifiable with individual communities. Because of its long history of human habitation, the Chukchi Sea coast is rich in cultural resources. This includes prehistoric, historic, and traditional land use sites. The general frequency of cultural resources sites is high, and density increases in areas where the distribution of subsistence resources is concentrated. Favorable topography, water supply, and other factors have contributed to human habitation of specific sites over time. Distant Early Warning (DEW) Line sites also constitute a human resource; several are located in the study area. Active sites generate air traffic in support of their mission; inactive sites are often used to support research or resource exploration teams and can be used during emergencies.

To provide resource managers, decisionmakers, and planners with a logical basis for determining oil spill countermeasure priorities, the sensitivity evaluations must be general because of the regional nature of the study, yet be presented clearly and in enough detail to be useful for contingency planning. To accomplish this, we developed and applied a three-level index (primary, secondary, and tertiary level of concern) to show in map and table formats the (a) Oil Residence Index (ORI), (b) Biological Sensitivity Index (BSI) and (c) Human Use Sensitivity Index (HUI). The use of three levels of concern is relatively simple and useful for resource management or decision making. However, with three resource types, up to 27 combinations are possible, allowing contingency planners sufficient detail to develop priorities for oil spill contingency planning.

The Oil Residence Index indicates how long oil that reaches the shoreline might be expected to persist. This is important because short persistence on residence times may reduce the need for (or even the possibility of) shoreline protection on cleanup countermeasures, and short residence times may reduce impacts on biological or human use resources. Expected long residence times, however, may require some countermeasure actions.

Potential oil residence is determined by:

- Wave exposure
- Substrate type
- Sedimentation processes
- Oil type
- Spill volume
- Oil form at impact zone

Many of these parameters cannot be determined until the time of the spill, so any a priori index must be necessarily general. Wave exposure, substrate type, and sedimentation processes can be evaluated prior to a spill, however, and provide a basis for developing the oil residence index.

Based on a detailed inventory of coastal landforms along the Chukchi Sea and a review of oil persistence studies in other areas, approximately 30 percent of the northern Chukchi Sea coast is expected to have potentially lengthy oil residence periods (greater than one open-water season) (Table 4-8). Shore-zone types most susceptible to lengthy oil persistence are low-energy beaches, wetlands, and river deltas of the protected lagoon coast. An additional 32 percent is considered to have variable residence periods, which will depend significantly on environmental conditions at the time of the spill and on spill characteristics. Residence periods of oil in the shore zone may range from a few weeks to more than one open-water season. Shorelines included in this category are prograding recurve spits near barrier island inlets and eroding low tundra cliffs which occur along much of the mainland lagoon coast. The remaining 38 percent of the coast is considered to have comparatively short oil residence periods and under normal open-water conditions would probably be self-cleaned in a period of days to weeks by wave action. Experimental oil spill studies in the Canadian arctic have shown that exposed shoreline (fetch distances greater than 100 km) can be cleaned rapidly (a few days) despite heavy oiling levels.

Shorelines included within this category are rock cliff, eroding tundra shorelines along the exposed Beaufort Sea coast, and exposed barrier island shorelines.

The highest concentration of shoreline where oil persistence is likely to be high occurs in the central portion of the study area, where over approximately 500 km of the lagoon shoreline is comprised of extensive wetlands, river deltas, and low-energy beaches.

The Biological Sensitivity Index (BSI) is a guideline for identifying which sections of the shoreline may be considered sensitive to oil spills because of the biological resources potentially present. The BSI levels of concern are defined on the basis of (a) the potential population-level effect an oil spill could have upon a sensitive "target" population or biological resource and (b) the potential recovery time. The BSI levels of concern reflect the assessment of the vulnerability and biological sensitivity of the particular population or community of concern. Vulnerability is the likelihood that some portion of the biological resource will actively or passively come into contact with oil if the oil is in the same area as the resource. Vulnerability of a resource or likelihood of contact involves a qualitative judgment based on abundance, distribution, and behavior of the biological resource in the area and on the spill characteristics, as well as weather and oceanographic conditions. The low, moderate, and high levels of vulnerability reflect the increasing proportion of the population/community that could come into contact with oil and the potential increase in the portion of the population/community potentially lost. Sensitivity is the expected impact on and response of the biotic resource following contact with oil. Response is evaluated in terms of potential mortality or diminished reproductive capacity and of the resilience of the potentially affected population/community (i.e., how quickly it is likely to recover from the oil spill impacts).

Oil spill impacts in the open-water season are likely to be high for about 5 percent of the shoreline. Most of these areas are wetlands in Kasegaluk Lagoon or adjacent water bodies where the ORI is primary or secondary; i.e., any oil that gets to these biologically sensitive areas is likely to persist for several seasons. The other areas are waterfowl nesting areas or seabird colonies which are not directly vulnerable (although the nesting areas on barrier islands could be directly affected if the oil spill occurred during a significant positive storm surge that overwashed the island or spit).

Over 11 percent of the shoreline is classified as secondary concern, primarily on the basis of smaller wetlands and smaller bird nesting or seabird colonies. Any one of these areas may be as vulnerable or sensitive as those classified as primary level of concern, but on an individual basis they are considered less important to the success of the population.

That nearly 84 percent of the shoreline is classified tertiary level of concern supports the general notion that most of the northern Chukchi Sea coast is not particularly productive, especially when compared to the adjacent Beaufort and Bering seas (Truett 1984).

The Human Use Sensitivity Index (HUI) explicitly includes people's perceptions and importance values in the evaluation of sensitivity and thus to the level of concern applied to each coastal resource or area. The human use sensitivity evaluation is similar in many ways to the biological sensitivity evaluation because many of the human uses of the Chukchi Sea shoreline are directly or indirectly based on biological resources.

The sensitivity of human resources to an oil spill is a function of (a) spill characteristics, (b) vulnerability or risk that the resource will be impacted, and (c) the importance of the resource.

Development of the Human Use Sensitivity Index incorporates the following human use criteria:

- Frequency of human use and presence
- Relative distribution and abundance of the resource
- Proximity of the resource to communities
- Importance of the resource to local residents (cultural significance, contribution to diet)
- Characteristics of the oil spill (e.g., size, type of oil, location of spill, etc.)

While large areas associated with each village are utilized, certain areas are more important than others. "Importance" depends on proximity to the village(s), use or harvest levels, and uniqueness of the human resources. In areas close to communities or of importance to local residents, perceptions of potential impact may actually exceed real impact.

The HUI has been developed for the following human resources of the Chukchi Sea coastal environment: (a) residential (communities), (b) transportation, (c) recreation (special use), (d) subsistence, and (e) cultural resources. The first three resources are relatively fixed in location, and, once established, the levels of concern or sensitivity values for these uses (e.g., presence of a house) should not vary much over time or on a seasonal basis.

However, the location and harvest of subsistence resources and the importance of their contribution to the community varies significantly on a month-to-month basis and from year to year. This variation and limitations to available data require some subjectivity in developing sensitivity classifications. Cultural resources are also fixed at specific areas. However, the importance of the same resource in different areas can vary widely, and the specific location can influence sensitivity to spill persistence and cleanup activities.

The oil spill impacts on the human uses of the Chukchi Sea coastline during the open-water season are likely to be high in only about 7 percent of the area. Most of these areas are along the open coast where oil residence is typically low (Table 4-9). The major human uses in these areas classified primary concern are villages, access to nearby subsistence areas, and some subsistence fishing or hunting, especially for waterfowl. Depending upon the circumstances of the spill, the oil residence may be very short and the level of concern may be less than predicted.

Oil residence is typically higher on the lagoon shorelines (Table 4-9), but the human uses of most of the lagoon shores is typically less important (Table 6-2), except in the immediate vicinity of villages and a few of the major passes.

Oil is most likely to enter the lagoons and affect wetlands or other sensitive habitats on the positive storm surges caused by the relatively rare major storms in the ice-free season.

Most of the effective oil spill countermeasures will be limited to the open water season. During the winter, most of the spilled oil would remain offshore under the ice. Though open-water containment and cleanup countermeasures may be practical from a technological standpoint, there may not be enough time to mobilize, transport, and deploy the personnel and equipment to the spill site before the oil reaches the shoreline. Therefore, we focussed on shoreline protection methods.

Shoreline cleanup techniques that could be employed during the open-water season include use of manual labor, light or heavy equipment, chemicals, in situ burning, and natural processes. Each has its advantages and limitations, depending upon the shore-zone type. However, in many if not most cases, letting natural processes "clean up" the shorelines may be the most environmentally, if not socially or politically, effective and acceptable method.

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CHUKCHI SEA COASTAL STUDIES: COASTAL GEOMORPHOLOGY, ENVIRONMENTAL SENSITIVITY, AND PERSISTENCE OF SPILLED OIL

PART II. COASTAL RESOURCE INVENTORY AND SPILL SENSITIVITY INDEX MAPS

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

1.0

INTRODUCTION

This volume contains the 84 Chukchi Sea coastal resource maps with corresponding oil spill index maps that display the Oil Residence Indices (ORI), Biological Sensitivity Indices (BSI), and Human Use Indices (HUI). The coastal resource maps present the physical, biological, and human use resources of the shore zone in a simple format. The format is directly useable by managers and other decision-makers for the usual coastal zone planning activities as well as by the on-scene coordinator during oil spill training sessions or actual oil spill events. More detail on the type, seasonality, distribution, and abundance of the physical, biological, or human use resources is presented in the main text (Part I) or in the Coastal Resource Tables (Part III).

2.0

USE OF COASTAL RESOURCE MAPS

2.1 GENERAL

This section describes how to use the maps and the information displayed on the maps. It also provides a brief description of the mapping methods as a basis for interpreting the maps.

The coastal resource maps only include the shore-zone resources; that is, those resources normally found between the low water line to the prominent storm surge line, typically about 2 meters above normal water level. The exceptions are the human uses and some of the biological resources in the major passes through the barrier islands and the human uses of the major lagoon systems. The physical, biological and human use characteristics of the nearshore and offshore open water areas were explicitly not included in this study (though they may be affected by an oil spill and be equally or more important then the shore-zone ones).

2.2 USE OF MAPS

The volume is organized so that it can be laid on a flat surface and the user can fold out the last page, the Index to Maps. The user can then identify the map number(s) of interest and open the map section at the approximate resource/index map pair(s). The 84 map pairs are numbered beginning at Pt. Barrow in the north and ending at Cape Thompson in the south.

The user can open the Coastal Resource Legend foldout to the left and the Coastal Sensitivity Legend foldout to the right for easy reference. This eliminates having to flip back and forth between the map pairs and the legends to interpret the information on the maps. With the Index to Maps foldout also opened out, the user need only lift the Coastal Sensitivity Legend to use the Index to Maps.

2.3 MAPPING METHOD

The mapping methods are described in detail in Part I but are described briefly here to facilitate understanding of how the unit identifiers are obtained and how to use the Coastal Resource Maps. The unit identifiers on the Coastal Resource Maps correspond to the unit identifiers listed in the left-hand column of the Coastal Resource Tables (Part III).

The general shore-zone types as well as the location of important biological and human use resources were identified from existing information (topographic charts, maps, aerial photography, published literature, personal communication with other experts, and previous experience). Additional information required to map these characteristics in sufficient detail was obtained from low-level, oblique aerial videotape and photographic coverage of the entire study area. A limited ground-truth survey (Figure 2-1) was conducted to verify or correct aerial interpretations.

The mapping method defines a series of shoreline units that are physically homogeneous along a section of coast (Figure 2-2). These units or shore-zone types represent a set of shore-zone components that occur repeatedly in the same combination throughout the study area. The across-shore components are based on geomorphological and/or textural characteristics that are homogeneous both across-shore and alongshore. These physical shore-zone components are described in Section 2.4.

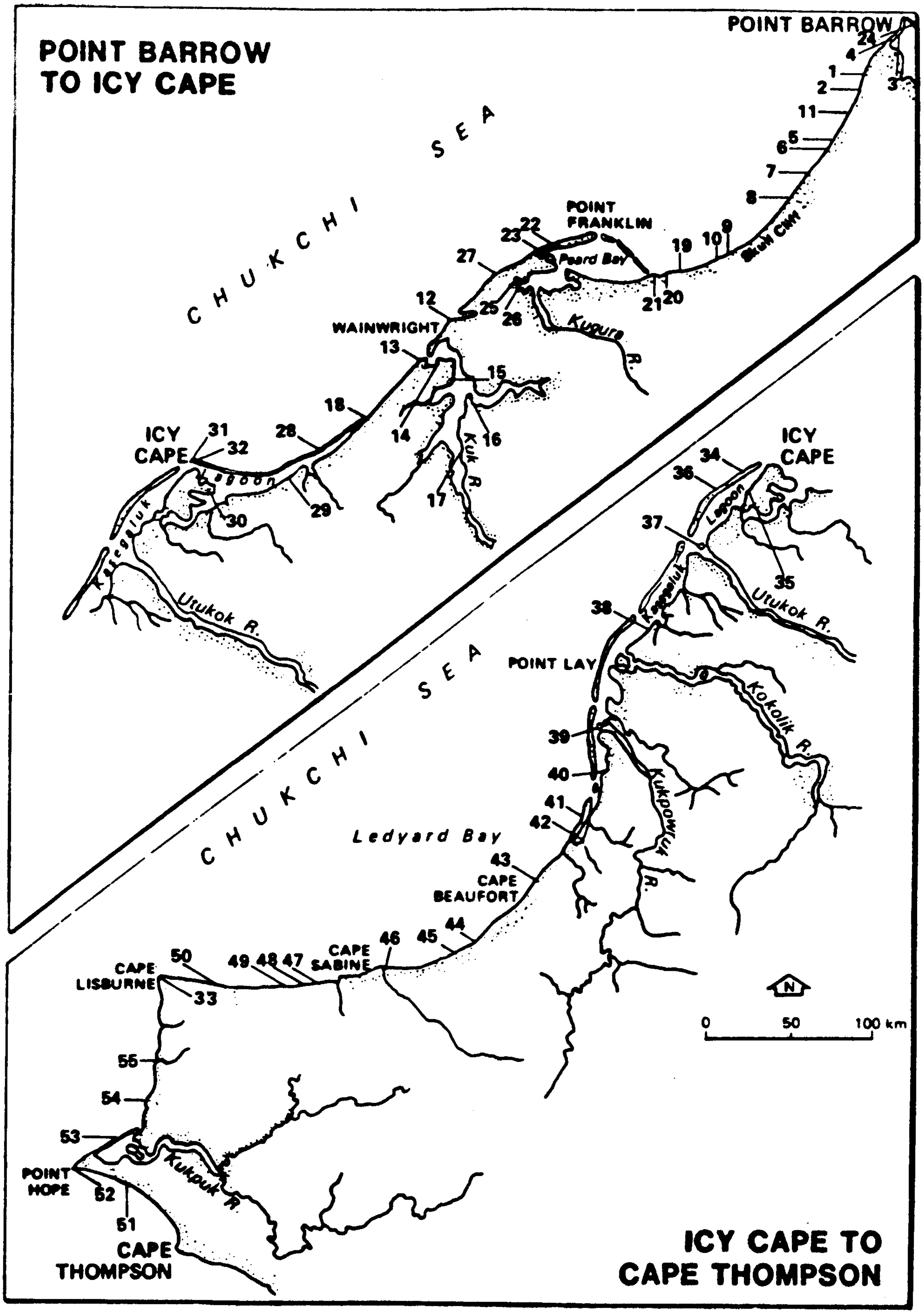

Figure 2-1. LOCATION OF GROUND TRUTH STATIONS

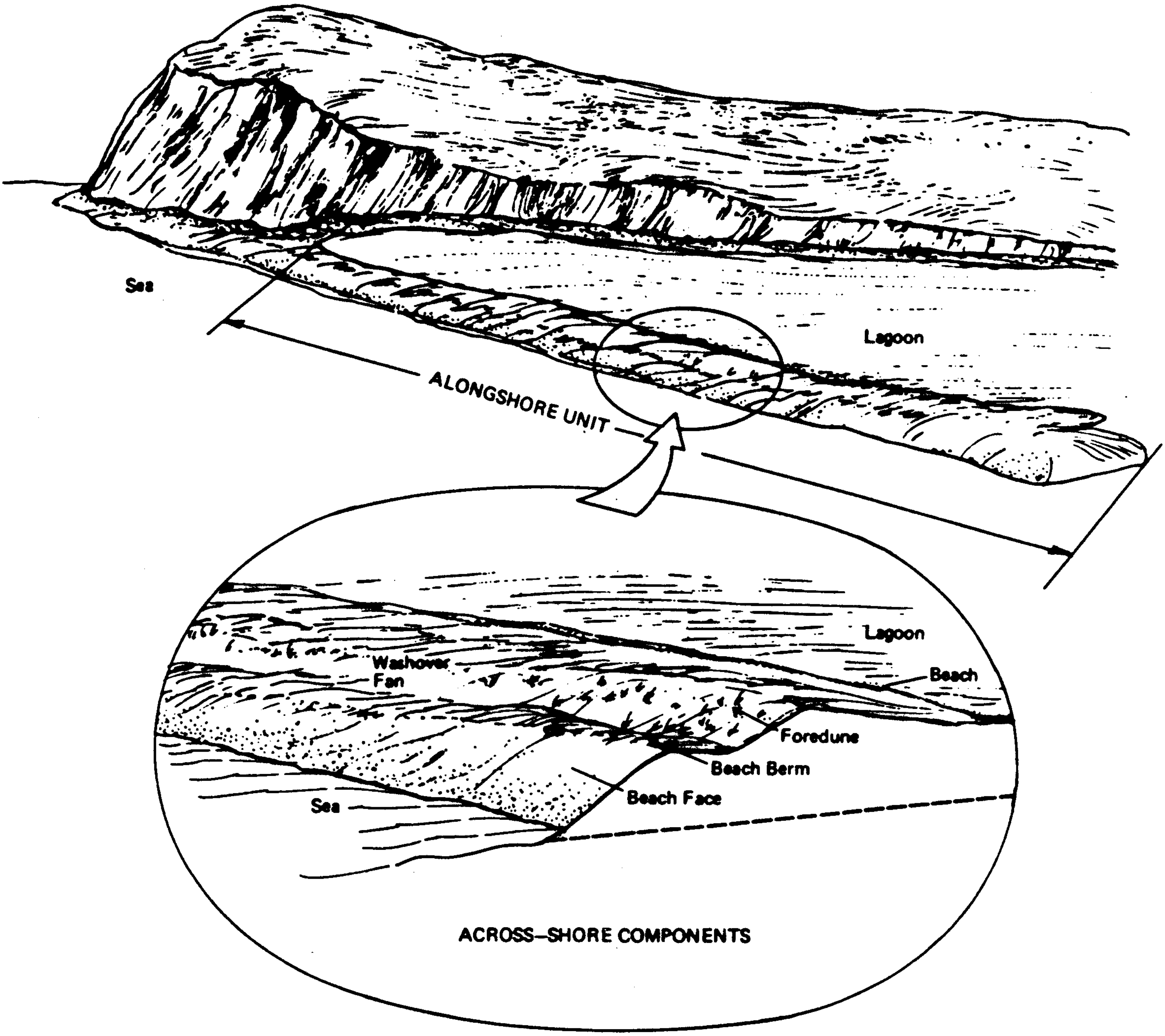

Figure 2-2. ILLUSTRATION OF THE MAPPING APPROACH

The map format identifies the boundaries of units longer than 0.25 km in two ways: (a) change in the distinct graphic pattern used for each shore-zone type (Figure 2-3) and (b) lines perpendicular to the shoreline at each end of the unit (Figure 2-4).

Each shore-zone unit on a map is uniquely identified for that map with a capital letter. Units identified by a letter followed by a superscript "prime" are located on the lagoon shoreline while letters without a "prime" are located on the open Chukchi Sea coast. Water bodies (e.g., lagoons, passes, bays, inlets) are identified by name. Where the same shore-zone type is present on both the lagoon and the Chukchi Sea sides of a barrier island or spit, the shore-zone is considered two separate units and each is given a unique unit identifier. The perpendicular line dividing them on the map is arbitrarily placed at the tip of the island or spit where maximum fetch and wave exposure changes.

The unit identifiers (i.e., the capital letters) are applied to the shore-zone units in a generally north to south direction. Where there are exposed or open as well as lagoon coasts, the unit identifiers are applied (a) first to the open coast side of the barrier island or spit, (b) next to the lagoon side of the barrier island or spit and (c) finally the mainland shore. Only one unit will be identified with a letter (which may be further modified with a "prime" sign) so ideally each letter would appear only once on each map. However, on some maps, it is easier to label the unit several times. Figure 2.4 illustrates the unit identifier labelling scheme.

Note that the unit identifiers are simply that. They uniquely identify the unit(s) on each map and in the tables. There is no explicit or implied relationship or similarity between units on different maps labelled with the same unit identifier. For example, the unit labelled D in Figure 2-4 is a sandy gravel beach while unit D on the adjacent map is a permanent inlet (Figure 2-5).

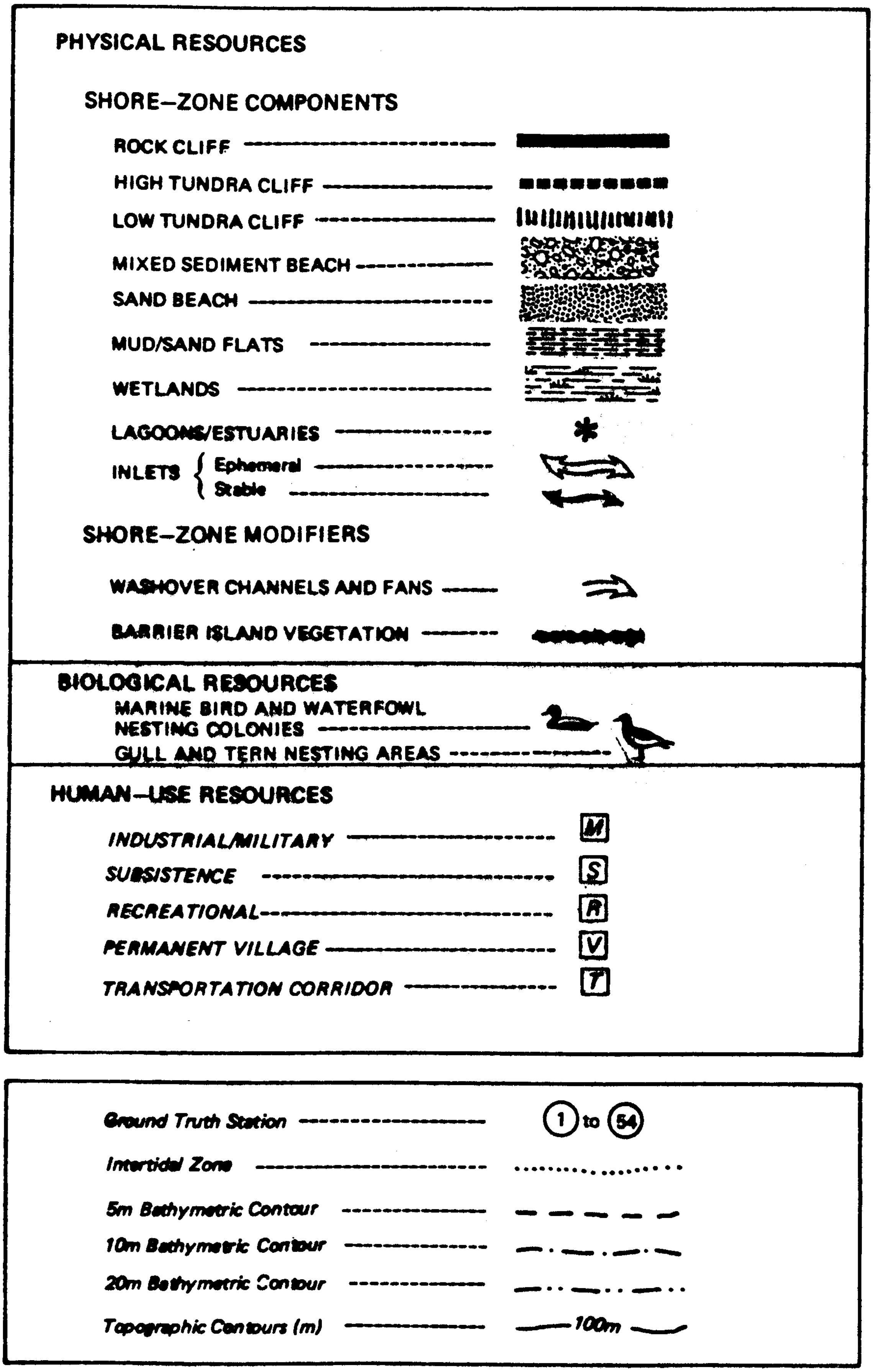

Figure 2-3. MAPPING PATTERNS USED FOR SHORE-ZONE COMPONENTS

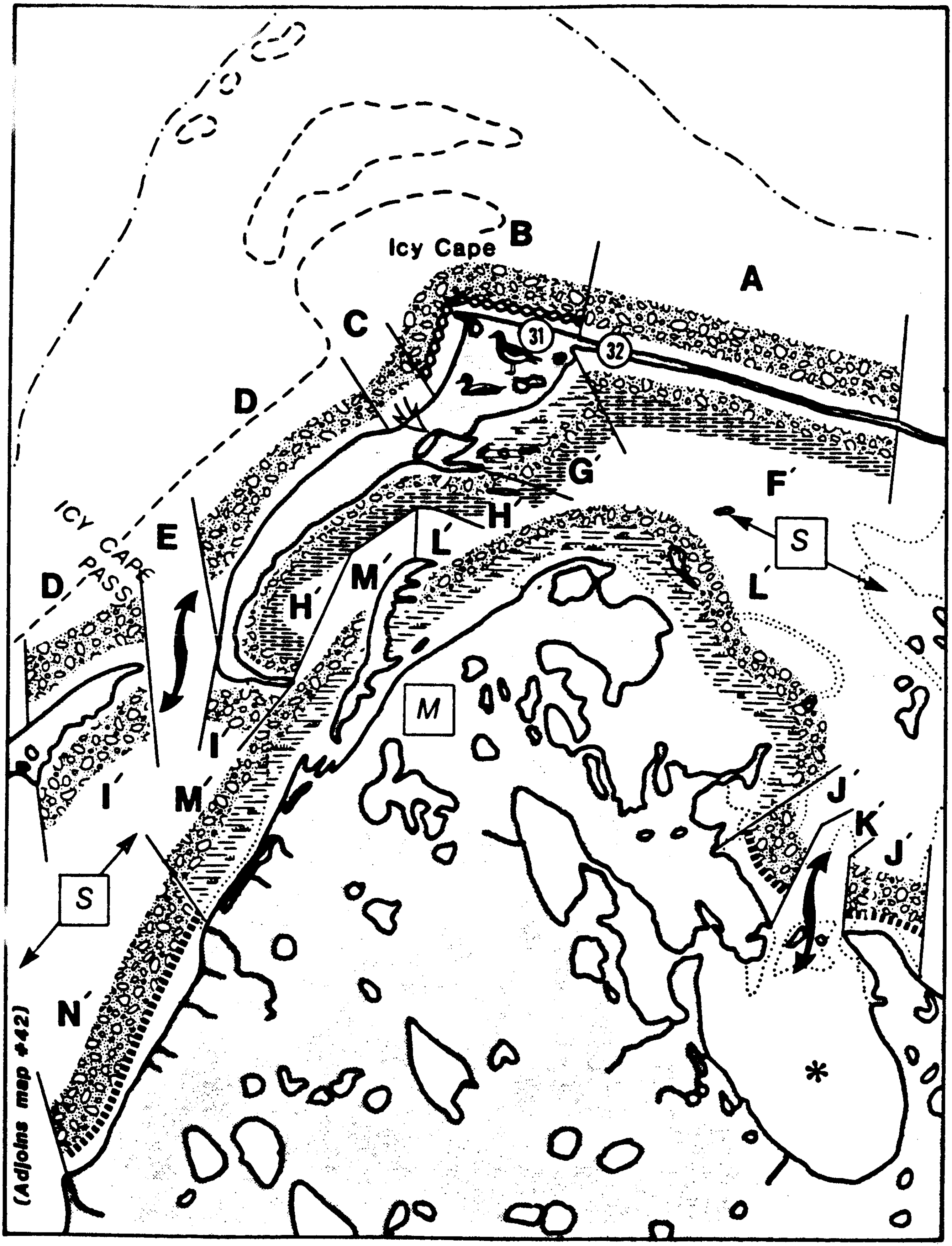

Figure 2-4. EXAMPLE OF COASTAL RESOURCE MAP FROM PART II

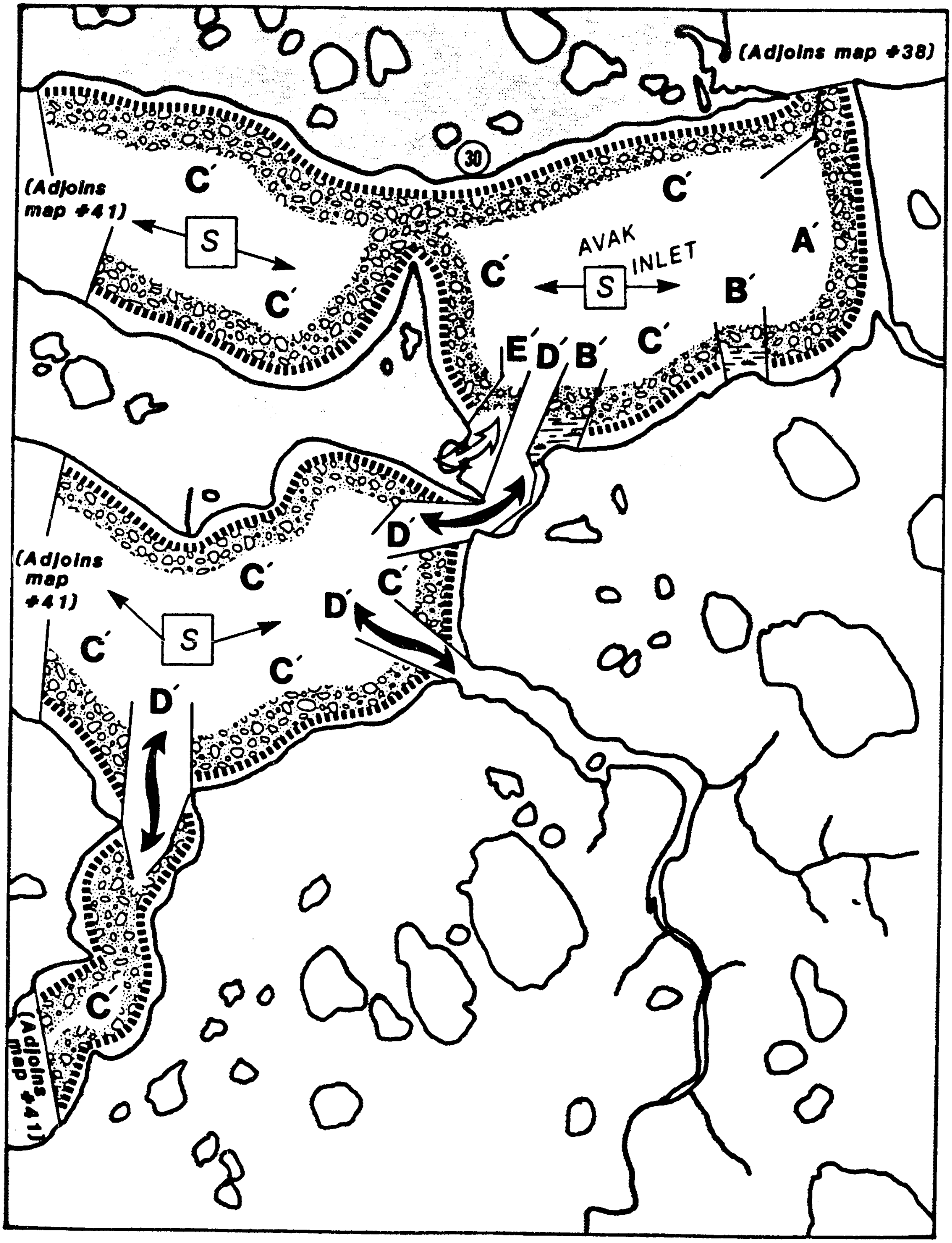

Figure 2-5. EXAMPLE OF COASTAL RESOURCE MAP FROM PART II

The location or boundaries for the biological and human use resources may not coincide with the physical shore-zone type boundaries. The wetlands, a biological resource, are also a physical shore-zone type. The boundaries in either category will generally be the same along the lagoon and bay shores. However, bird nesting areas or seabird colonies are typically much smaller than the physical unit. The human use resources which can be mapped as discrete sites, principally villages, military areas and archeological sites are typically less areally extensive than the adjacent shore-zone type(s) with which they are associated. Also, these resources are typically above the storm surge line and thus out of the shore-zone as defined in this study. Transportation corridors subsistence and recreational areas can not be as precisely defined. They are shown on the Coastal Resource Maps by arrows indicating their approximate extent which typically includes several physical shore-zone units, often over several consecutive maps.

2.4 EXPANDED COASTAL RESOURCE LEGEND

2.4.1 Physical Resources

Repetitive shore-zone components are used as a combined representation of morphology and substrate types in mapping the shore-zone character of the Chukchi Sea coast. Each repetitive component is indicated by a distinctive pattern (Figure 2-3) on the coastal resource maps. A detailed description of each repeatable component, illustrated by a series of photographs, is presented in Part I.

More than one repetitive shore-zone component may occur within a shore-zone unit. The repetitive components are not necessarily mutually exclusive, and by combining two or more within a unit, a composite picture of the shore-zone character is established. However, not all components can be combined (e.g., rock cliffs and tundra cliffs cannot occur within the same unit). Washover fans are used as a modifying symbol within some units. These shore-zone modifiers differ from shore-zone components in that they cannot be used alone to represent a unit.

The expanded legend (Table 2.1) provides a concise summary of shore-zone components and modifiers which are used on the maps.

2.4.2 Biological Resources

In the Chukchi Sea shore-zone area, there are a number of species and habitats of direct concern in an oil spill. They include spotted seals, several species each of seabirds, waterfowl, and shorebirds as well as the wetland and protected lagoon habitats. Most of these are subsistence species. They are mostly migratory species, arriving around breakup and leaving by freezeup. They tend to concentrate in certain areas to feed, breed, raise their young, and rest prior to migrating out of the area.

Oil spill counter-measures should focus on those activities that are predictable in the spatial context and that are essential for the survival of the population. For most of these species, the breeding and nesting areas are the main spatial or "real-estate oriented" aspect of their activities in the arctic that are predictable from year to year, through the exact site on the barrier islands where eiders or terns nest might vary somewhat. These nest sites or seabird colonies can therefore be the focus of counter-measure planning a priori. The nesting areas, seabird colonies and immediately adjacent intensely-used water areas are also small enough (in most cases) for effective counter-measure implementation. Of course, most of the actual nest sites and colonies are above the storm surge line so that spilled oil probably would not directly impact them. However, oiled adult birds will contaminate their nests, eggs and chicks. Also, the shoreline protection and cleanup activities are likely to disturb the nesting birds.

The exact location(s) of areas that are used for feeding, molting, staging, etc. are usually less predictable due to weather, sea-ice presence, oceanographic conditions, location of prey, etc. Oil spill counter-measure planning and implementation for these areas, most of which are not directly associated with the shore-zone, is better done at the time of the spill. Otherwise, as an example a biological resource

Table 2.1. EXPANDED LEGEND OF PHYSICAL SHORE-ZONE COMPONENTS

SHORE-ZONE COMPONENTS

Rock Cliffs - primary morphology is that of a steep cliff cut by waves into the bedrock substrate. Cliff slopes are typically steep (greater than 45°) and fringing beaches are rare. Pocket beaches of gravel sized material may occur in small indentations along the base of the cliffs. Bedrock types include sedimentary sandstones in the northern portion of the study area (Skull Cliff, Peard Bay, Kuk River) to meta sedimentary and igneous in the southern portion of the study area (Cape Sabine, Cape Lisburne, Cape Thompson).

High Tundra Cliffs - wave-cut cliffs formed in unconsolidated Quaternary sediments. Relief from cliff base to cliff edge is greater than 5 m (approximately 15 ft). Cliff sediments are bonded by permafrost and are usually "ice-poor", although massive ice beds do occur locally. Slopes are usually less than 45° and are dominated by surface wash and debris slide mass-wasting processes. Coastal retreat rates, where documented, are less than 1 m/yr. Fringing gravel beaches typically occur at the cliff base.

Low Tundra Cliffs - wave-cut cliffs formed in unconsolidated Quaternary sediments. Relief from cliff base to cliff edge is less than 5 m (approximately 15 ft). Cliff sediments are bonded by permafrost and are usually "ice rich." These cliffs are most common in lagoons and near open-coast river mouths. Coastal retreat con be rapid (> 1m/yr) on some cliffs (usually steep slopes, >45°, indicate rapidly retreating cliffs), although most cliffs appeared retreating only slowly in comparison with those of the Beaufort Sea coast. Narrow fringing sand or gravel beaches are typically associated with these cliff types.

Mixed Sediment Beaches - the vast majority of beaches along the Chukchi Sea coast are comprised of a mixture of sand and gravel-sized sediment. Mixed-sediment beaches are widely distributed and are associated with both/barrier islands and tundra cliffs. Additional detail on size composition of sediment within the unit is provided in the resource tables. (Note: gravel includes sediment greater than 2 mm in diameter; sand includes sediments with diameters of 0.06 to 2.0 mm).

Sand Beaches - sand beaches occur at the distal ends of some barrier spits (the eastern Peard Bay spit, for example). Sand-sized material comprises more than 80 percent of the total sediment mass. Sand beaches may occur locally along the lagoon shores as well.

Table 2.1. EXPANDED LEGEND OF PHYSICAL SHORE-ZONE COMPONENTS (continued)

SHORE-ZONE COMPONENTS

Mud/Sand Flats - wide (>100 m or 300 ft) intertidal flats occur within the lagoon systems of the Chukchi Sea coast. These flats are typically associated with river deltas, flood-tidal deltas on the seaward side of the lagoon, with washover fans on the barrier islands and with other smaller scale coastal features along the mainland coast. Sediment texture on the flats usually grades from sand-sized material in the upper portion of the shore zone to mud-sized material in the lower shore-zone.

Wetlands - low elevation, generally flat areas with standing water for most of the snow or ice-free season. They are subject to occasional storm innundation but are generally not covered by the normal astronomical tides. Vegetation is salt-tolerant and dominated by the grass, Puccinella spp. Wetlands are low energy environments primarily on borders of small estuaries, deitas and the lagoon side of barrier islands.

Lagoons/Estuaries - protected embayments such as small lagoons or estuaries, which are too small to map separately, are delineated by a site symbol. Lagoons and estuaries typically encompass low-energy coastal features such as mudflats or wetlands, which can not be shown on the map due to the small scale of the feature. Lagoons and estuaries are necessarily connected to marine water areas by either a washover channel, or an inlet.

Inlets - inlet provide a critical water exchange link between protected lagoons, estuaries or bays. Inlet widths vary, although most are less than 1.5 km (approximately 0.25 mi) in width (with the exception of the Peard Bay inlets). Inlets which have been permanently open for the past few years are mapped as stable inlets. Inlets which are only open seasonally, such as during spring freshet or during storm-surges or which open and close on a year-to-year basis are mapped as ephemeral inlets.

SHORE-ZONE MODIFIERS

Washover Channels and Fans - washover fans and channels are activated during storm surges and provide an important water exchange conduit during storm surges. Water exchange is in only one direction, landward-directed (return flow occurs through inlets or through ground-water seepage. Washover channel and fans are found on low, usually unvegetated, barrier islands and on small baymouth bars enclosing lagoons and estuaries.

Table 2.1. EXPANDED LEGEND OF PHYSICAL SHORE-ZONE COMPONENTS (concluded)

SHORE-ZONE COMPONENTS

Barrier Island Vegetation - barrier island vegetation is mapped as a shore-zone modifier for open coast barrier islands where significant densities of vegetation occur. Vegetation on the Chukchi Sea side of the barrier islands is primarily dune grass (*Elymus arenarius mollis*). On the lagoon side, the vegetation is typically one for more species of grass, primarily *Puccinella* spp. The presence of vegetation usually indicates a greater barrier island stability (i.e., stable or accretional) and less frequent over-topping during storm surges.

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such as oldsquaw or eider molting and staging area would be mapped on almost every map in Kasegaluk Lagoon (Map Nos. 33-59). This defeats the purpose of identifying important areas that are of a size that is amenable to oil spill counter-measure planning and implementation.

The other "real-estate oriented" biological resource considered important in the sensitivity analysis is wetlands, both salt-tolerant ones and freshwater wetlands below the prominent storm surge line. These areas could be inundated with oil especially during a storm. The salt marshes and adjacent mudflats are especially important to black brant and shorebirds. Brant use the coastal salt marshes, particularly those in the vicinity of Icy Cape and Peard Bay, between early June and late September. They are particularly abundant there as spring migrants in June (~37,000 birds) and again in late August and September as fall migrants (70,000-80,000 birds). In these staging habitats, they feed on salt marsh vegetation (grasses, sedges). The distribution of staging shorebirds is dictated by the presence of saltmarsh and mudflat habitats in which the birds feed. The most extensive of these habitats are in the northern part of Kasegaluk Lagoon, especially near Icy Cape. Less extensive habitats occur on the spits and mainland shores of Peard Bay.

The waterfowl, gull, and tern nesting areas, and the marine bird colonies are identified on the maps with appropriate symbols (Figure 2-3). The number of breeding pairs of each species (if reported in the literature) is presented in the Coastal Resource Tables (Part III).

Wetlands are identified with a distinctive pattern (Figure 2-3) as part of the physical characterization of the shore-zone. However, on the maps, no distinction is made between large and small wetlands or sparse and lush vegetation (except for the length of the shore-zone unit). The known or expected use of each wetland is identified in the Coastal Resource Tables (Part III).

Other biological resources such as spotted seals, beluga whales, waterfowl and shorebirds that may utilize a section of the shoreline or adjacent water body (lagoon, bay, pass) are also identified in the Coastal Resource Tables (Part III). However, as described previously, they are not depicted on the Coastal Resource Maps because their temporal and spatial distribution is unpredictable except in a very general way.

2.4.3 Human Use Resources

Human use resources include resources (i.e., property, public facilities, subsistence resources, cultural resources), and shoreline uses (transportation, fishing sites, boat storage). Many human use patterns of the coastline can be identified with individual communities (i.e., Barrow, Wainwright, Point Lay, and Point Hope), although the patterns also reflect traditional uses that preceded the formation of permanent communities. Activities are intense in the immediate vicinity of each village, and include subsistence hunting and gathering, transportation (boat traffic and storage on the beach, three-wheeler traffic along the shoreline, airstrips with daily schedule traffic) and excursions to traditional use sites. However, local residents travel extensively outside their communities to harvest subsistence resources so village use areas extend tens of miles from the permanent communities.

Other human resources are less identifiable with individual communities. The general cultural resources sites is high, and density increases in areas there the distribution of subsistence resources is concentrated. Distant Early Warning (DEW) Line Sites also constitute a human resource; several are located in the study area. Active sites generate air traffic in support of their mission; inactive sites are often used to support research or resource exploration teams and can be used during emergencies.

Some human uses resources are predictable and obvious in terms of location (e.g., villages, boat storage areas, airstrips, DEW Line stations, cultural resource and archaeological sites). They are shown on the maps with the appropriate symbol at the site. More detail is presented in the Coastal Resource Tables (Part III).

Other human uses are not as predictable in the spatial or temporal context. For example, subsistence hunting and fishing may be very predictable in the case of egg collecting at the Cape Lisburne or Cape Thompson bird colonies, but quite unpredictable in the case of waterfowl, beluga or spotted seal hunting. Also, transportation along the beach by three-wheelers or nearshore by boat may be generally predictable, but the actual routes will depend on a large number of variable circumstances.

In these cases, the appropriate symbol for subsistence, recreational or transportation activities is presented in the map with arrows indicating the general directions in which the activities take place.

3.0
USE OF COASTAL SENSITIVITY MAPS

3.1 INTRODUCTION

A primary objective of this study is to provide an evaluation of the sensitivity of shore-zone resources which in turn will provide a partial basis for determining oil spill counter-measure priorities. The sensitivity evaluation must be necessarily general because of the regional nature of the study yet must be of sufficient detail to be of use for contingency planning. For these reasons, we developed a three level index (primary, secondary and tertiary levels of concern) to illustrate sensitivities for (a) potential oil residence, (b) biological sensitivity and (c) human-use sensitivity.

While the use of three levels of concern for the three resource types is relatively simple, and therefore useful to resource managers, there are 27 possible combinations possible. As such, the approach provides planners with sufficient detail to develop priorities for the oil spill contingency plan. The development of the oil residence, biological and human-use sensitivity indices is discussed in detail in Part I.

3.2 DEFINITION OF INDICES

3.2.1 Oil Residence Index (ORI)

The Oil Residence Index indicates how long oil that reaches the shoreline might be expected to persist. This is important because short persistence on residence times may reduce the need for (or even the possibility of) shoreline protection on cleanup counter-measures, and short residence times may reduce impacts on biological or human use resources. Expected long residence times, however, may require some counter-measure actions.

Potential oil residence is determined by:

- wave exposure
- substrate type
- sedimentation processes
- oil type
- spill volume
- oil form at impact zone.

Many of these parameters cannot be determined until the time of the spill so any *a priori* index must be necessarily general. Wave exposure, substrate type and sedimentation processes can be evaluated prior to a spill, however, and provide a basis for developing the Oil Residence Index (Table 3.1).

The wave exposure is the primary process influencing potential residence of oil. It should be emphasized, however, that wave exposure refers only to the open-water season. From approximately October through June, ice cover is continuous in the Chukchi Sea and there is no wave activity at the shore. Areas of low wave exposure, such as lagoons and estuaries, are likely to have lengthy oil residence periods. Most outer coast areas are comparatively exposed, with wave fetch distance exceeding 500 km during most open-water seasons. Wave exposure is lower in the northern portion of the study area, near Point Barrow, as a result of (a) the shorter open-water season and (b) shorter fetches during the open water season due to the normal proximity of pack ice.

Substrate type may influence potential residence (Table 3.1). Coarse sediment beaches allow penetration of the oil into the substrate where it is no longer exposed to mechanical wave action. For beaches of equal

Table 3.1. RATIONALE FOR ESTIMATING POTENTIAL OIL PERSISTENCE IN THE SHORE ZONE

Shore-Zone Type	Wave Exposure[1]	Substrate Type[2]	Coastal Stability	Level of Concern
Open Coast				
Rock Cliffs	High	Rock	Erosional	Tertiary
Tundra Cliff	Moderate	Sandy gravel	Erosional	Tertiary
Barrier Island	High	Gravelly sand	Stable to erosional	Tertiary
Barrier Island with Vegetation	High	Gravelly sand	Stable to accretional	Secondary to tertiary
Lagoon Coast				
Tundra Cliffs	Low	Sandy gravel	Erosional	Primary to secondary
Barrier Island	Low	Gravelly sand	Stable	Primary
Deltas	Low	Muddy sand, vegetation	Accretional	Primary to secondary
Wetlands	Low	Mud, peat, vegetation	Stable	Primary

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[1] Exposure based on maximum open-water fetch lengths
High - fetch > 100 km
Moderate - fetch 10 to 100 km
Low - fetch <10 km

[2] Terminology of Folk, 1968

wave exposure, persistence will be greater on coarse-sediment beaches than fine-sediment beaches. Similarly, mudflats often have short oil residence periods because the fine sediments and the associated high water content of the sediments prevent the oil from penetrating or adhering to the substrate.

Coastal stability and its effect on coastal sedimentation patterns will influence potential oil residence periods. Eroding coastal areas, by nature, will have short potential oil residence periods due to the coastal retreat, particularly since retreat rates of 1 m/yr are not uncommon. Oil residence may be increased, however, on accretional shorelines, where there is potential for oil burial, hence removal from exposure to wave action.

3.2.2 Biological Sensitivity Index (BSI)

The Biological Sensitivity Index (BSI) is a guideline for identifying which sections of the shoreline may be considered sensitive to oil spills because of the biological resources potentially present. The BSI levels of concern are defined on the basis of (a) the potential population-level effect an oil spill could have upon a sensitive "target" population or biological resource described in Volume 1 and (b) the potential recovery time. The BSI is not based on the potential effects to individual organisms (i.e., the "body count" impact assessment approach) although the effect on the population is obviously related to the effects on individuals. The BSI does not include elements of "risk" (i.e., probability that an oil spill will occur and the oil will reach the area occupied by the biological resource) or the effectiveness of countermeasure response and implementation. It also does not include the human-perceived sensitivity (i.e., all "cute" mammals and birds are more sensitive than worms or snails.)

The BSI levels of concern reflect the assessment of the vulnerability and biological sensitivity of the particular population or community of concern. Vulnerability is the likelihood that some portion of the biological resource will actively or passively come into contact with oil if the oil is in the same area as the resource. Vulnerability of a resource or likelihood of contact involves a qualitative judgment based on abundance, distribution and behavior of the biological resource in the area and on the spill characteristics as well as weather and oceanographic conditions. The low, moderate and high levels of vulnerability reflect the increasing proportion of the population/community that could come into contact with oil and the potential increase in the portion of the population/community potentially lost. For example, clumped resources such as nesting seabirds or molting oldsquaw are considered more vulnerable than those with relatively non-clumped distributions such as gulls, terns, cormorants, or spotted seals. Birds that dive for their food (alcids) are more vulnerable than those that do not (shorebirds). Animals that move through an area quickly (whales or migrating waterfowl) are less vulnerable than slow-moving (molting waterfowl) or stationary (wetlands) resources.

Sensitivity is the expected impact on and response of the biotic resource following contact with oil. Response is evaluated in terms of potential morality or diminished reproductive capacity and of the resilience of the potentially affected population/community (i.e., how quickly it is likely to recover from the oil spill impacts). For example, seals and whales are not likely to suffer any substantial impacts and their sensitivity is rated low. Seabirds such as murres at Cape Lisburne may experience substantial direct adult, juvenile and egg mortality plus reduced reproductive ability for one or more years, thus resulting in a substantial population level impact requiring several years for recovery.

3.2.3 Human Use Index

The Human Use Index (HUI) explicitly includes peoples' perceptions and importance values in the evaluation of sensitivity and thus to the level of concern applied to each coastal resource or area. The human use sensitivity evaluation is similar in many ways to the biological sensitivity evaluation because many of the human uses of the Chukchi Sea shoreline are directly or indirectly based on biological resources.

The sensitivity of human resources to an oil spill is a function of (a) spill characteristics, (b) vulnerability or risk that the resource will be impacted and (c) the importance of the resource.

Development of the human use sensitivity index incorporates the following human use criteria:

- frequency of human use and presence
- relative distribution and abundance of the resource
- proximity of the resource to communities
- importance of the resource to local residents (cultural significance, contribution to diet)
- characteristics of the oil spill (e.g., size, type of oil, location of spill, etc.)

While large areas associated with each village are utilized, certain areas are more important than others. "Importance" depends on proximity to the village(s), use or harvest levels, and uniqueness of the human resources. In areas close to communities or of importance to local residents, perceptions of potential impact may actually exceed real impact.

The HUI has been developed for the following human resources of the Chukchi Sea coastal environment: (a) residential (communities), (b) transportations, (c) recreation (special use), (d) subsistence, and (e) cultural resources. The first three resources are relatively fixed in location, and, once established, the levels of concern or sensitivity values for these uses (e.g., presence of a house) should not vary much over time or on a seasonal basis.

However, the location and harvest of subsistence resources and the importance of their contribution to the community varies significantly on a month-to-month basis and from year to year. This variation and limitations to available data require some subjectivity in developing sensitivity classifications. Cultural resources are also fixed at specific areas. However, the importance of the same resource in different areas can vary widely, and the specific location can influence sensitivity to spill persistence and cleanup activities.

The vulnerability of resources and uses to oil spill impact is an important aspect of sensitivity. Some of the human uses are directly vulnerable to oil spill impacts; i.e., spilled oil could directly contact the resource or interfere with the activities of interest to people. These uses include most of the subsistence hunting and fishing activities, recreation where it depends on shoreline use or access, and transportation. The recreation and transportation uses are most likely to be affected during the containment and cleanup which may involve an increase in people and vehicle activities and thus interference with these uses. The subsistence hunting and fishing activity may be directly affected because oil could ruin nets, foul boats, and generally be unpleasant to work around; however, few of the resources except waterfowl themselves are likely to be directly affected. Increased activity associated with spill cleanup may also cause subsistence resources to avoid the area.

Some human uses are not likely to be directly affected (vulnerable); i.e., oil on the water or shoreline is not likely to directly contact villages, military operations, most cultural resources, or even many recreation or transportation uses. However, the oil spill cleanup operations may have a major impact on these human uses, especially if large amounts of equipment and number of people are moved into the area.

3.3 LEVELS OF CONCERN

3.3.1 Background

The significance of the potential effects of an oil spill on shore-zone and coastal resources is expressed as three general levels of concern, labelled primary, secondary, and tertiary or high, moderate and low, respectively. This three level system is simple, unlike most other oil spill sensitivity indices that employ four or more sensitivity levels (see Part I). The three-level system combines information of varying quality into easily understood categories typically used by decision-makers, especially in actual oil spill events.

In practical terms, the three levels of concern, regarding any of the components of the three resource categories, can be described in the context of an actual oil spill. The Primary (or High) category has high visibility with the public, government agencies, and other concerned groups. There will be considerable public and official pressure to implement protective or cleanup counter-measures without regard to cost or practicality. The majority of knowledgeable sources will agree that there will be (or is perceived to be) a significant impact to the resource if oil contacts it. The Tertiary (or low) category attracts very little attention. There is little pressure from any knowledgeable source to take counter-measure actions because there is general agreement that the resources will not be affected. The Secondary (or moderate) category, however, includes those situations where there is considerable debate in the media and among knowledgeable sources about the importance of the resource, the cost-effectiveness of counter-measures and the likely impact of oil contacting the resource.

In most cases, decisions about the need to take counter-measure actions in areas assigned Primary or Tertiary Levels of Concern will be straight-forward (although the actual implementation may not be) and can be planned for on an a priori basis. However, decisions in areas assigned a Secondary Level of Concern are probably best made at the time of the spill though some planning can take place on an a priori basis.

Not uncommonly, the level of concern is influenced or even established by policy makers, government regulatory bodies, or the public on the basis of perceived sensitivity of the biological or human use to oil spills. This perceived sensitivity and usually high level of concern may not reflect the real ecological or human use sensitivity. That is, the species, habitat or human activities may not be substantially affected by the oil and, on a strictly ecological or economic basis, should be assigned a lower level of concern. For example, there is very little evidence from past oil spills that pinnipeds or whales in open water situations are adversely affected by oil spills, so long as the pinnipeds or whales are allowed to move about on their own accord. Yet pinnipeds and their haulout or shoreline rookery areas and whale intensive-use areas are often assigned a high level of concern by decision-makers and the lay public based on a perceived sensitivity.

Estimation of the level of concern is necessarily subjective due to the large amount of uncertainty about the physical, biological and human use conditions at the time of an actual spill and about the characteristics of the spill itself. The indices or levels of concern do not include an estimate of the likelihood of an oil spill occurring. The levels of concern presented on the maps are based on the experience and professional judgment of the authors and on the pertinent literature on the short and long-term effects of spilled oil on shore-zone resources. More accurate estimates of the level of concern, especially for Secondary categories, can be made at the time of the spill when the numerous variables affecting the level of impact can be evaluated in real time.

3.3.2 Use of Coastal Sensitivity

For each Coastal Resource Map, there are three Coastal Sensitivity Maps which display the levels of concern for the indices. These maps only display the spatial distribution of the ORI, BSI and HUI. They do not indicate the seasonal distribution of the level of concern; that is displayed on the "Seasonal Variability of Indices" table (discussed later).

The criteria for each level of concern used for each of the three indices are shown in the Coastal Sensitivity Legend (Figure 3-1). Each level of concern is depicted on the maps and the "Seasonal Variability of Indices" table with a distinctive pattern:

- Primary - solid black stripe
- Secondary - black and white candy stripe
- Tertiary - clear stripe

For the shore-zone resources and uses, the longshore bounds over which each level of concern is applicable is indicated by perpendicular lines from the shoreline to the level of concern stripe (Figure 3-2).

For the biological or human use resources associated with the lagoons or bays, the primary or secondary level of concern is shown as a box around the identifier (Figure 3.2). The biological or human use resources in the lagoons and bays at a tertiary level of concern are not shown.

There may be different shore-zone types affecting the oil residence time (ORI) or biological (BSI) or human use (HUI) resources on a single map (Figure 3-2). Each component is assigned a unique identifier ("R" for ORI, "B" for BSI, and "H" for HUI) so that the seasonal variability of each component can be described in the "Seasonal Variability of Indices table (Figure 3-2).

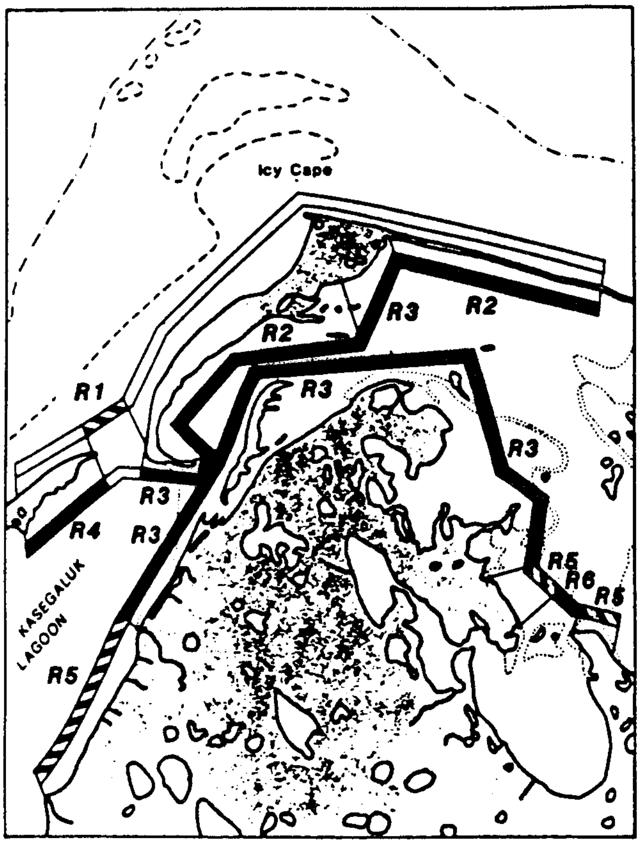
Occasionally, there will be more than one resource in the same shore-zone section, and one will be assigned a secondary level of concern while the other is assigned a primary level of concern. On the map, this will appear as a solid black line to indicate the higher priority concern. However, in the "Seasonal Variability of Indices" table, all resources within the identified section of shore-zone will be shown along with the seasonal distribution of the level of concern. Figure 3-3 provides an example where the BSI identifier B1 includes a primary level

COASTAL SENSITIVITY LEGEND

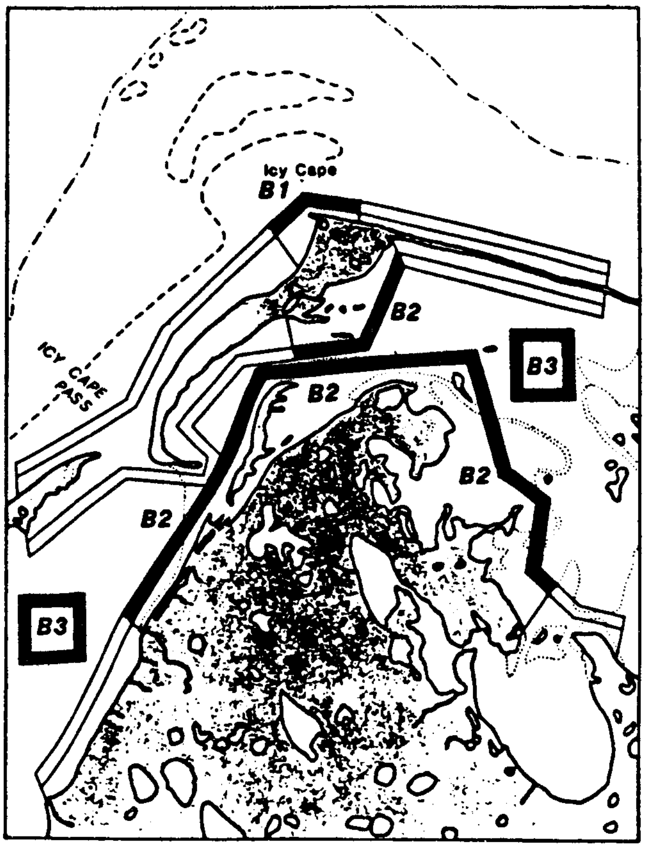
OIL RESIDENCE INDEX	PRIMARY CONCERN	▬	Lengthy oil-residence time (more than one open-water season); low mechanical wave-energy levels at the shore likely to result in a slow removal rate of stranded oil.
	SECONDARY CONCERN	▨	Variable oil-residence time (weeks to more than one open-water season); residence time may vary substantially due to variations in wave exposure, substrate type, and spill characteristics.
	TERTIARY CONCERN	═	Short oil-residence time (days to weeks of open-water season); high mechanical wave energy levels at the shore and substrate types that prevent oil penetration are likely to result in rapid removal of oil from the shore.
BIOLOGICAL SENSITIVITY INDEX	PRIMARY CONCERN	▬	Major change expected in distribution, size, structure or function of affected biotic resources (population, community or habitat); recovery from these changes likely to require several open-water seasons.
	SECONDARY CONCERN	▨	Moderate change expected in distribution, size, structure or function of affected biotic resources (population, community or habitat); recovery from these changes are expected to require one to several open-water seasons.
	TERTIARY CONCERN	═	Little or no change expected in distribution, size, structure or function of affected biotic resources (population, community or habitat); recovery from these changes are expected to require less than one open-water season.
HUMAN USE INDEX	PRIMARY CONCERN	▬	Important or intensive human-use activities likely to be disrupted for one or more open-water seasons.
	SECONDARY CONCERN	▨	Moderate impact of some human-use activities for some portion of one open-water season.
	TERTIARY CONCERN	═	Non-intensive human-use activities unlikely to be impacted for more than a short period of one open-water season.

Figure 3-1. CRITERIA FOR ASSIGNING LEVEL OF CONCERN FOR EACH INDEX

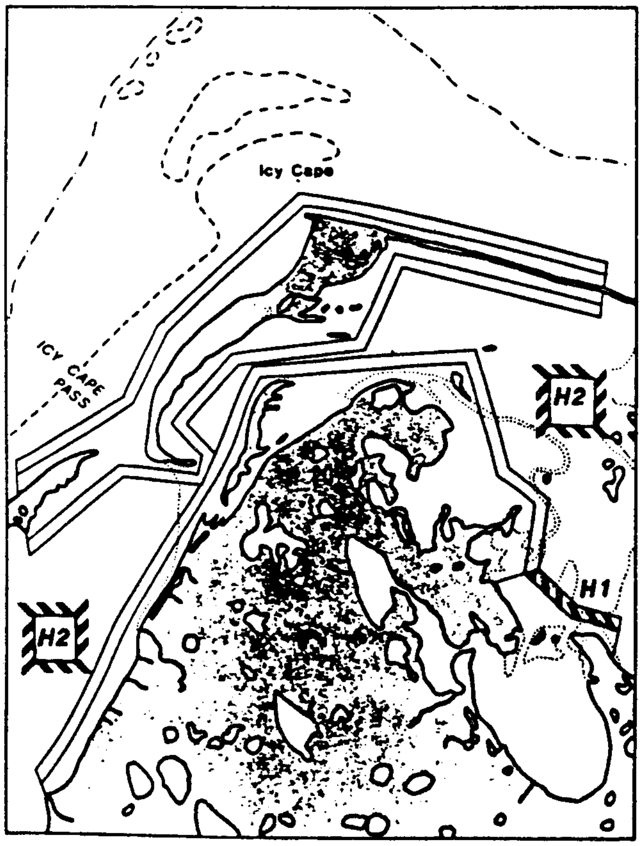
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



HUMAN USE INDEX

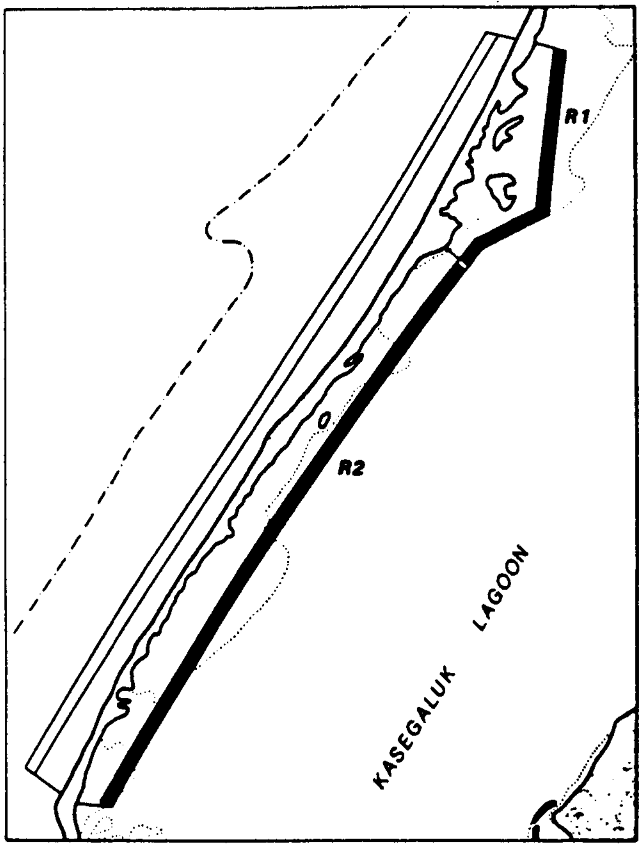


Seasonal Variability of Indices

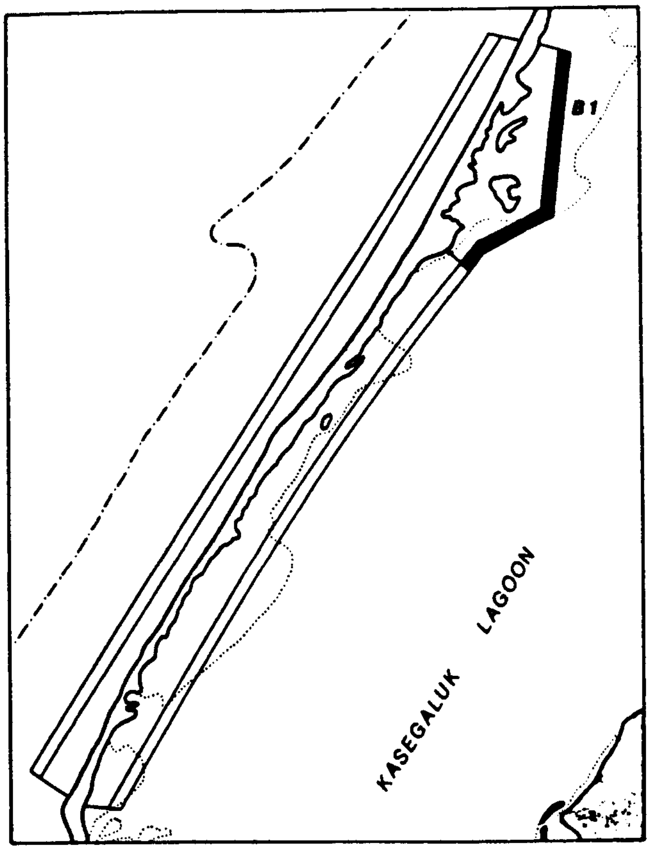
		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Stable inlet; recurve spits				▨	▨	▨	▨	
R2	Low energy beach; mudflat				▬	▬	▬		
R3	Low energy beach; mudflat; wetland				▬	▬	▬		
R4	Low energy beach				▬	▬	▬		
R5	Protected tundra cliff				▨	▨	▨		
R6	Stable inlet; lagoon				▬	▬	▬		
R7	Low energy beach; Wetland				▬	▬	▬		
B1	Eider (62 pr), gull (2 pr) and arctic tern (6 pr) nesting			▬	▬				
B2	Extensive mudflats and wetlands			▬	▬	▬	▬	▬	
B3	Kasegaluk Lagoon (Icy Cape area)			▬	▬	▬	▬		
	Extensive mudflats and wetland			▬	▬	▬	▬		
H1	Fishing			▨	▨	▨	▨		
H2	Beluga whale hunting				▨	▨			
	Spotted seal hunting				▨	▨			
	Fishing			▨	▨	▨	▨		

Figure 3-2. EXAMPLE OF SENSITIVITY INDEX MAPS AND TABLE

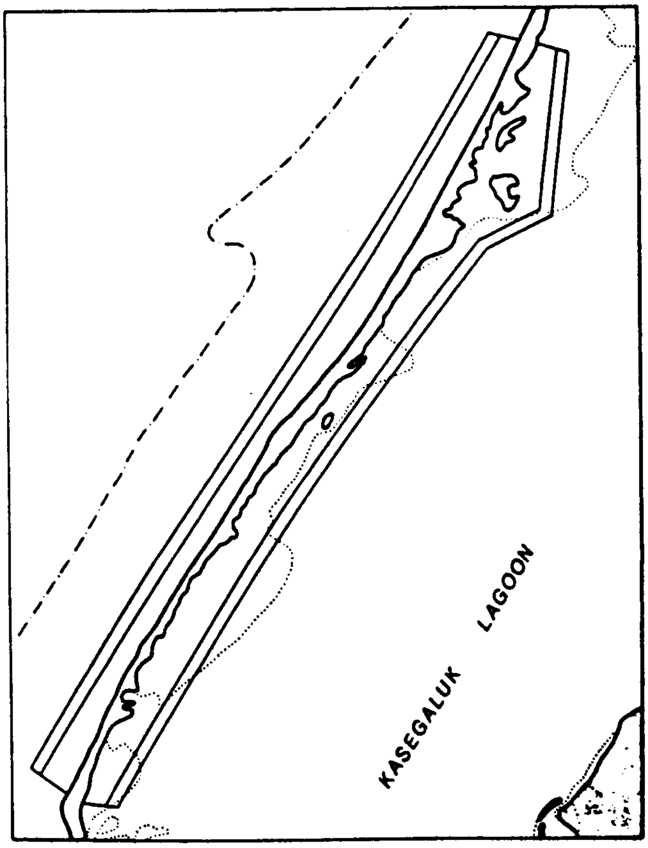
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



HUMAN USE INDEX



Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Mudflat; Wetland			■	■	■	■		
R2	Mudflat; Low energy beach			■	■	■	■		
B1	Wetland			■	■	■	■		
	Eider (22 pr), arctic tern (16 pr) and brant (4 pr) nesting			▨	▨				

Figure 3-3. EXAMPLE OF MORE THAN ONE RESOURCE IN THE SAME SECTION OF SHORE ZONE

of concern for wetlands but only a secondary level of concern for waterfowl and tern nesting areas.

3.4 SEASONAL VARIABILITY OF INDICES

The temporal or seasonal variability of oil persistence, or biological and human use resource sensitivity levels cannot be shown on the maps easily without cluttering them. However, the seasonal distribution of resources and activities may be very significant in oil spill counter-measure planning or implementation. For example, there is no need to plan for or to implement counter-measures at a waterfowl nesting area in early September because the birds will have left the area weeks before. That information would not be readily apparent from the maps, however.

Along with the maps, we include a table showing the seasonal variability of the primary and secondary levels of concern for each identified component for each index (Figure 3-2 and 3-3). Tertiary levels of concern are not shown. Only the open water season is included because it is unlikely oil will reach the shore-zone during the winter when sea ice covers the nearshore-shoreline area.

COASTAL RESOURCE LEGEND

PHYSICAL RESOURCES

SHORE–ZONE COMPONENTS

ROCK CLIFF		▬
HIGH TUNDRA CLIFF		▪▪▪▪▪▪▪▪▪
LOW TUNDRA CLIFF		❘❘❘❘❘❘❘❘❘❘❘❘
MIXED SEDIMENT BEACH		⁘
SAND BEACH		▒
MUD/SAND FLATS		≡
WETLANDS		≡
LAGOONS/ESTUARIES		*
INLETS	Ephemeral	⇄
	Stable	⟷

SHORE–ZONE MODIFIERS

WASHOVER CHANNELS AND FANS	⇒
BARRIER ISLAND VEGETATION	◆◆◆◆◆◆

BIOLOGICAL RESOURCES

MARINE BIRD AND WATERFOWL NESTING COLONIES	🦆
GULL AND TERN NESTING AREAS	🐦

HUMAN–USE RESOURCES

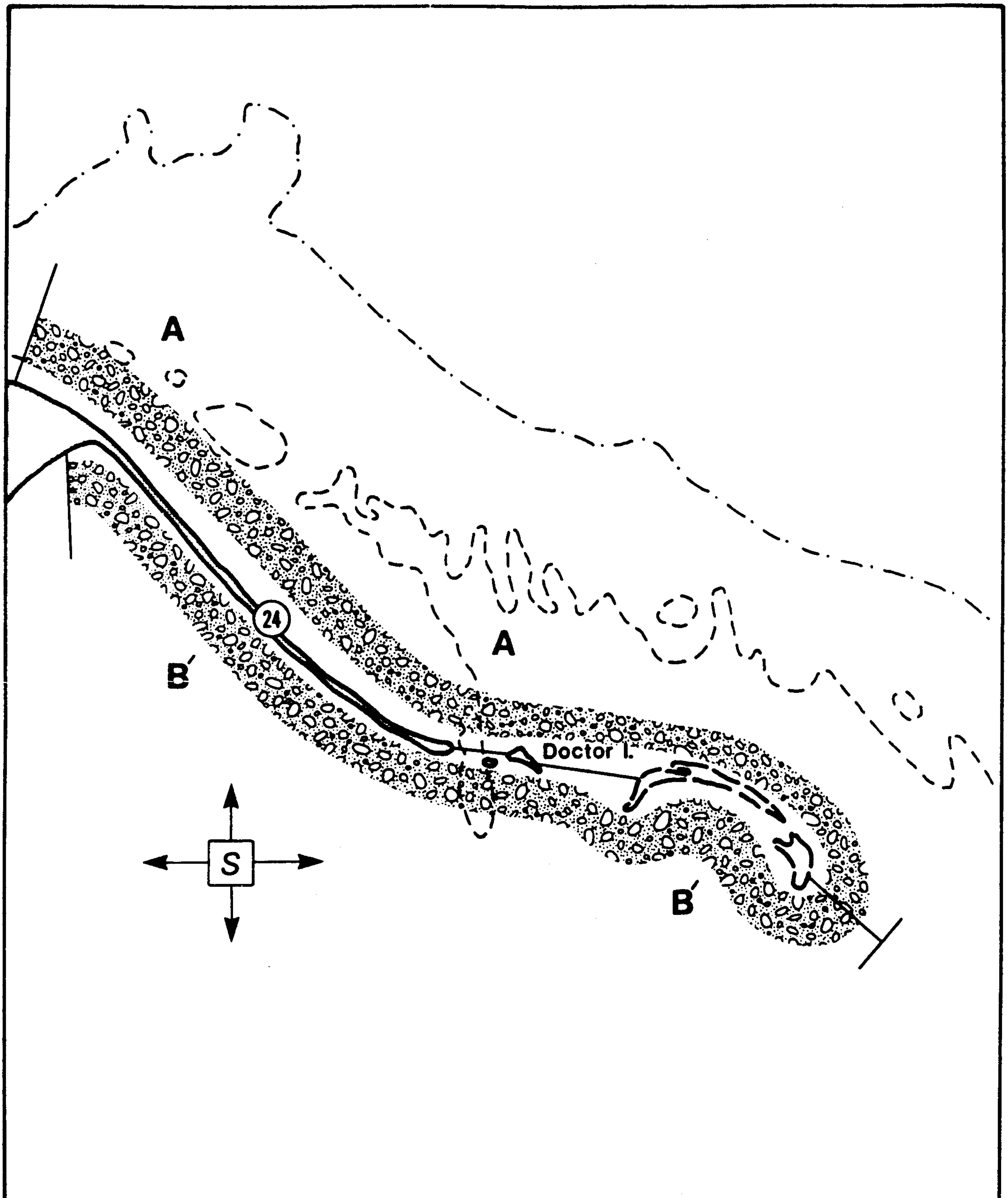
INDUSTRIAL/MILITARY	M
SUBSISTENCE	S
RECREATIONAL	R
PERMANENT VILLAGE	V
TRANSPORTATION CORRIDOR	T

Ground Truth Station	① to (54)
Intertidal Zone	···········
5m Bathymetric Contour	— — — — —
10m Bathymetric Contour	— · — · — · —
20m Bathymetric Contour	— · · — · · — · ·
Topographic Contours (m)	—— *100m* ——

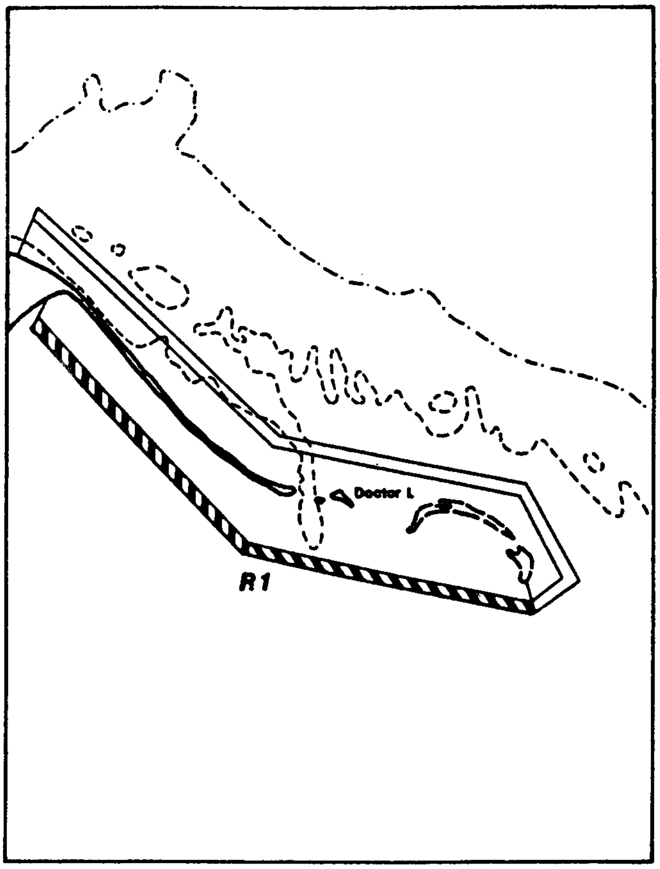
0 *1km*

Scale 1:50,000

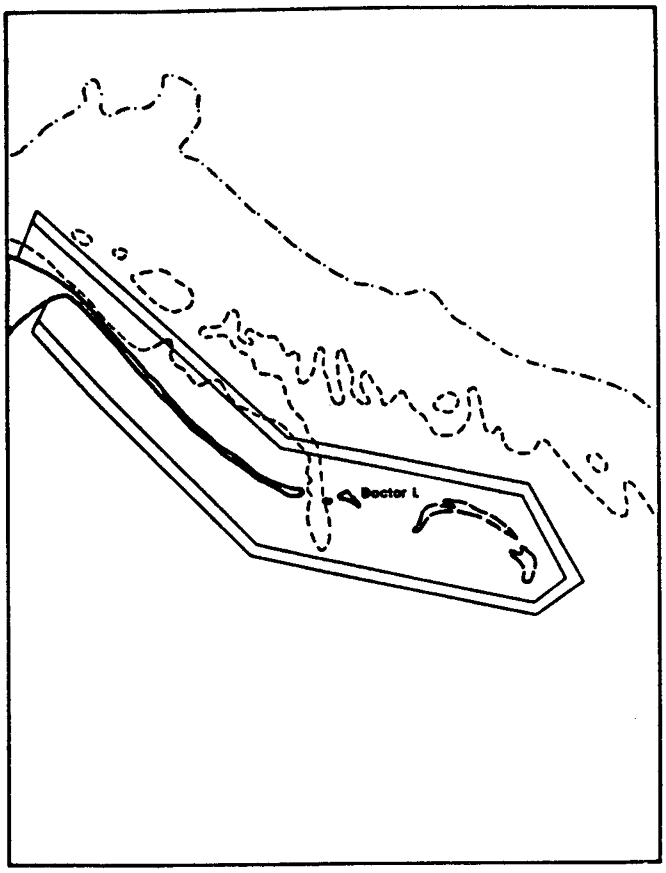
CHUKCHI SEA COASTAL RESOURCE MAPS


A
A
24
B′
Doctor I.
S
B′
1

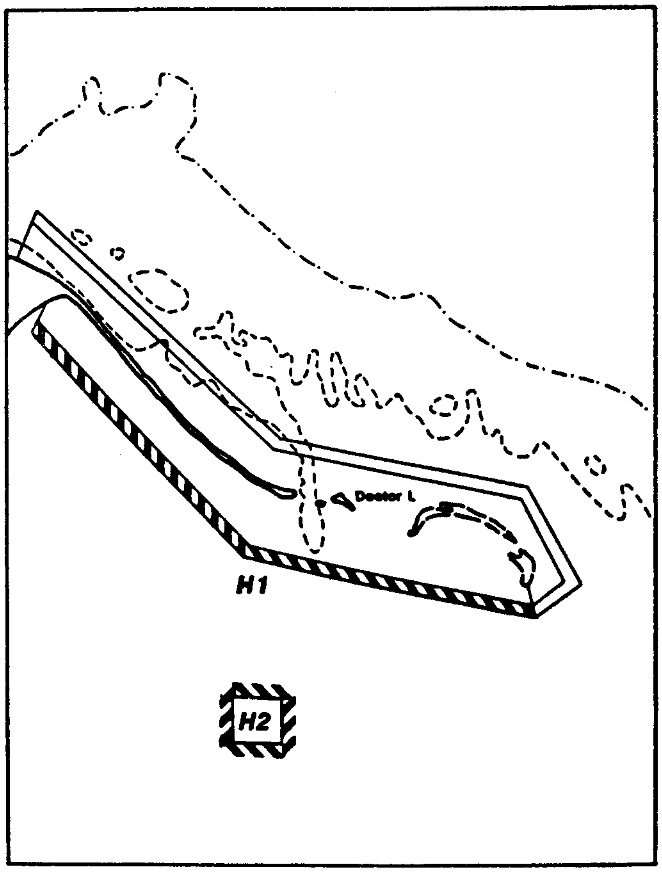
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



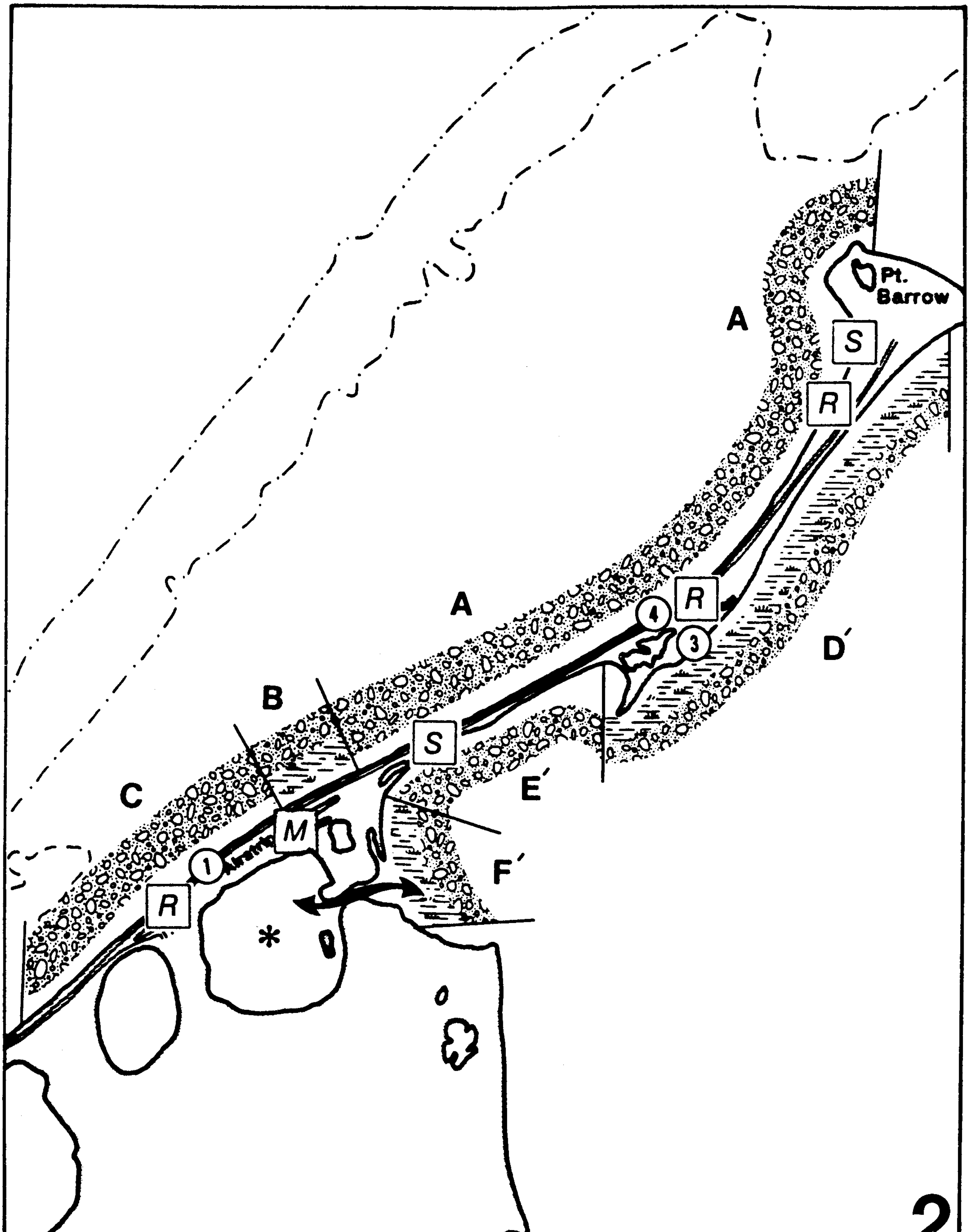
HUMAN USE INDEX



Seasonal Variability of Indices

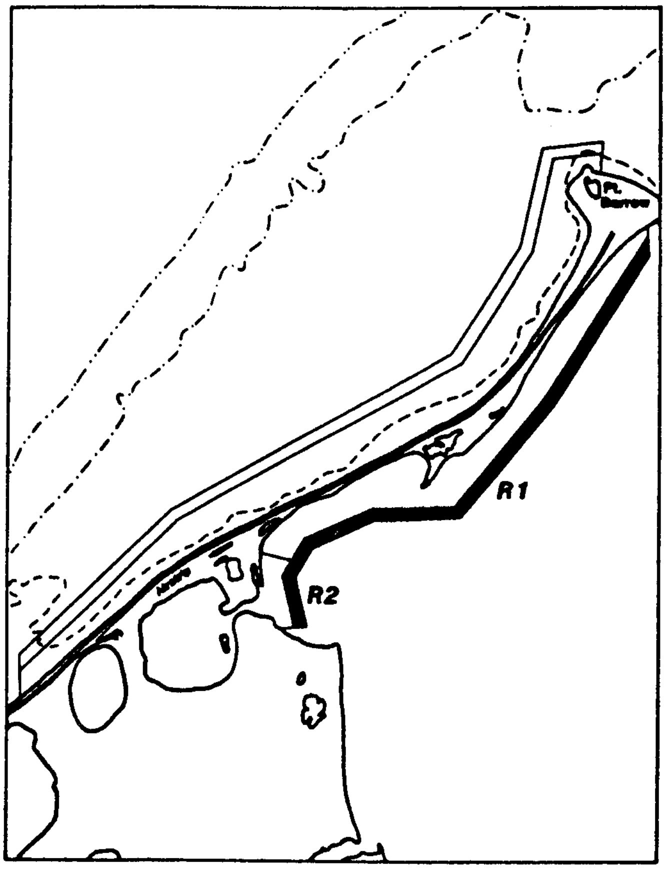
Identi-fier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach				▨	▨	▨		
H1	Waterfowl hunting			▨	▨	▨	▨		
H2	Fishing					▨	▨	▨	

1

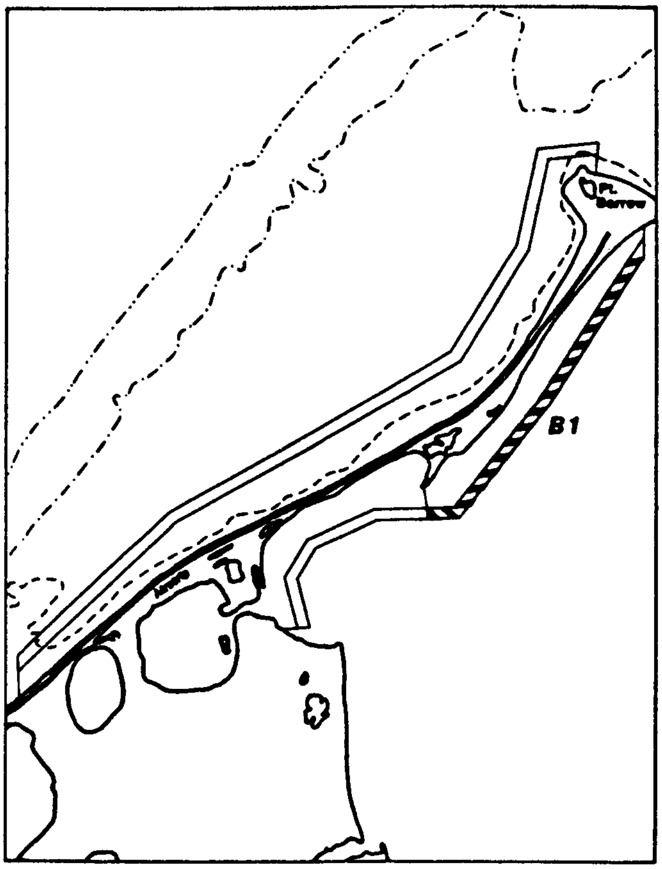


2

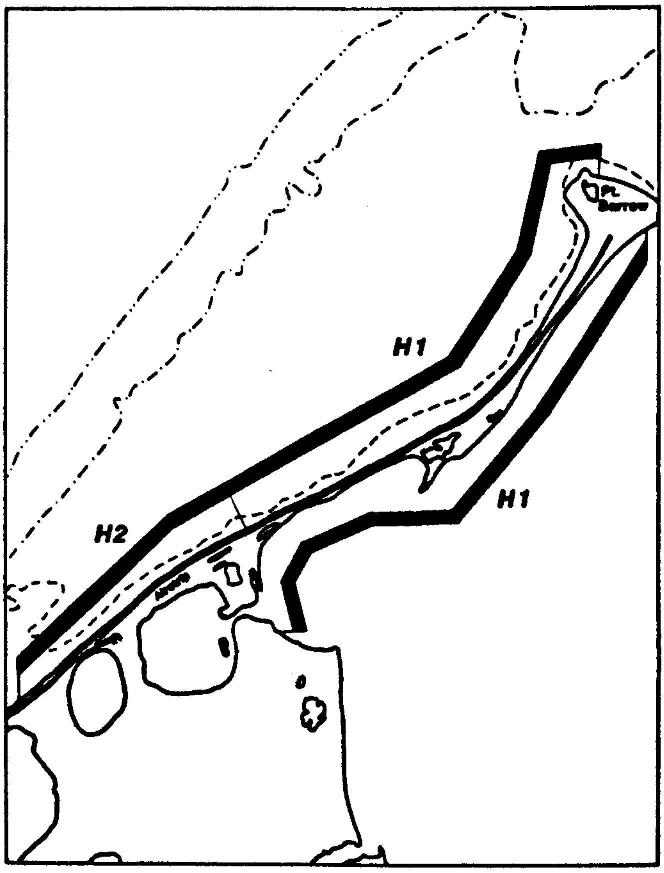
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



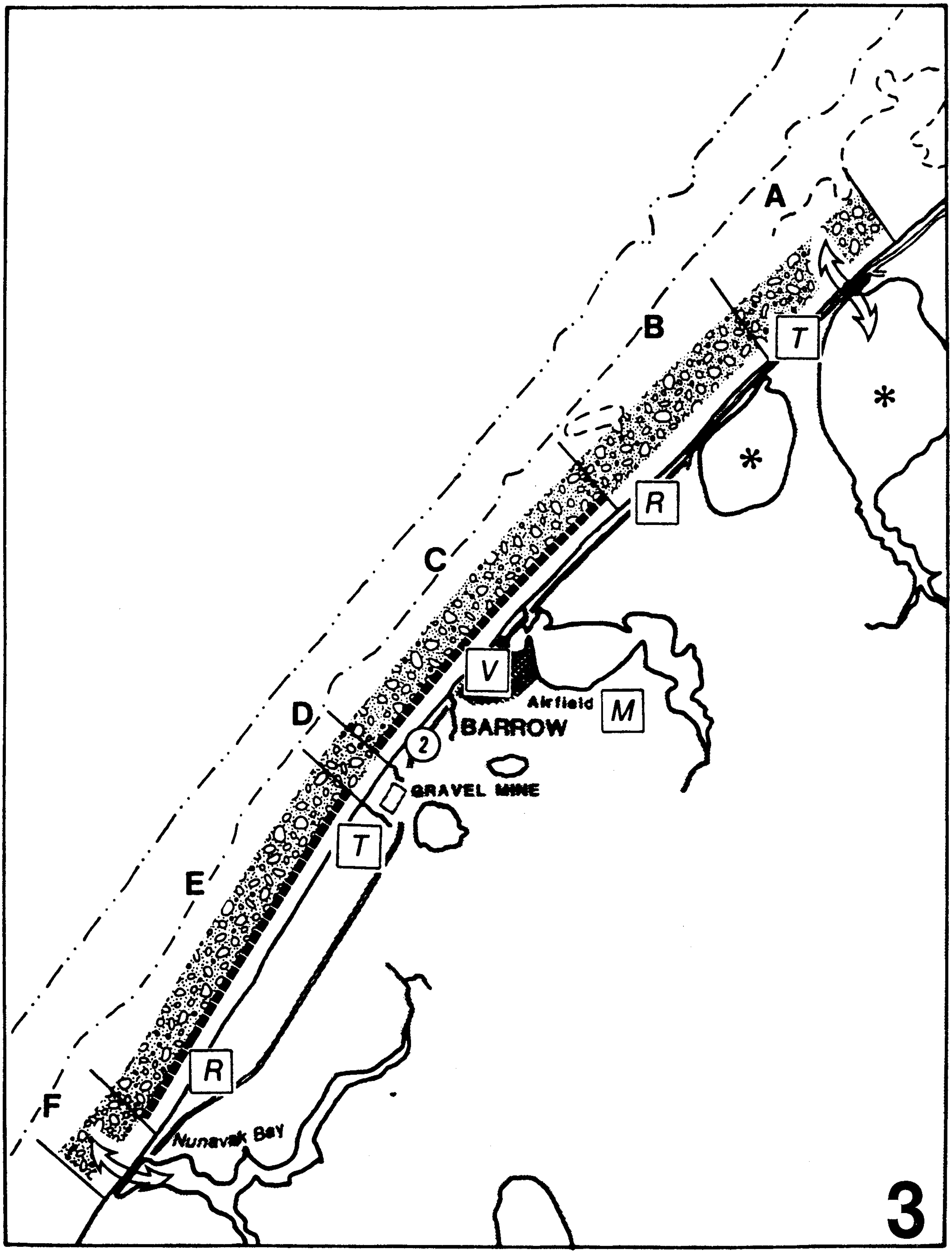
HUMAN USE INDEX



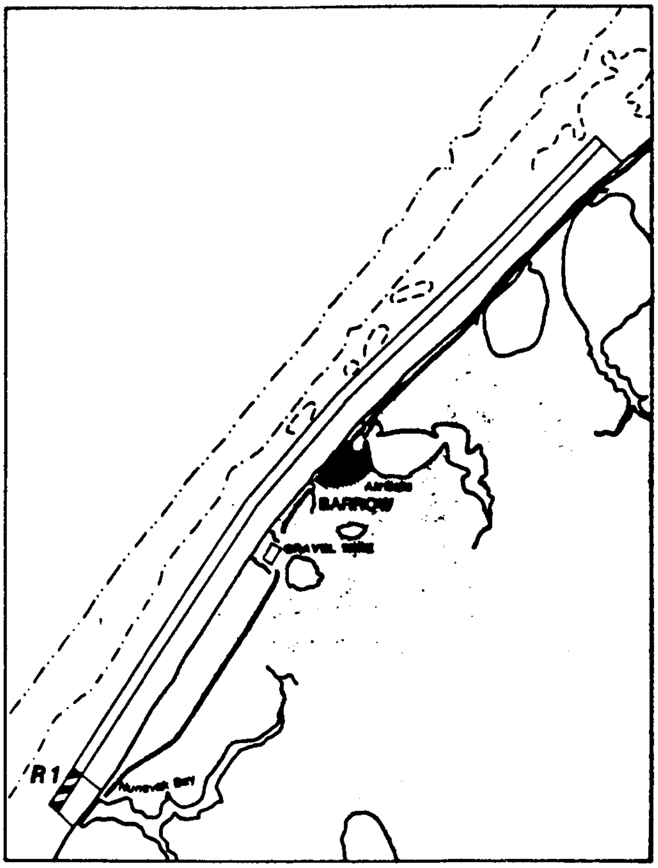
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach				▬	▬	▬		
R2	Low energy beach; Lagoon				▬	▬	▬		
B1	Wetland			▨	▨	▨	▨	▨	
	Marine bird, shorebird, waterfowl use				▨	▨	▨		
H1	Waterfowl hunting				▬	▬	▬		
	Subsistence access			▬	▬	▬	▬	▬	
	Resident recreation			▬	▬	▬	▬	▬	
H2	Subsistence access			▬	▬	▬	▬	▬	
	Resident recreation			▬	▬	▬	▬	▬	

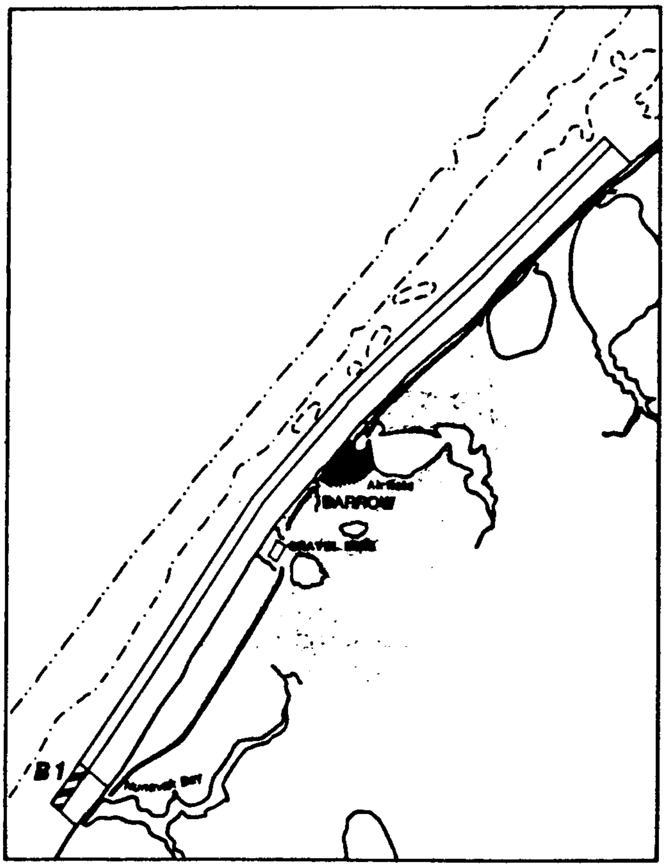
2


A
B
T
*
*
R
C
V
Airfield
M
BARROW
D
2
GRAVEL MINE
T
E
R
F
Nunavak Bay
3

OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



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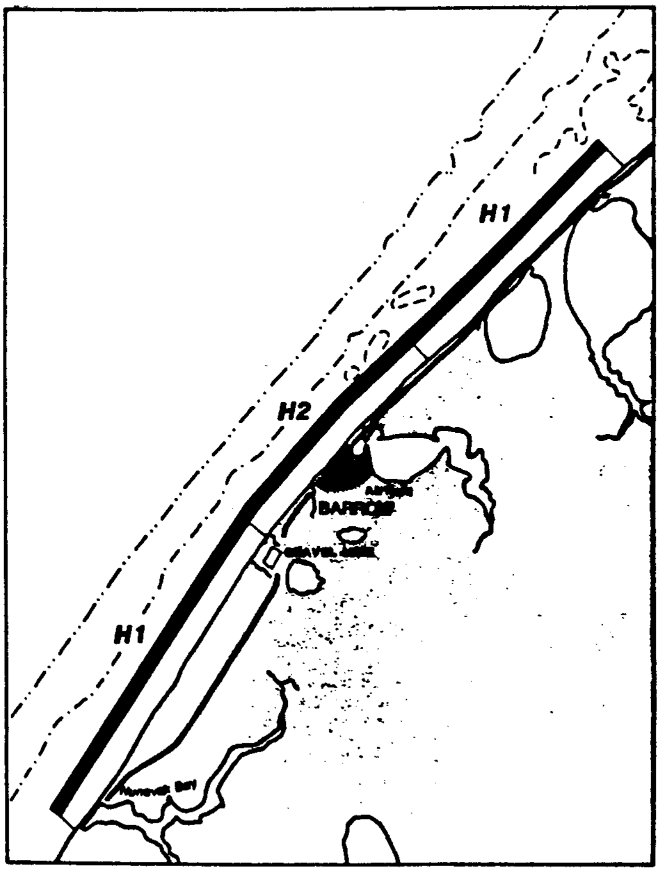
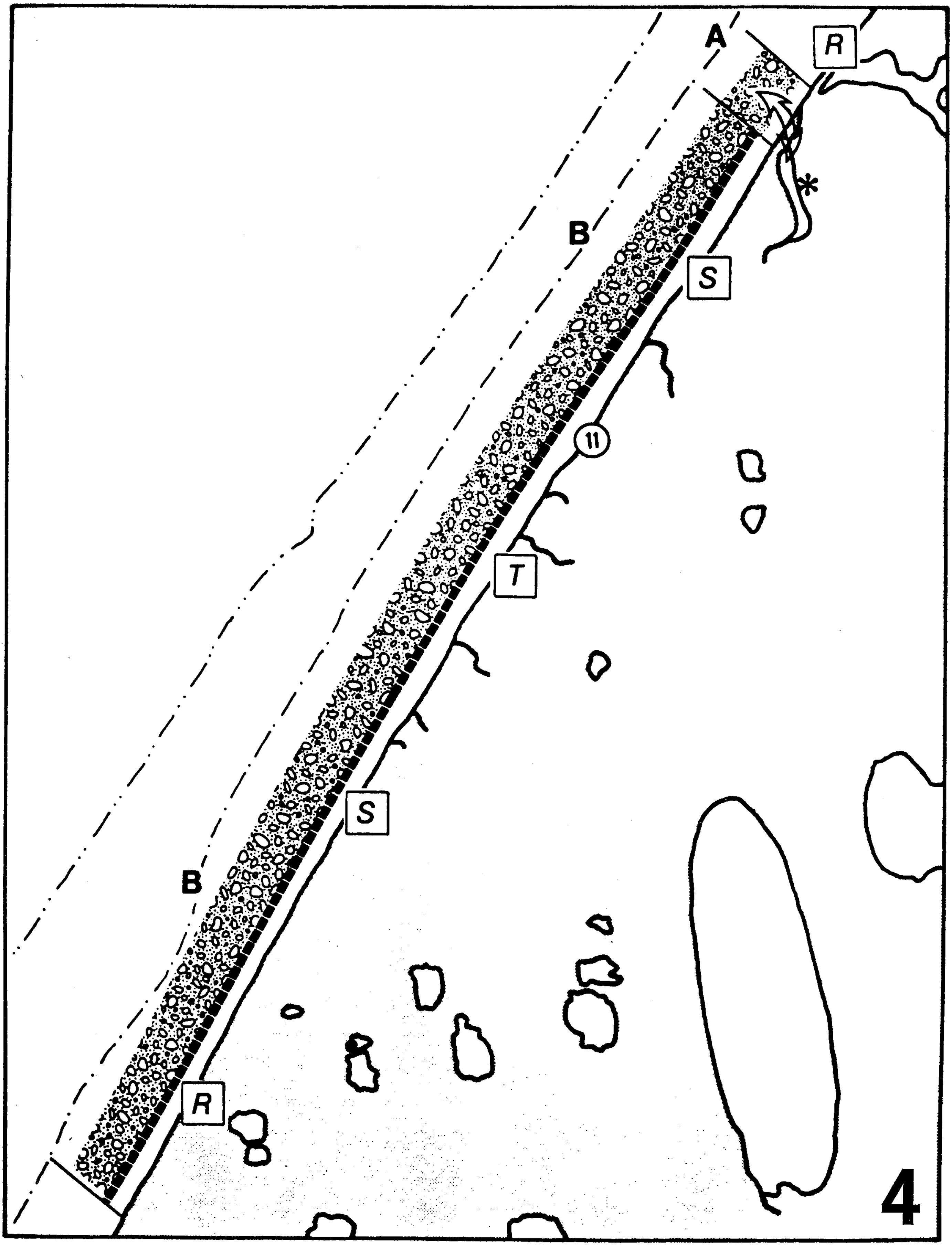


Seasonal Variability of Indices

Identi-fier	RESOURCE	SEASON Winter	Break-Up/Summer/Freeze-Up May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Lagoon				▨	▨	▨		
B1	Lagoon				▨	▨	▨	▨	
H1	Subsistence access Resident recreation			■ ■	■ ■	■ ■	■ ■	■ ■	
H2	Village of Barrow Subsistence access Resident recreation			■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	■ ■ ■	

3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11
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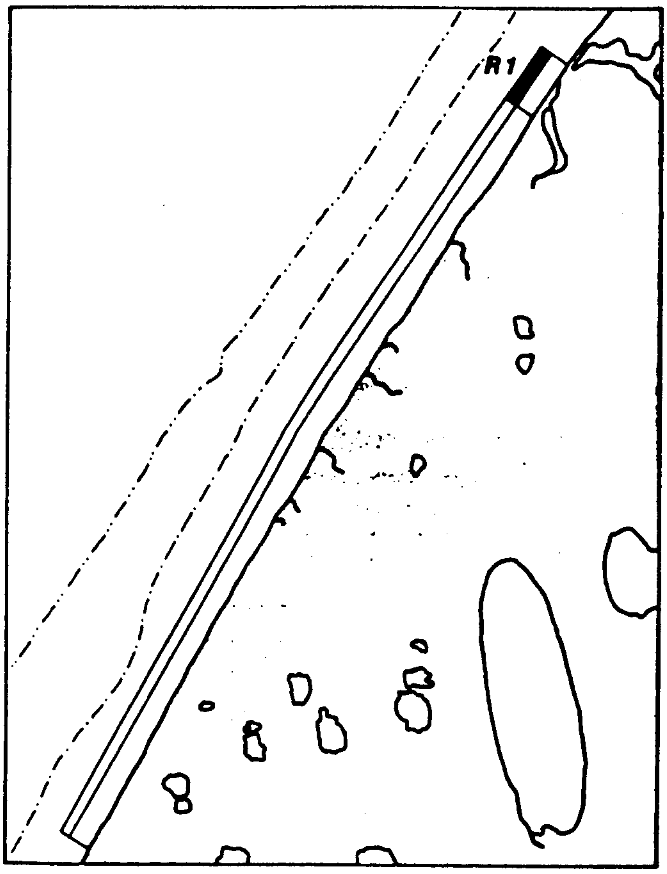
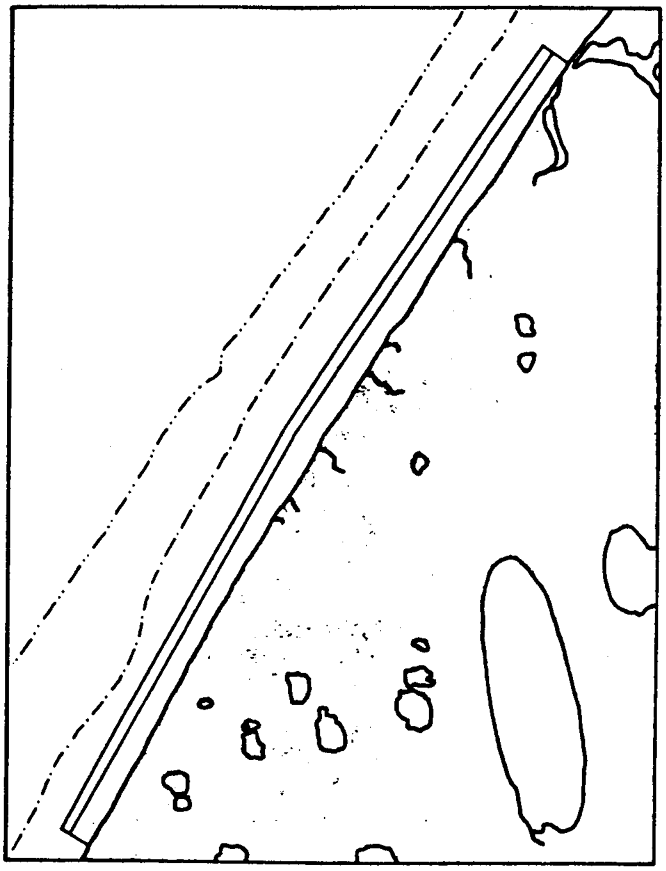
B
R
4

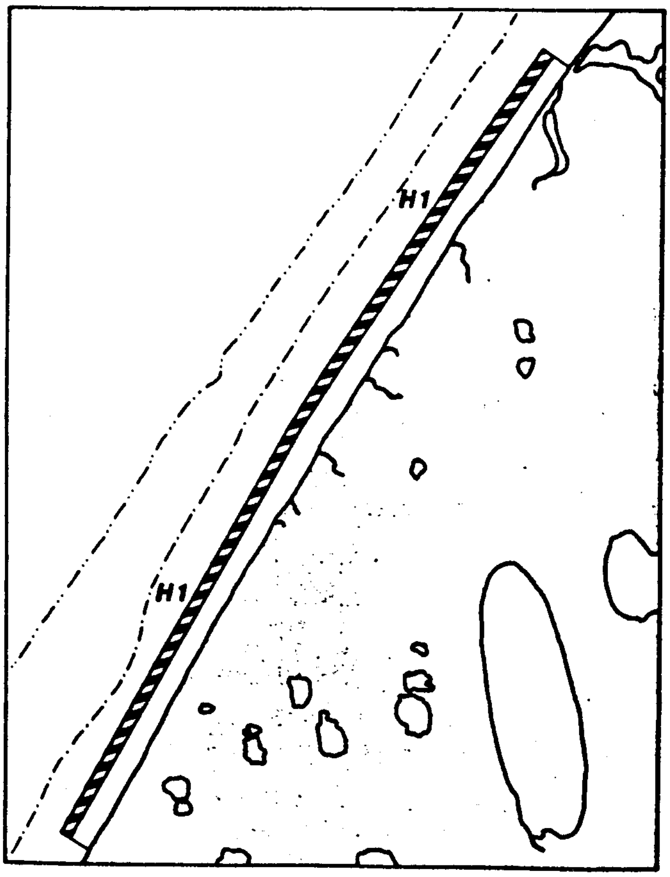
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



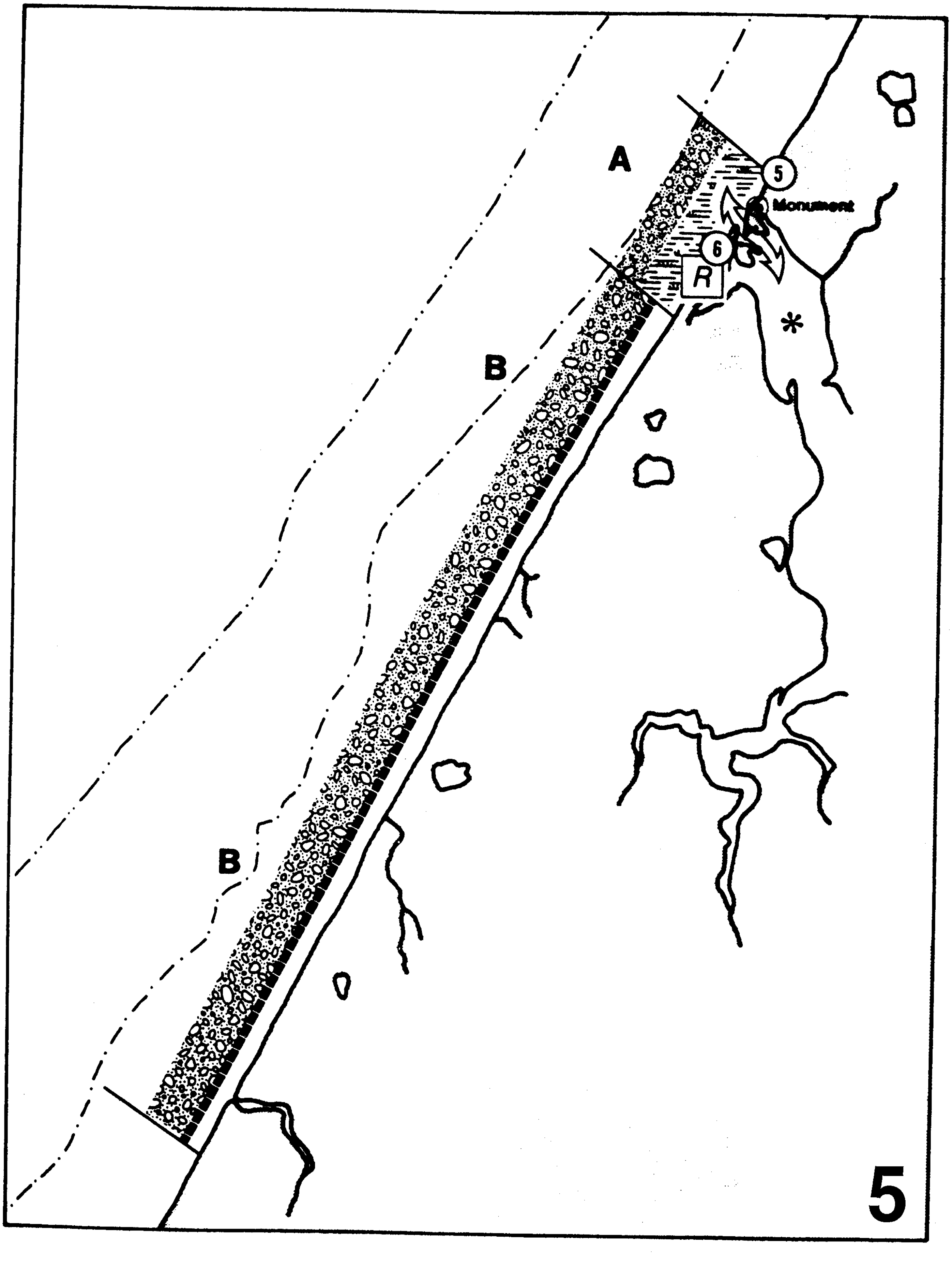
HUMAN USE INDEX



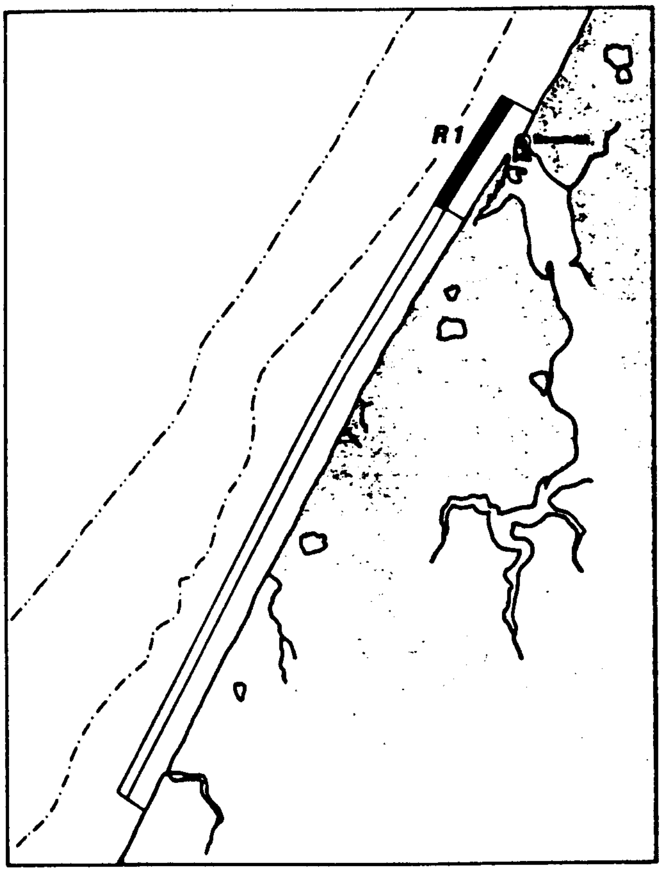
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Lagoon				■	■	■		
H1	Subsistence access			▨	▨	▨	▨	▨	
	Resident recreation			▨	▨	▨	▨	▨	

4


A
5
Monument
6
R
*
B
B
5

OIL RESIDENCE INDEX



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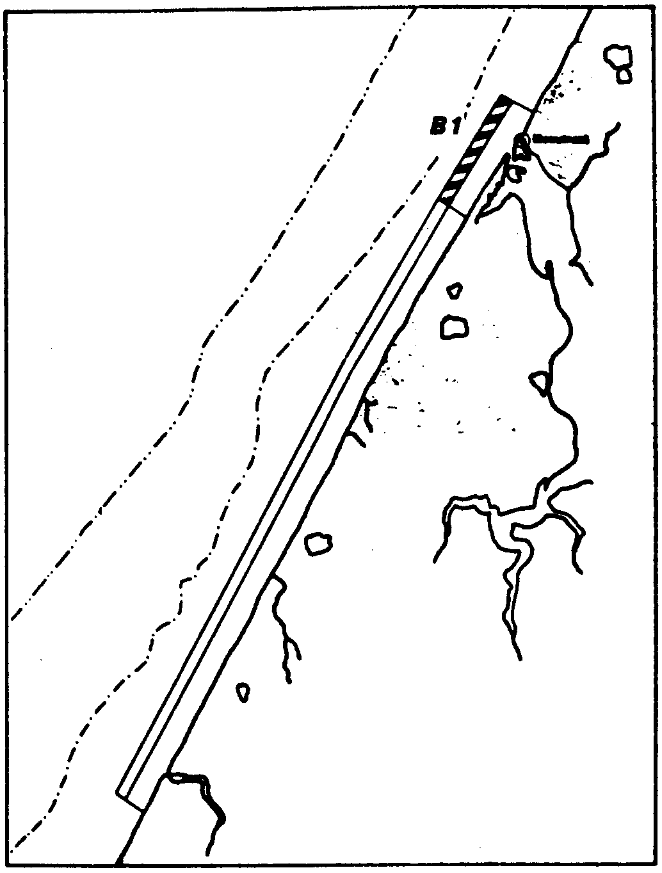
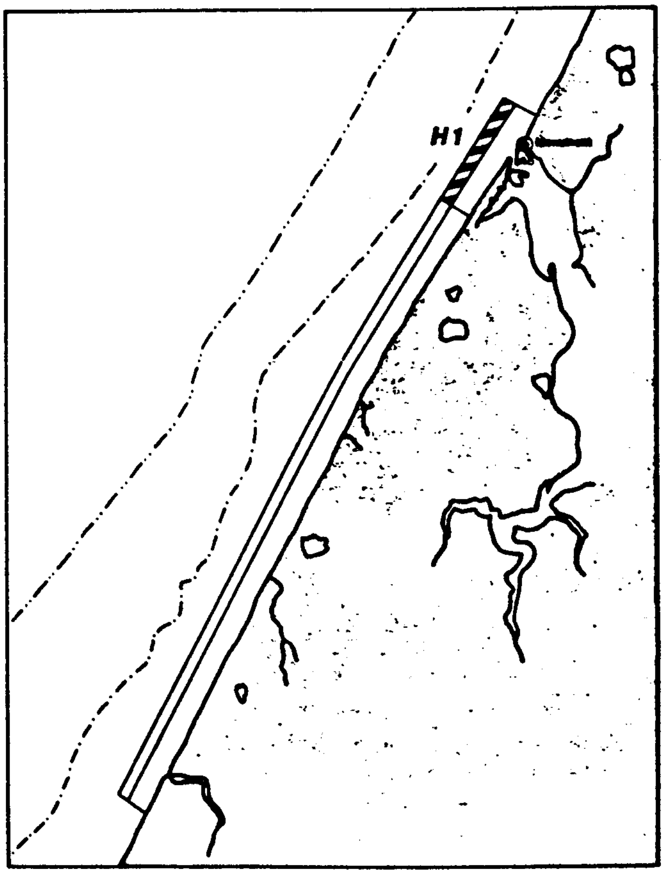


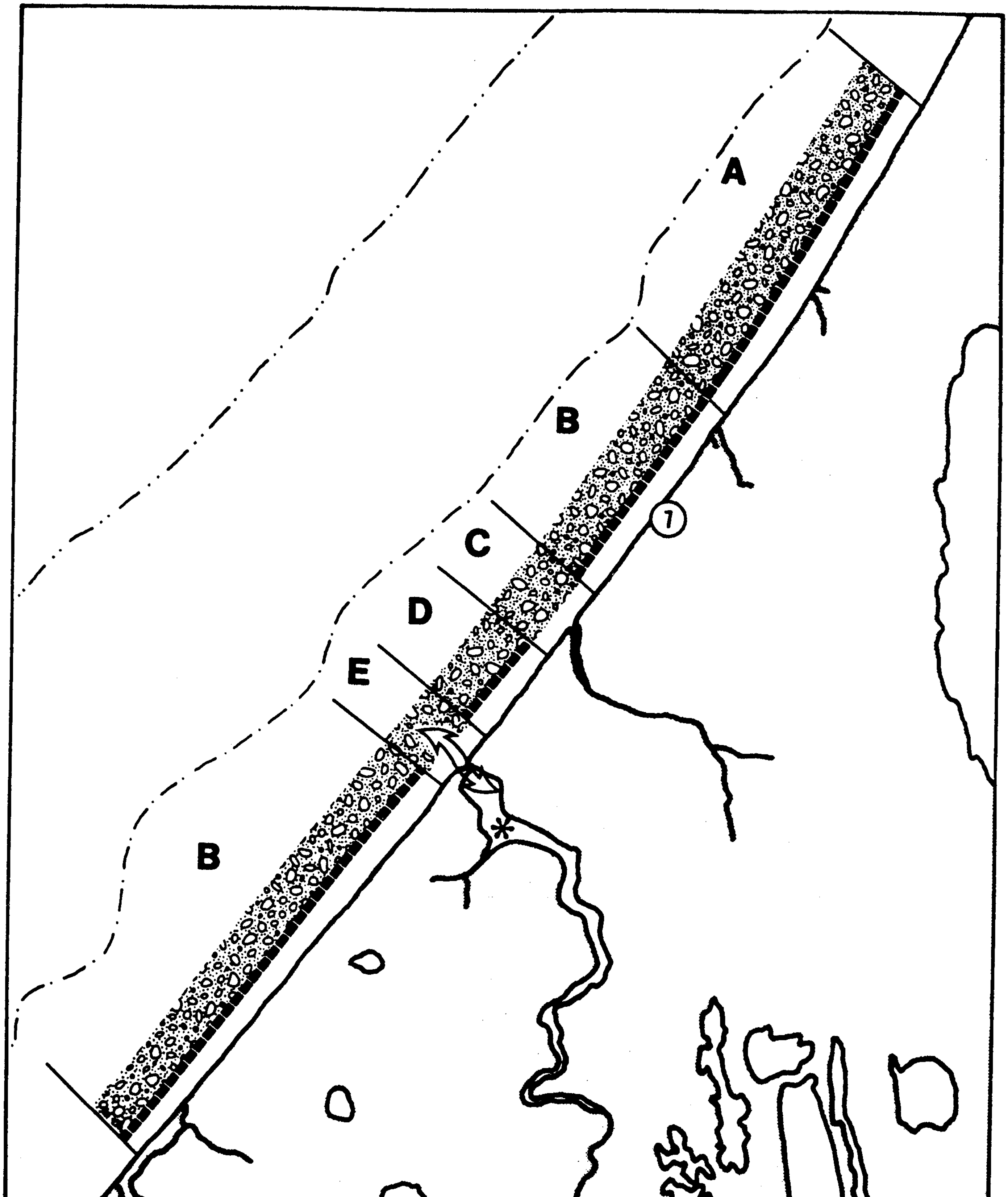
HUMAN USE INDEX



Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Lagoon				■	■	■		
B1	Lagoon				▨	▨	▨	▨	
H1	Resident recreation			▨	▨	▨	▨	▨	

5


A
B
7
C
D
E
B
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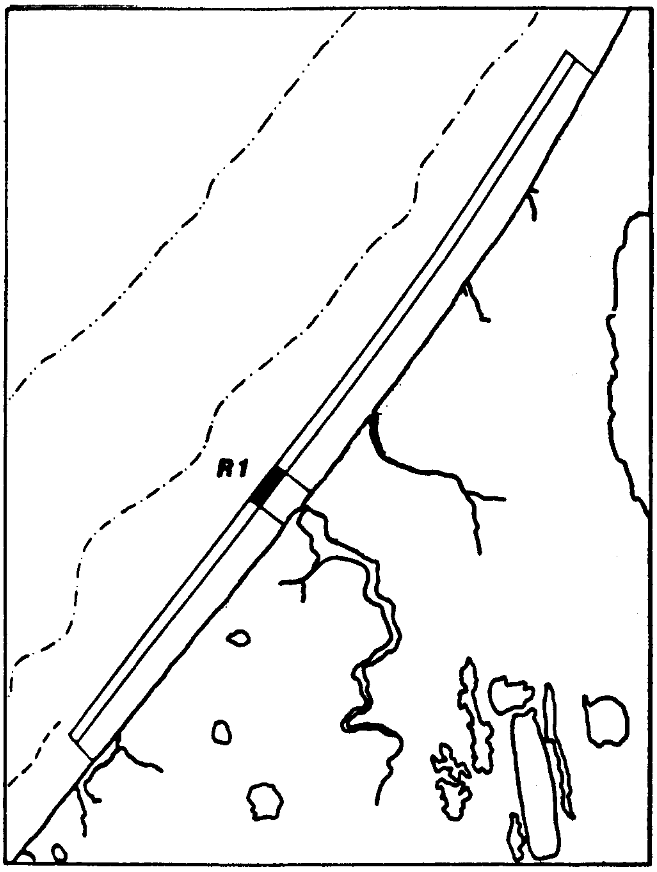
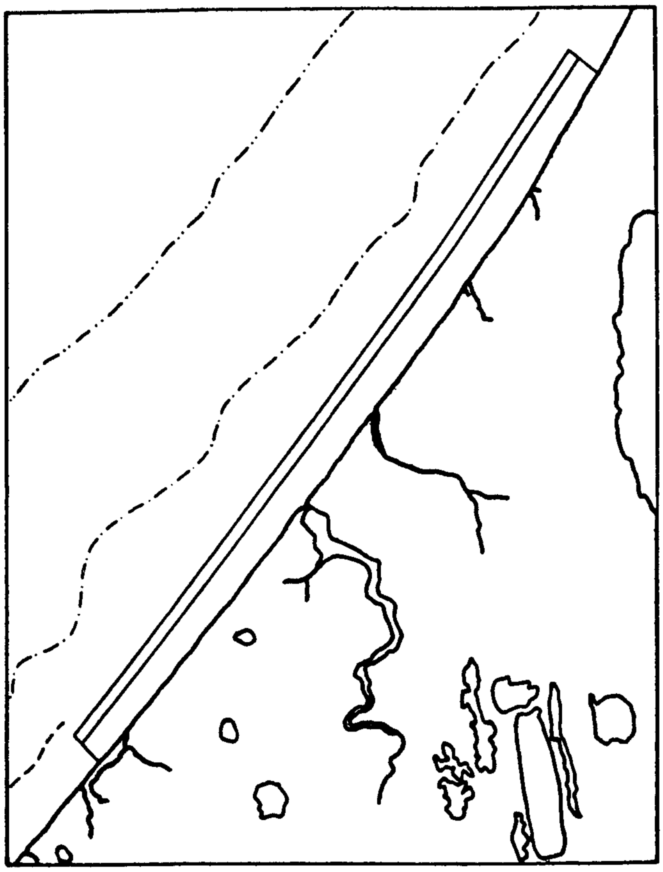
6

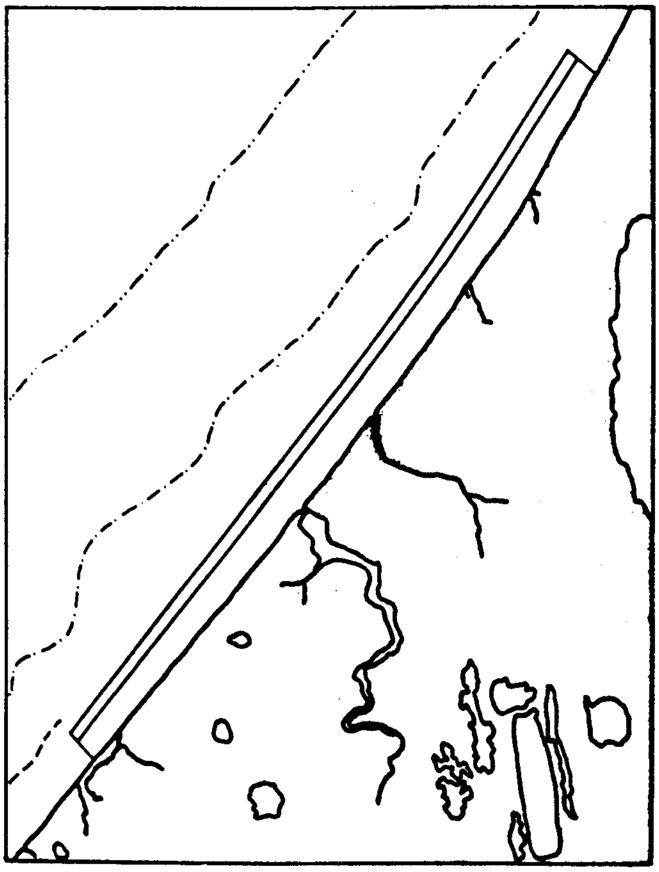
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



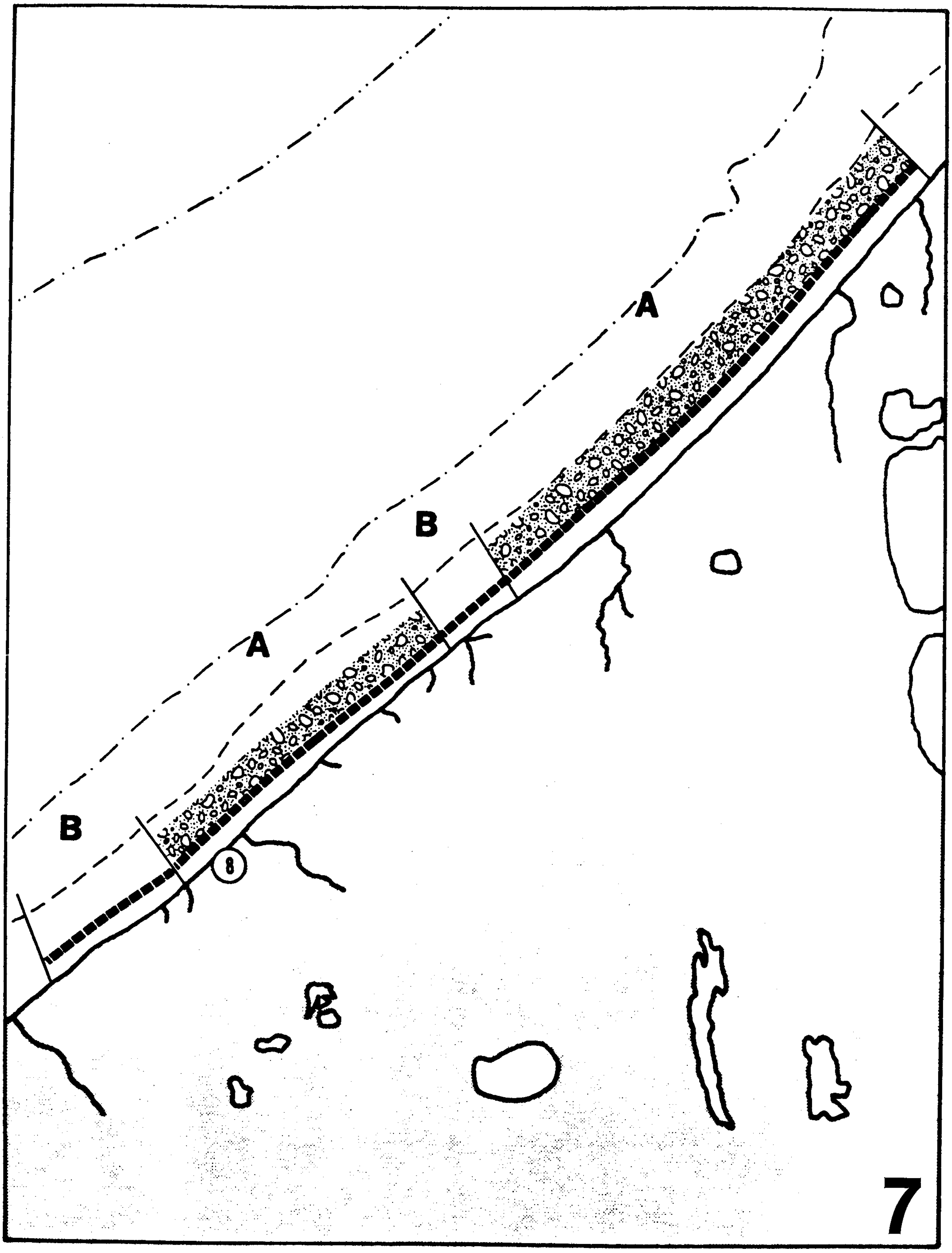
HUMAN USE INDEX



Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Lagoon				■	■	■		

6


A
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A
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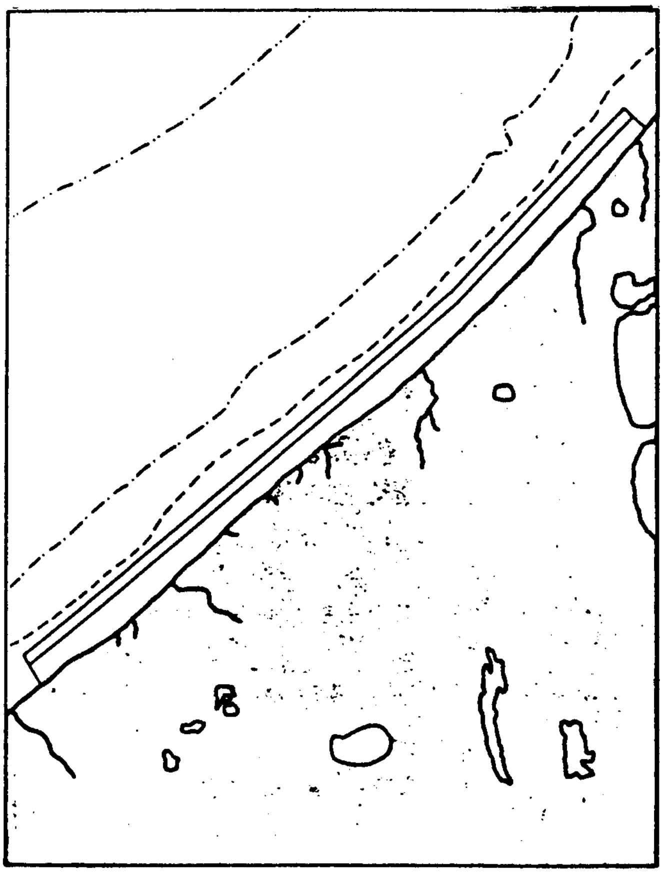
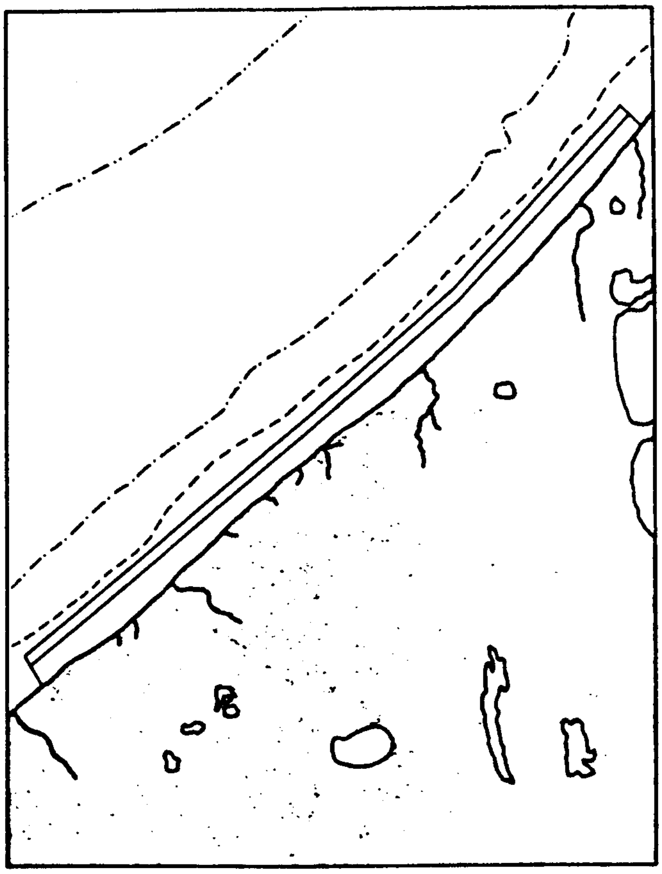
7

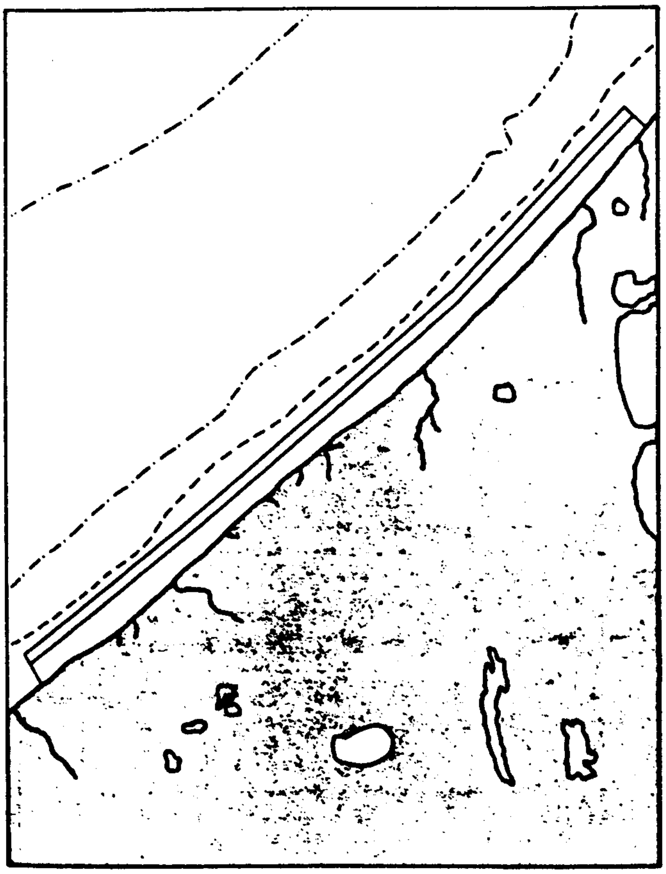
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



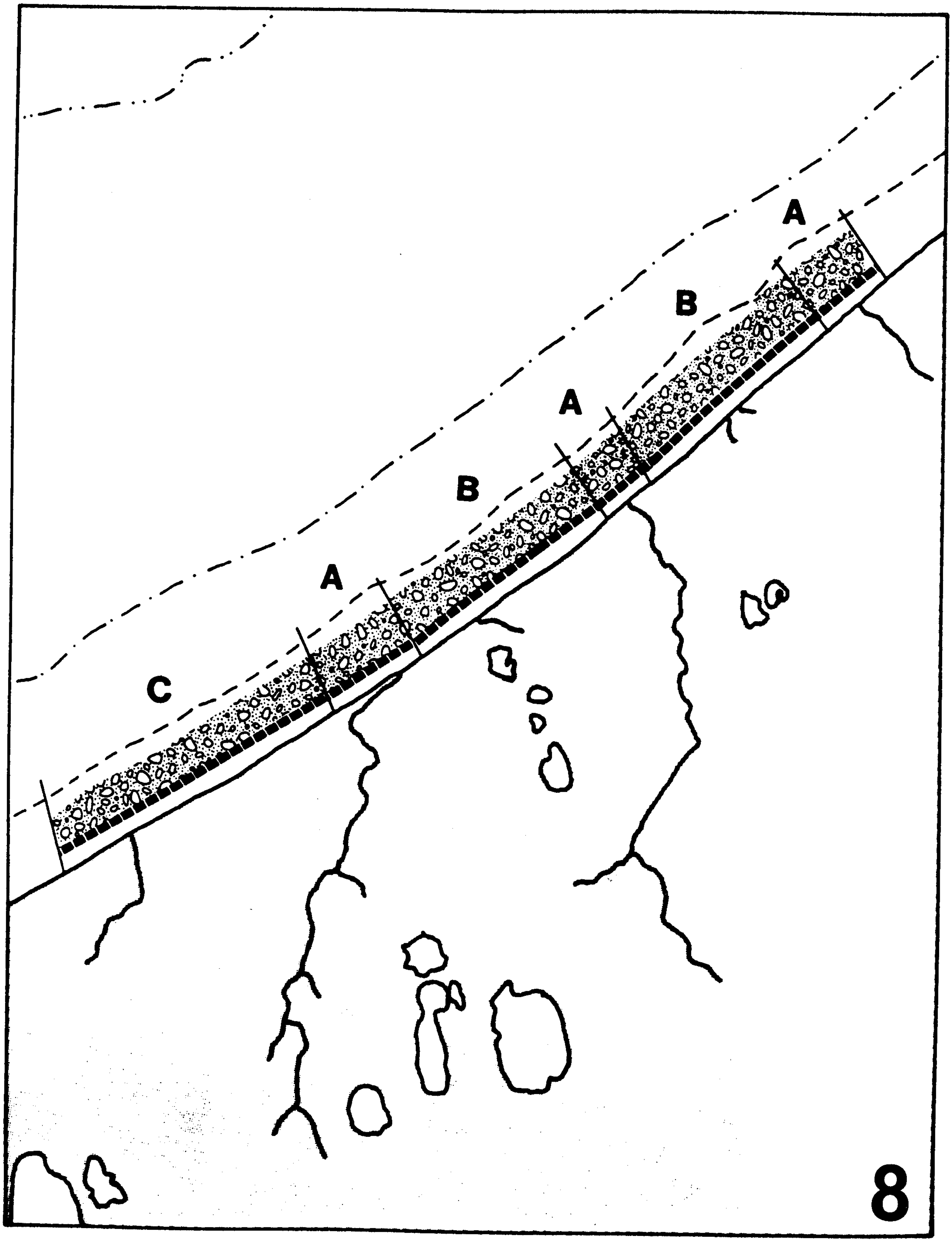
HUMAN USE INDEX



Seasonal Variability of Indices

		SEASON							
Identi-fier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
	NO PRIMARY OR SECONDARY SENSITIVITIES								

7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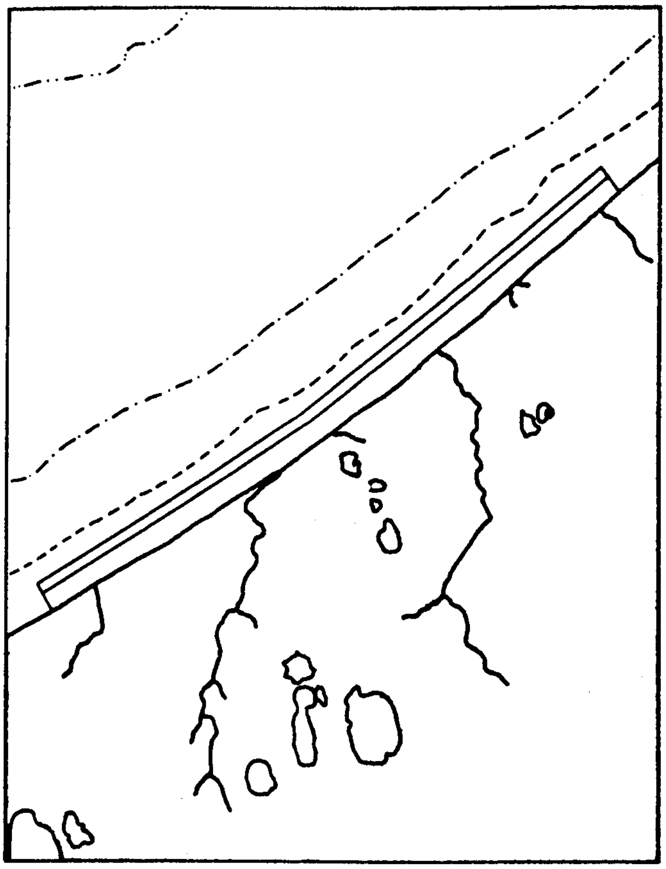
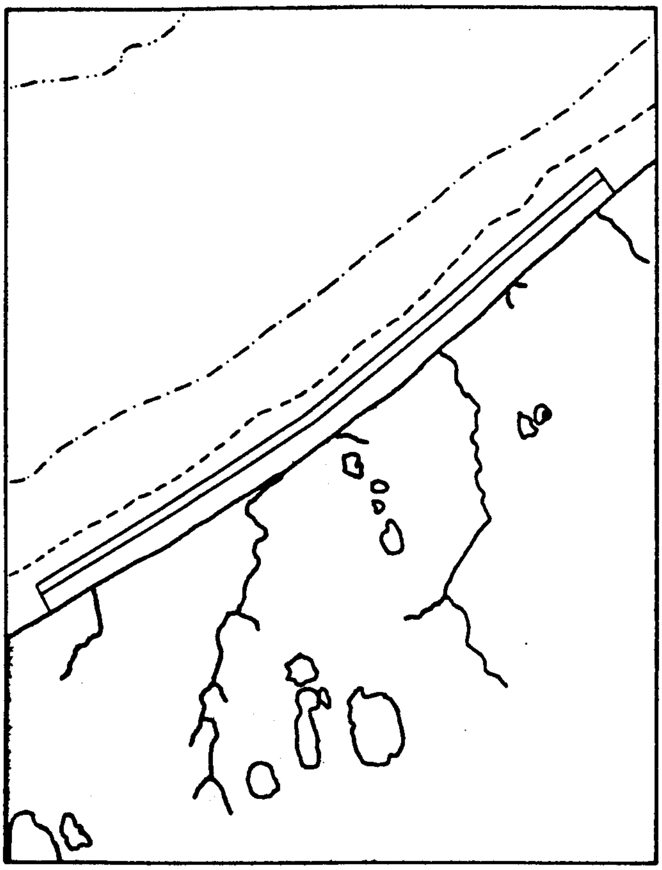
A
B
A
C
8

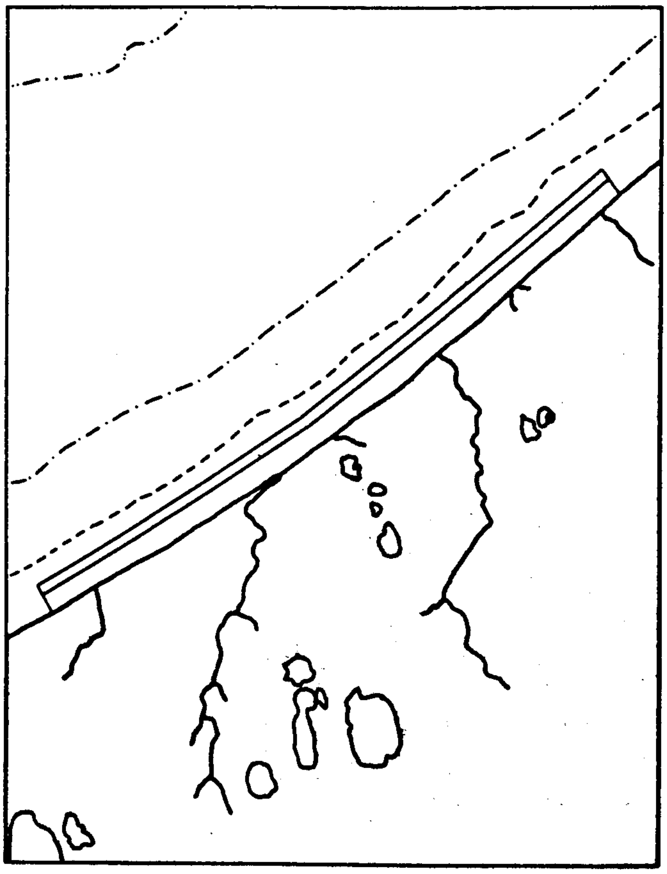
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



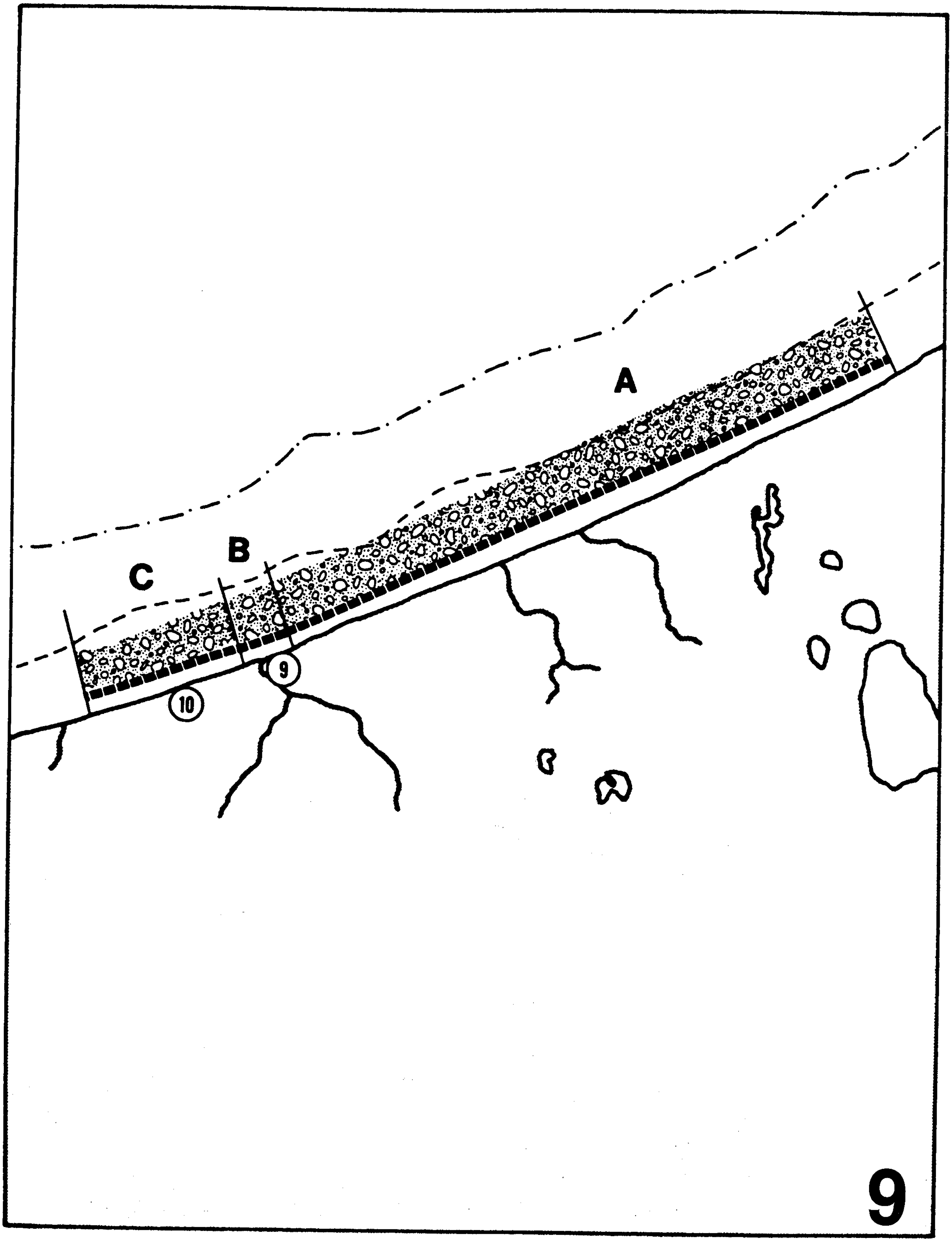
HUMAN USE INDEX



Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
	NO PRIMARY OR SECONDARY SENSITIVITIES								

8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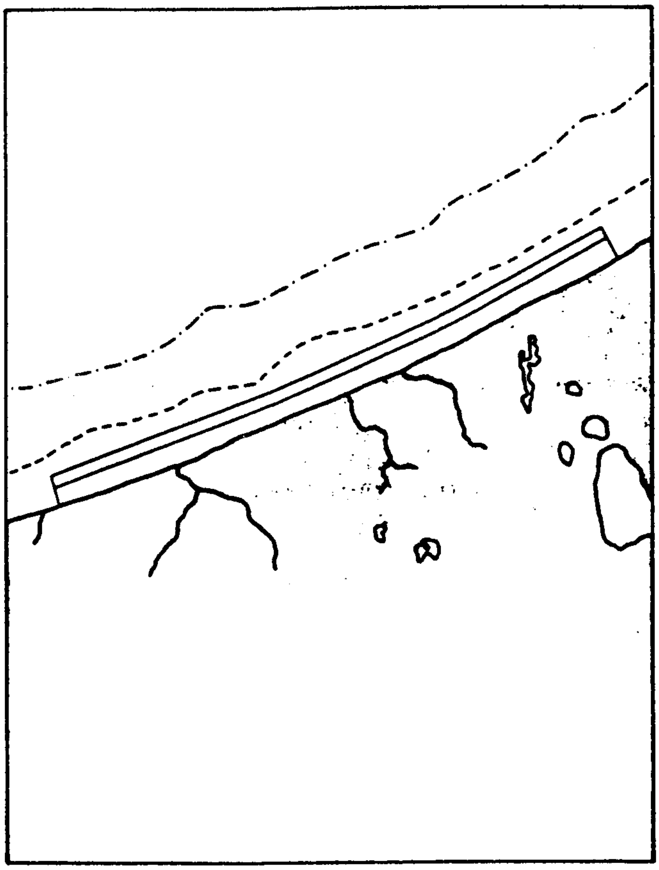
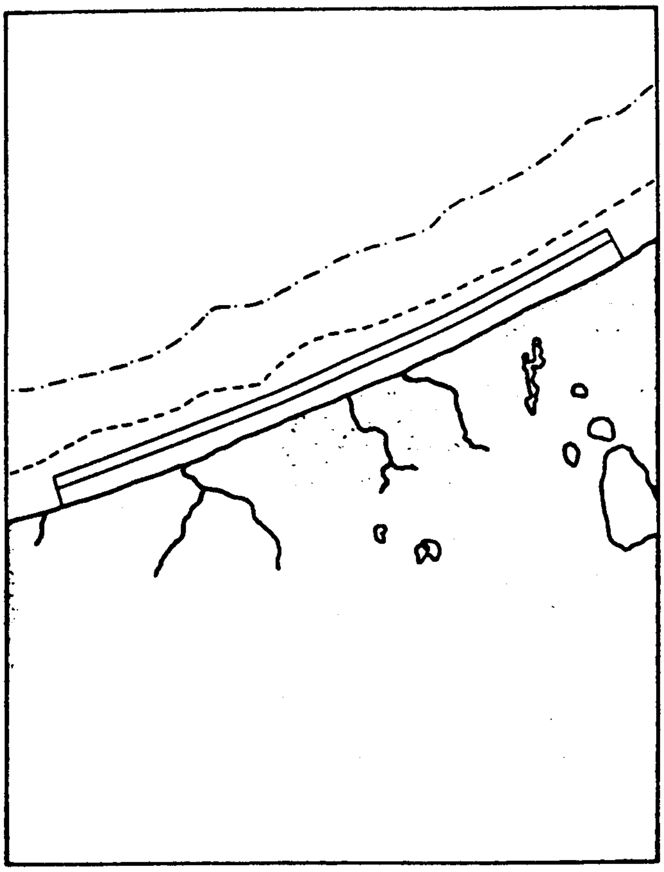
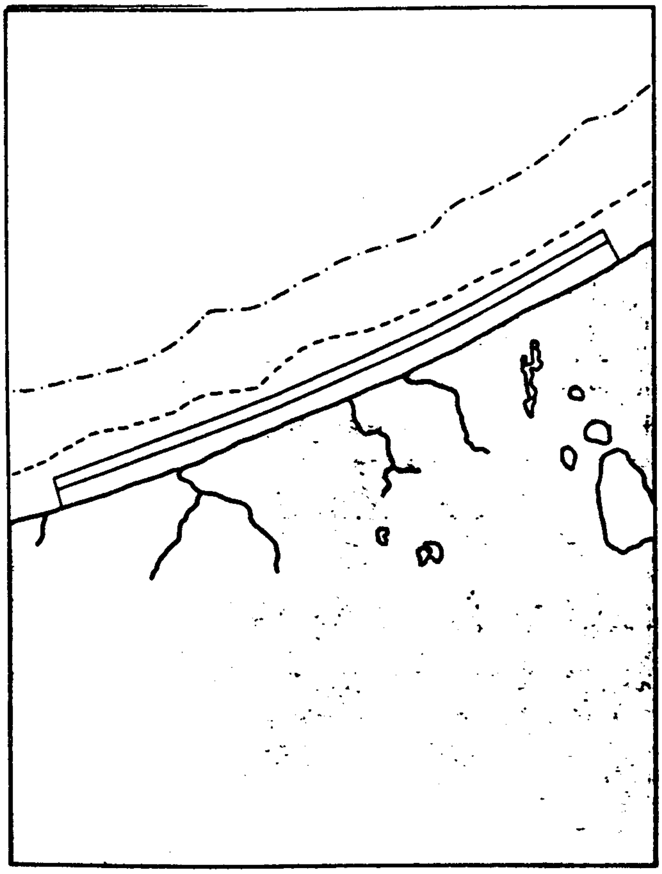
9



OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX

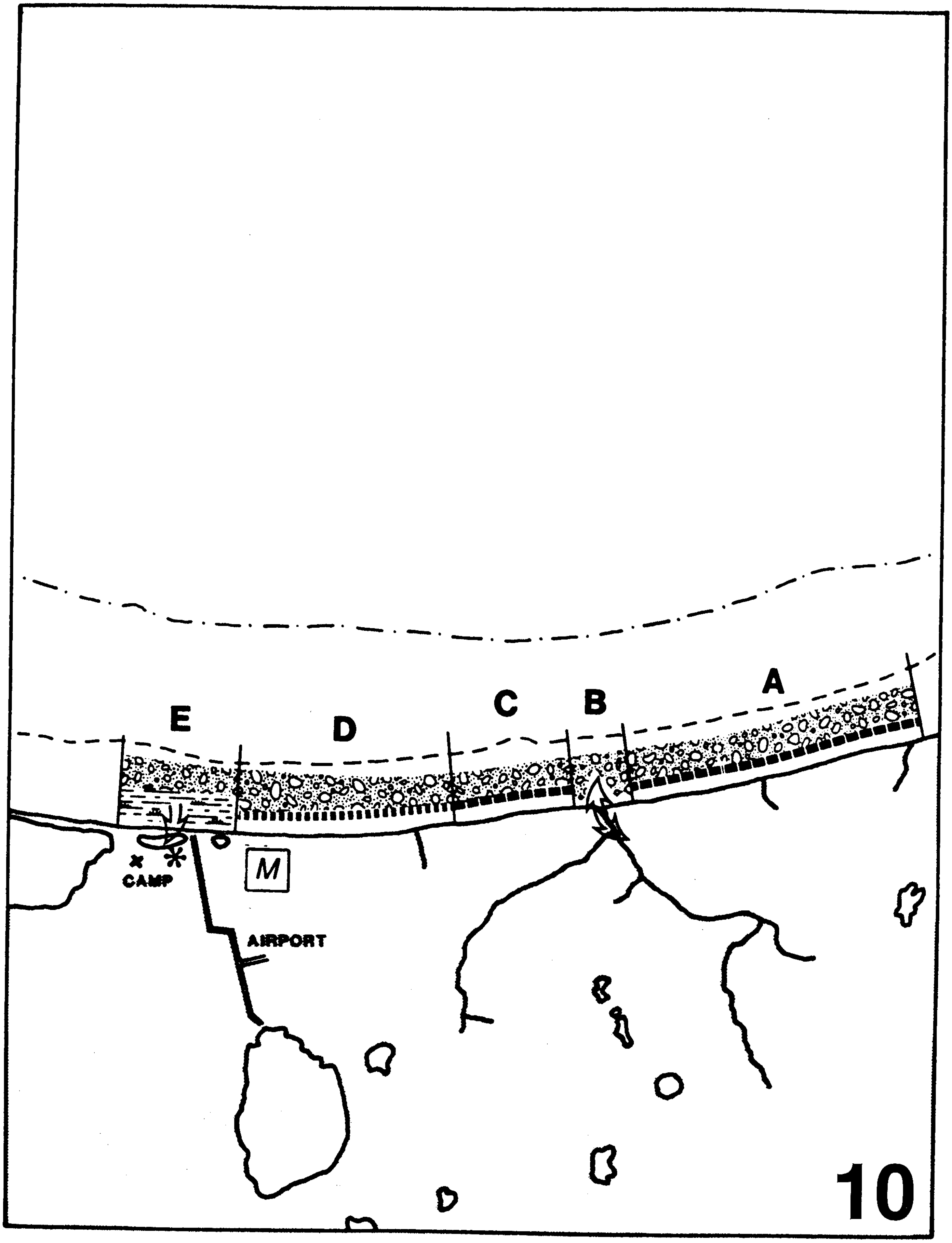


HUMAN USE INDEX

Seasonal Variability of Indices

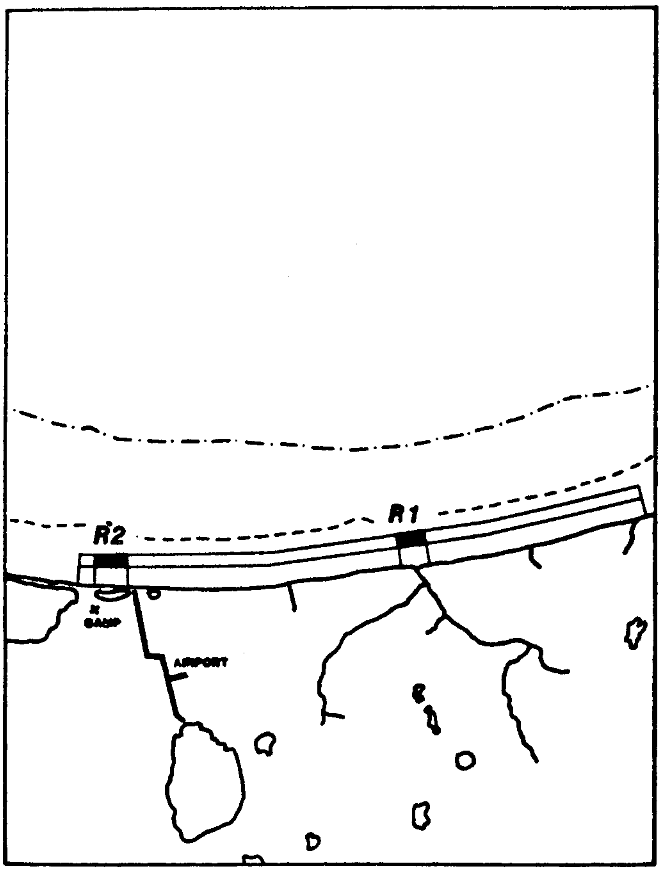
		SEASON							
			Break-Up/Summer/Freeze-Up						
Identi-fier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
	NO PRIMARY OR SECONDARY SENSITIVITIES								

9

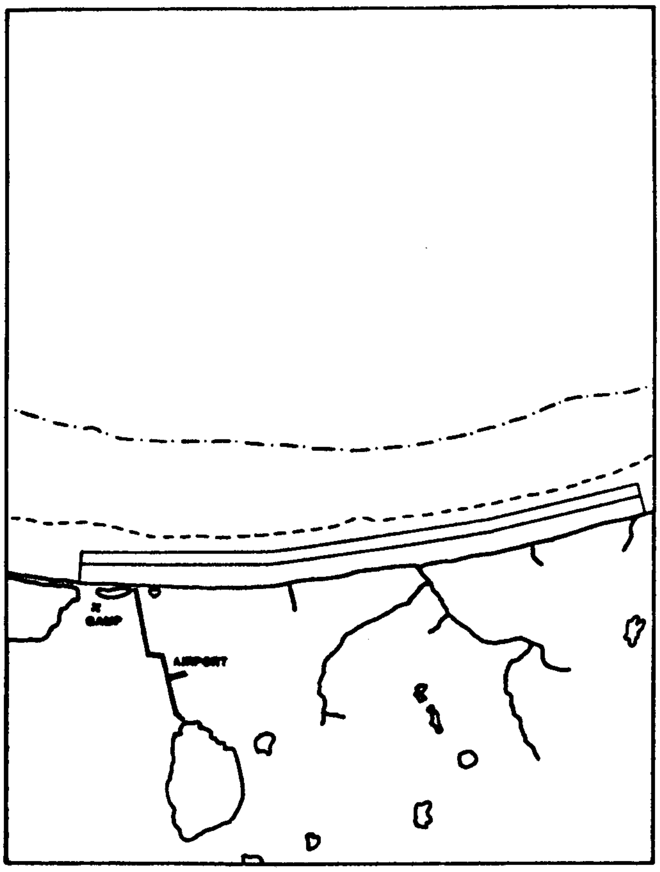


10

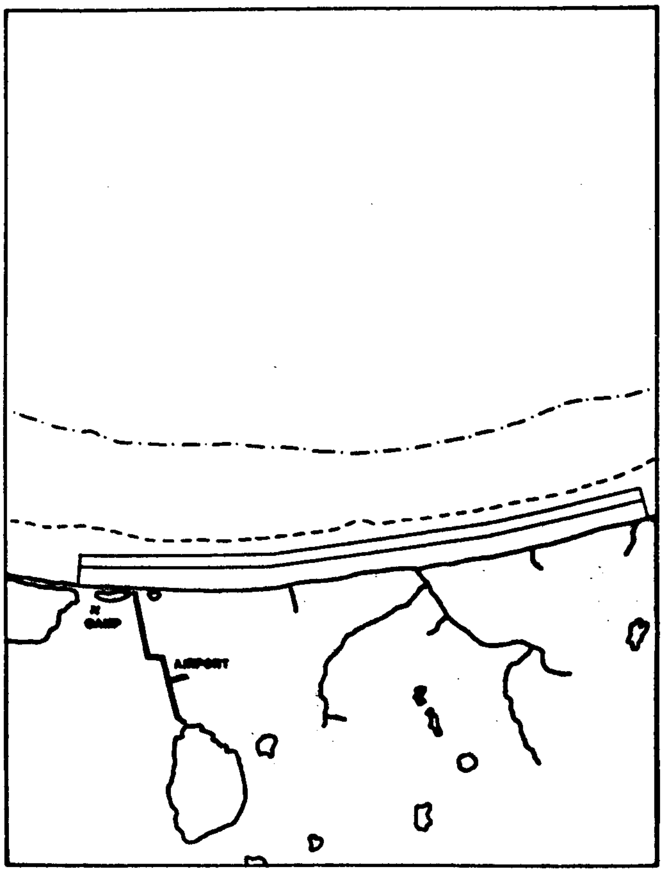
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



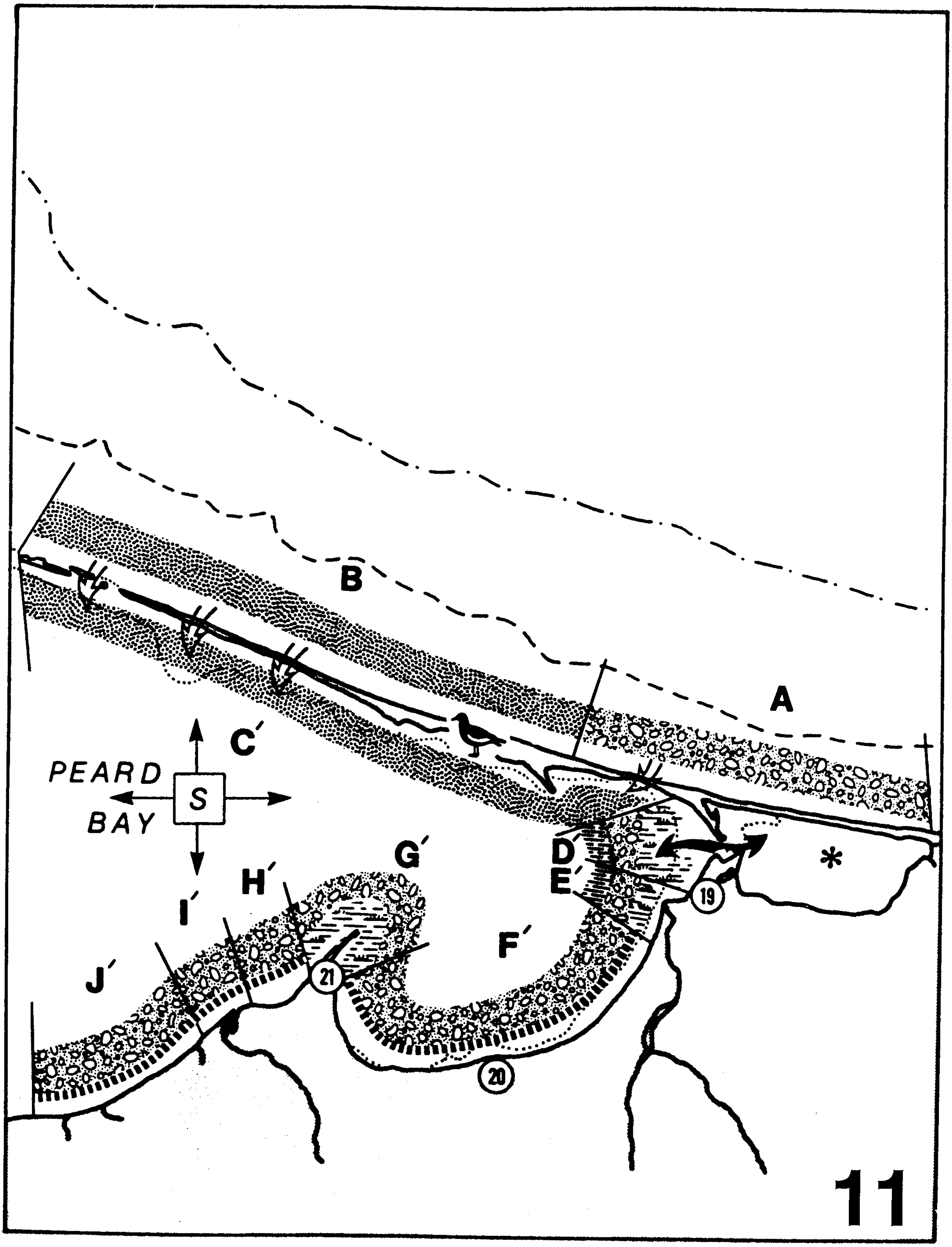
HUMAN USE INDEX



Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Lagoon				■	■	■		
R2	Washover channel; Wetland				■	■	■		

10


B
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BAY
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I′
J′
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19
20
21
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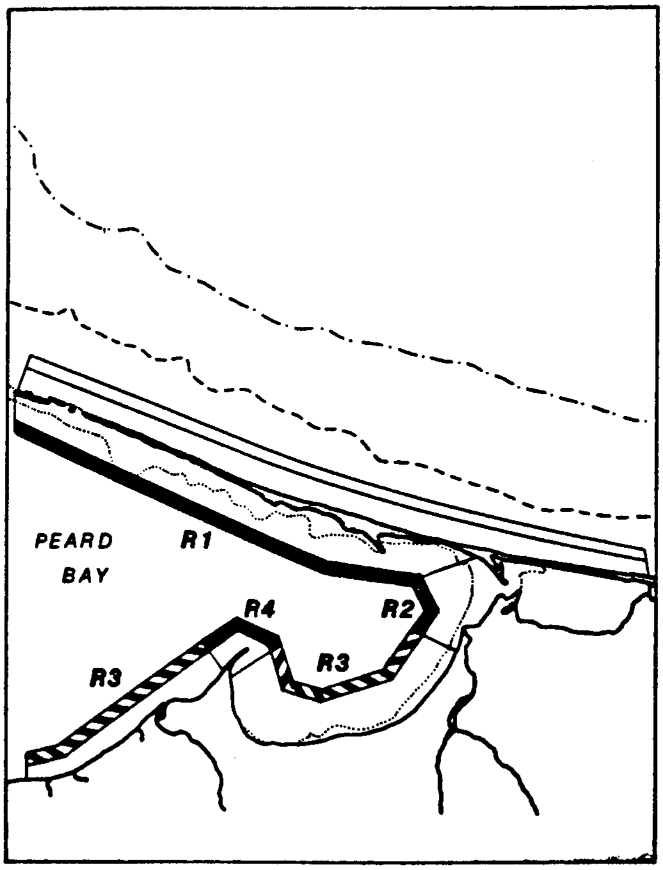
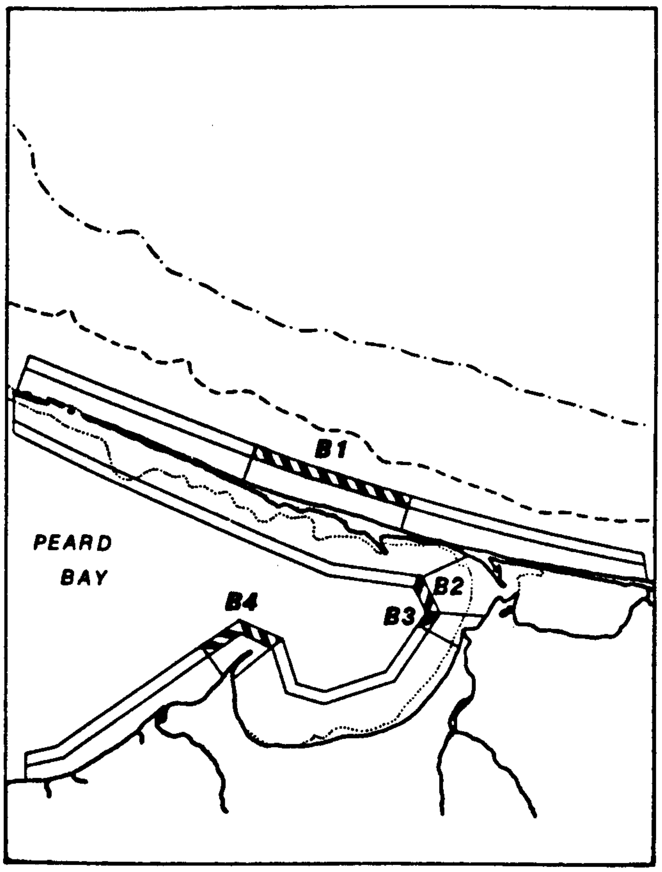
11

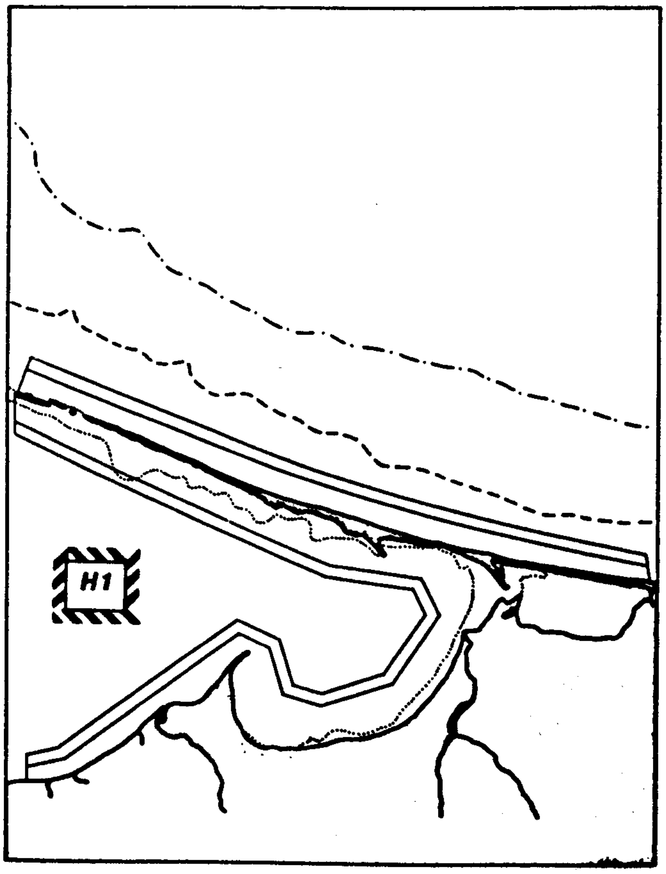
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



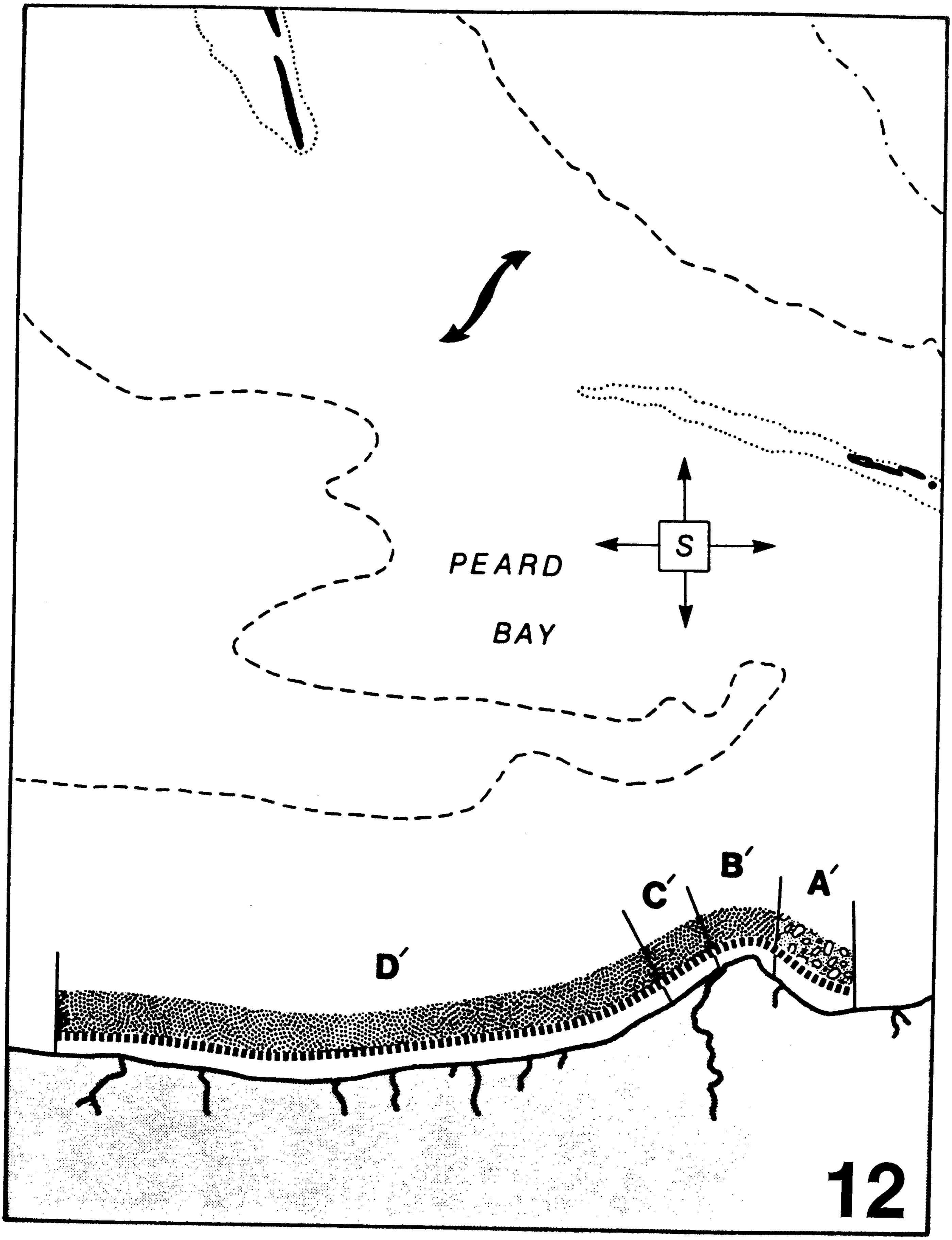
HUMAN USE INDEX



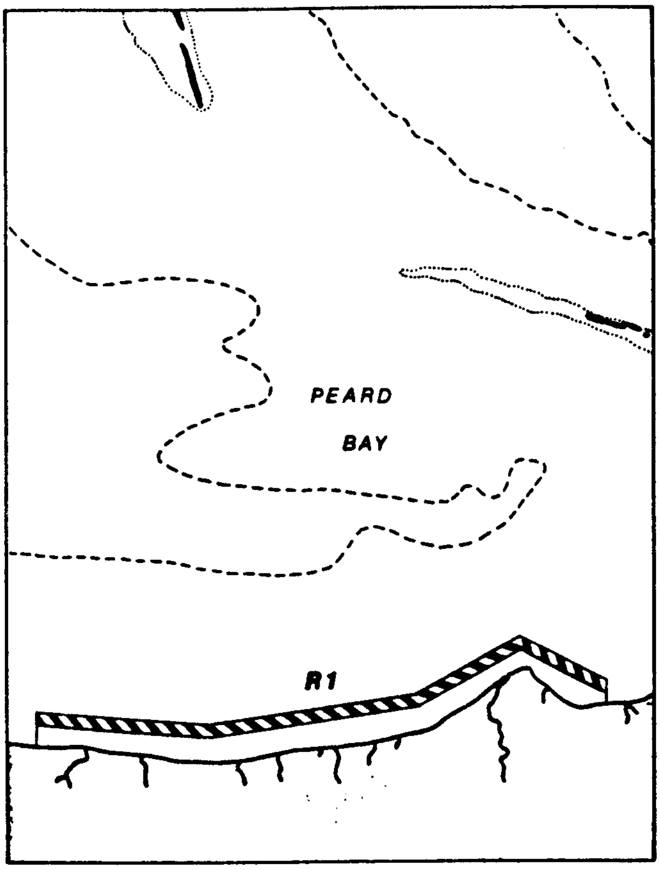
Seasonal Variability of Indices

		SEASON							
			Break-Up/Summer/Freeze-Up						
Identifier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Low energy beach				■	■	■		
R2	Lagoon				■	■	■		
R3	Protected tundra cliff				▨	▨	▨		
R4	Low energy beach; Wetland				■	■	■		
B1	Arctic tern nesting (25 pr)			▨	▨				
B2	Lagoon				▨	▨	▨		
B3	Wetland			▨	▨	▨	▨	▨	
B4	Wetland				▨	▨	▨		
H1	Beluga whale hunting				▨	▨			

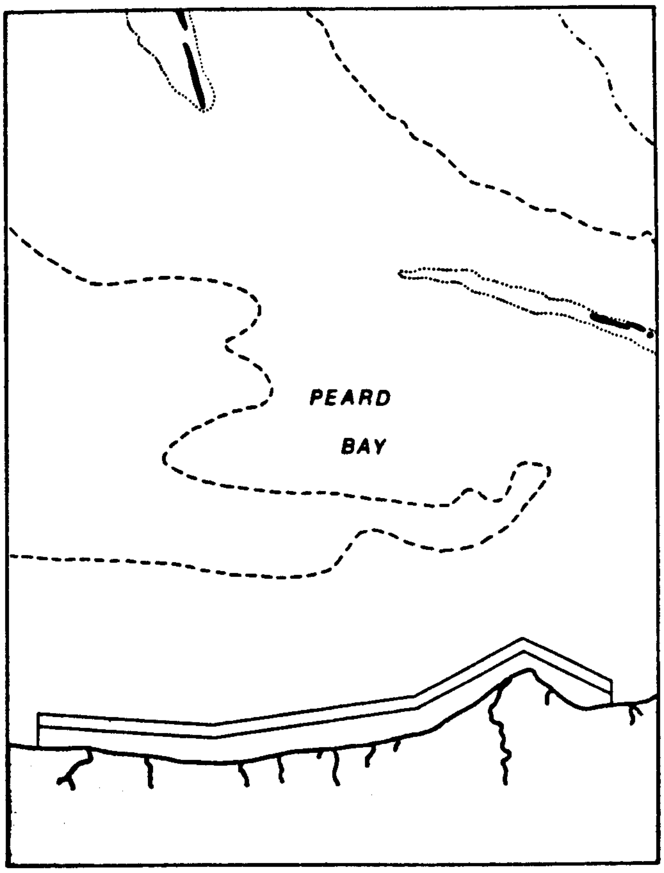
11


PEARD
BAY
S
A′
B′
C′
D′
12

OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



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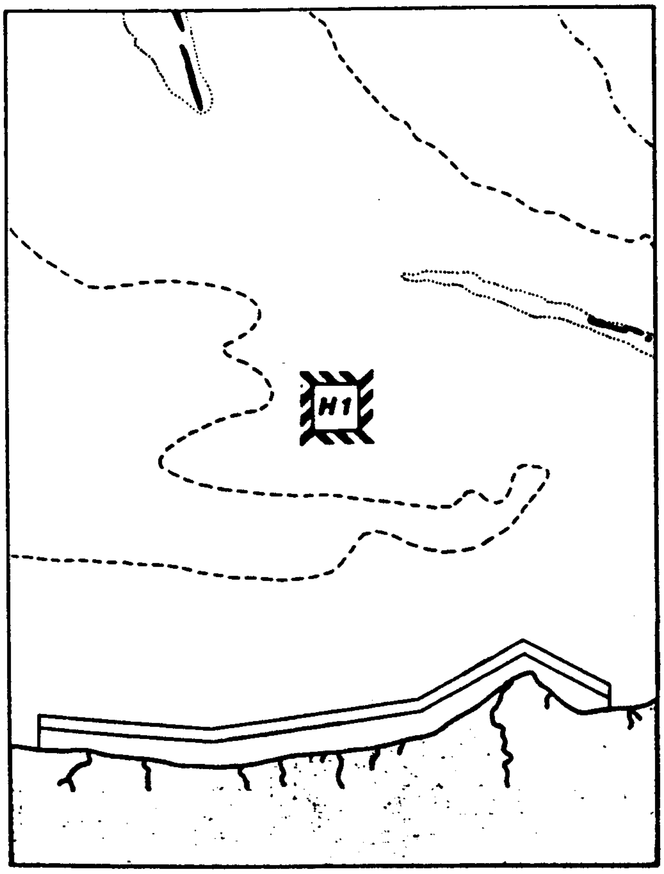
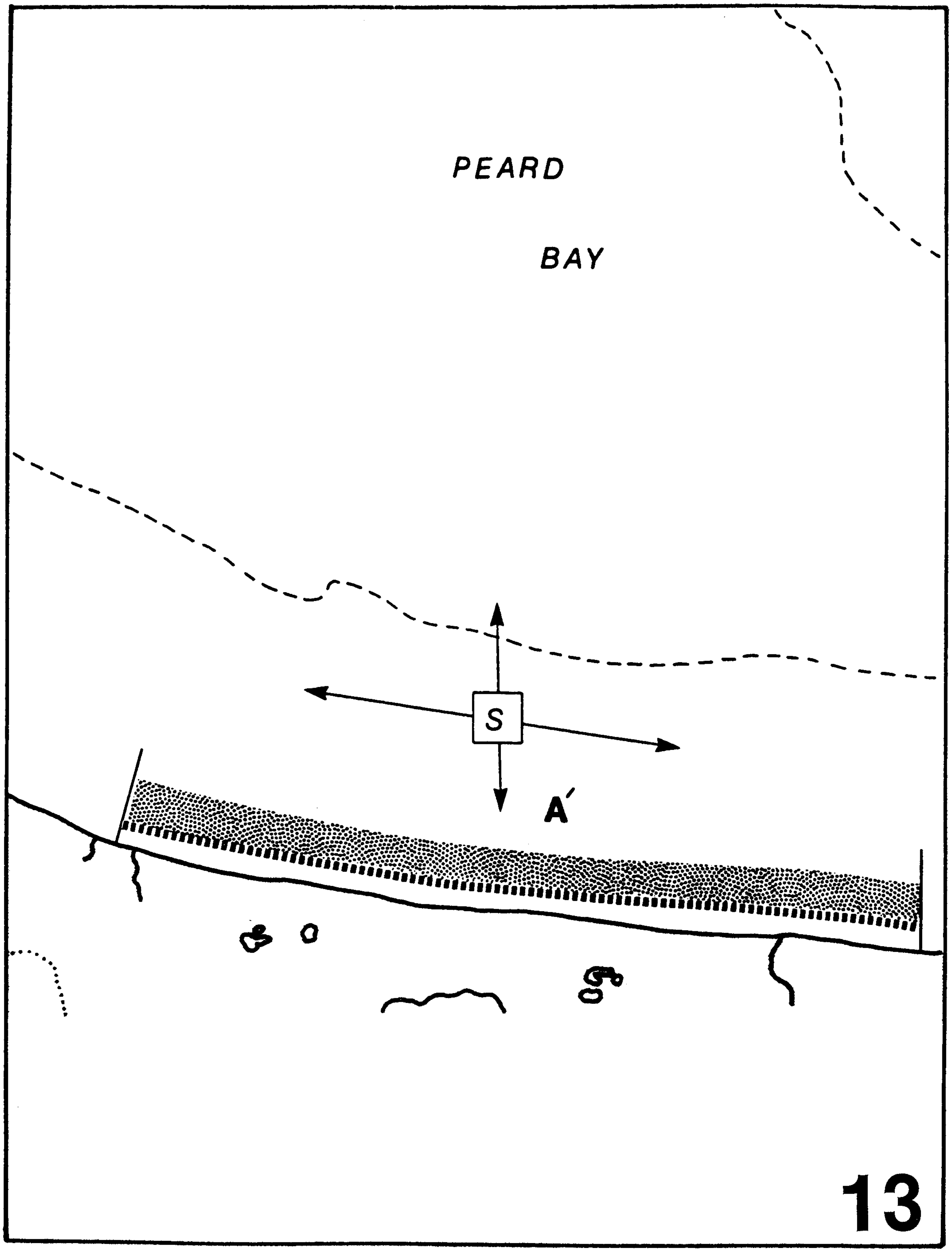


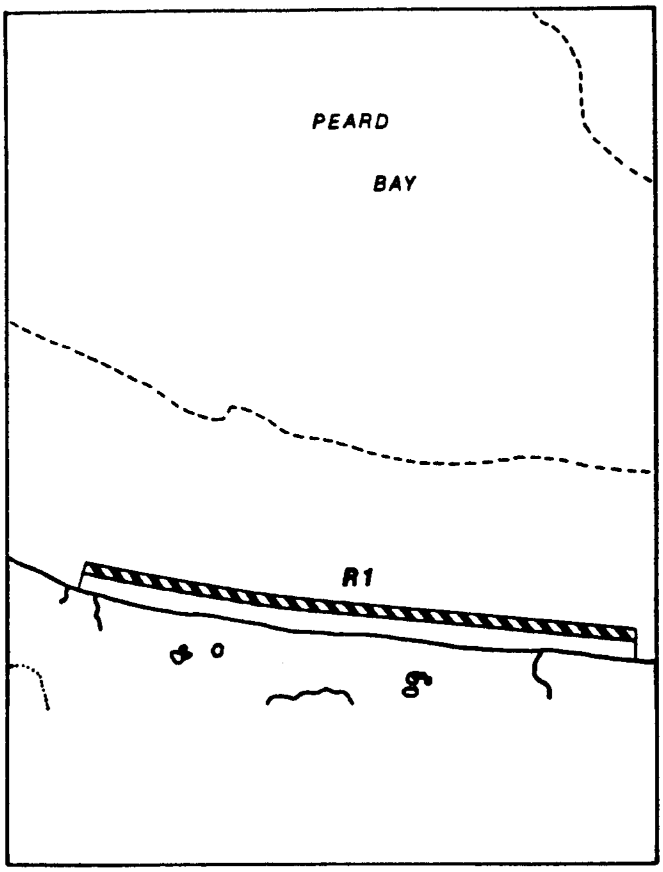
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff				▨	▨	▨		
H1	Beluga whale hunting				▨	▨			

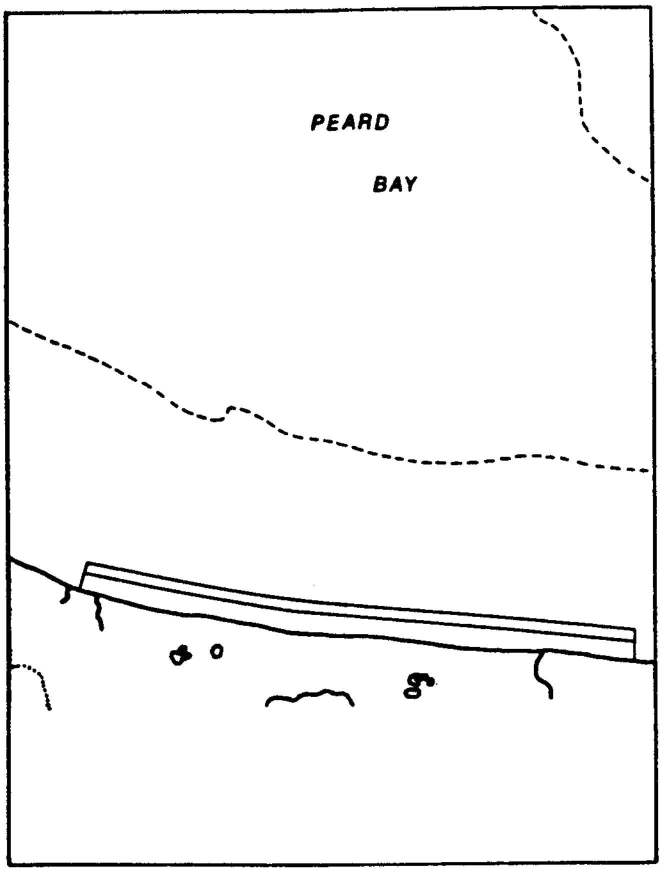
12


PEARD
BAY
S
A′
13

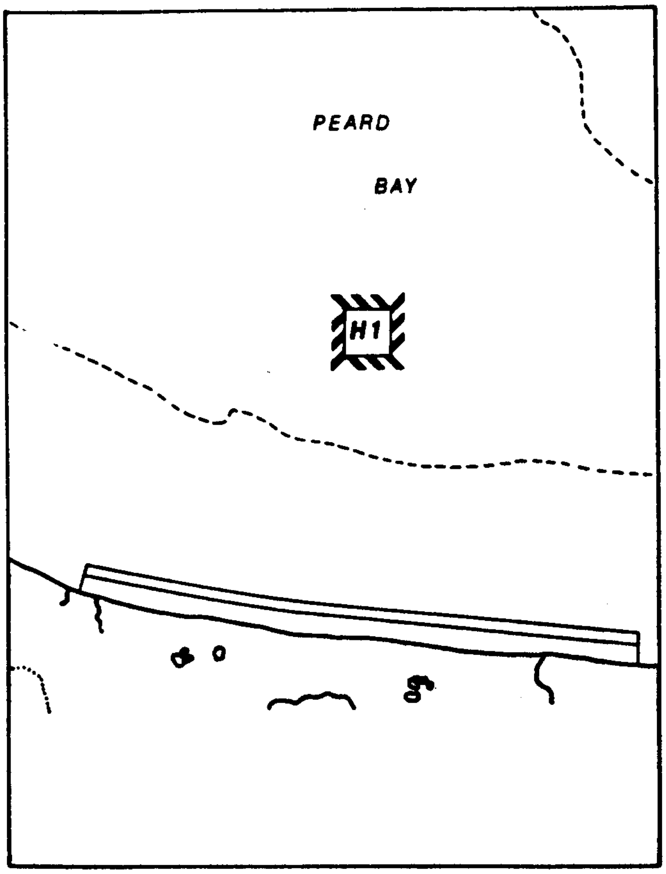
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



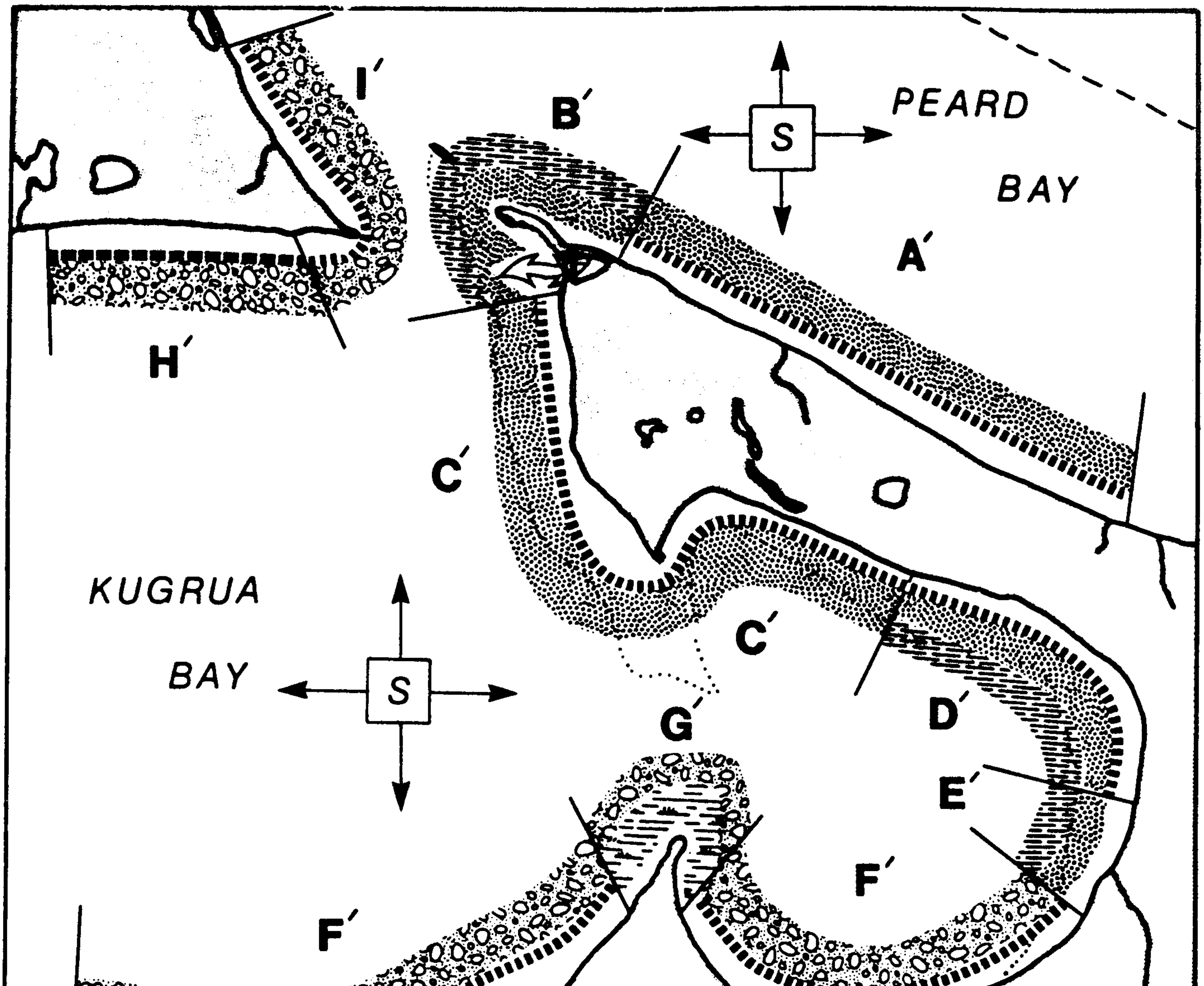
HUMAN USE INDEX



Seasonal Variability of Indices

		SEASON							
			Break-Up/Summer/Freeze-Up						
Identifier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Protected tundra cliff				▨	▨	▨		
H1	Beluga whale hunting				▨	▨			

13


I′
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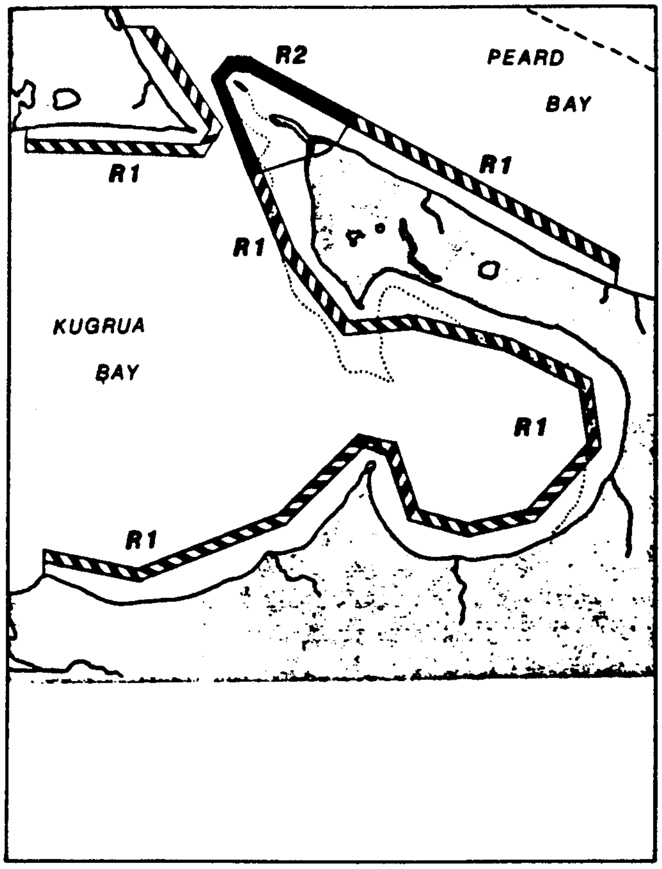
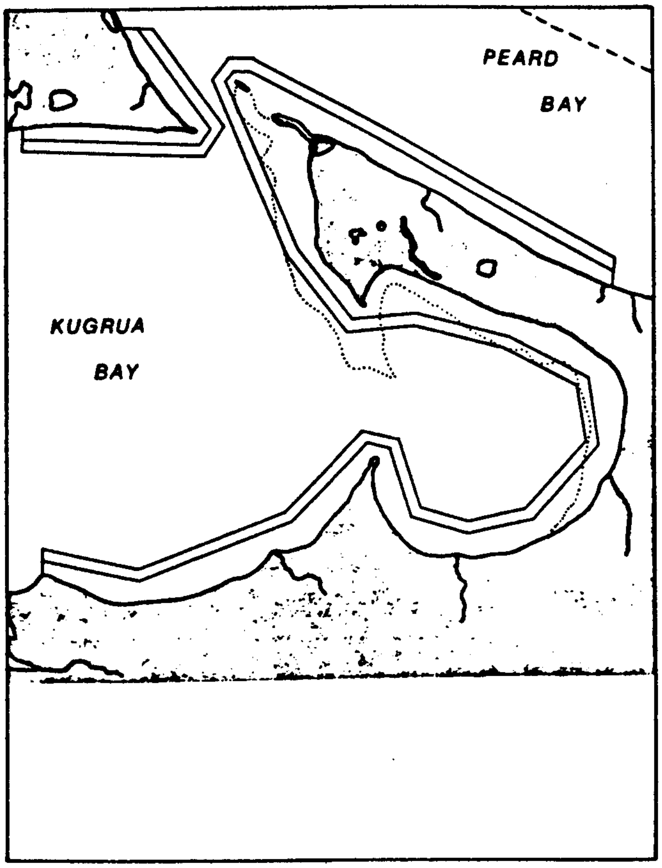
PEARD
S
BAY
A′
H′
C′
KUGRUA
BAY
S
C′
G′
D′
E′
F′
F′
14

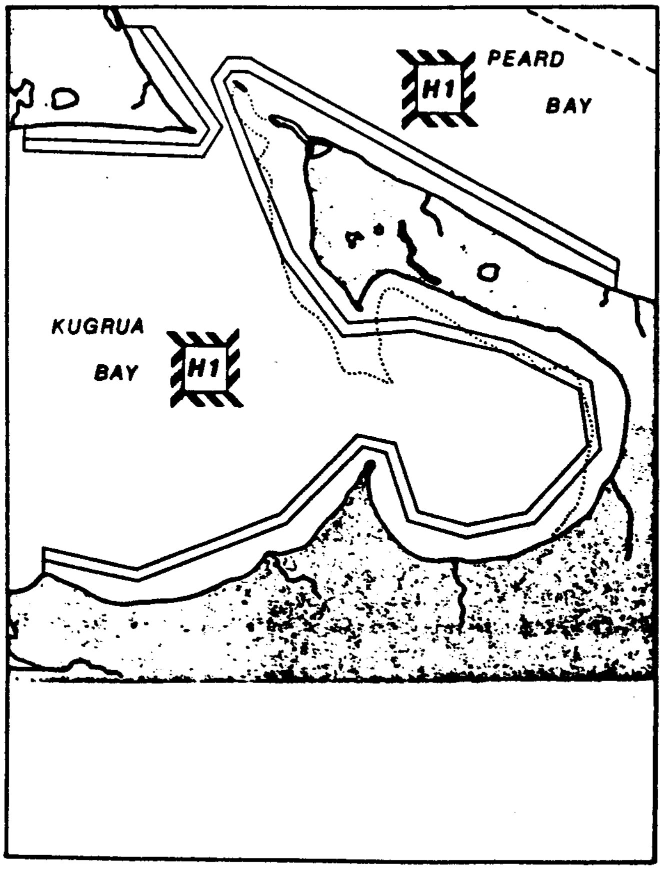
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



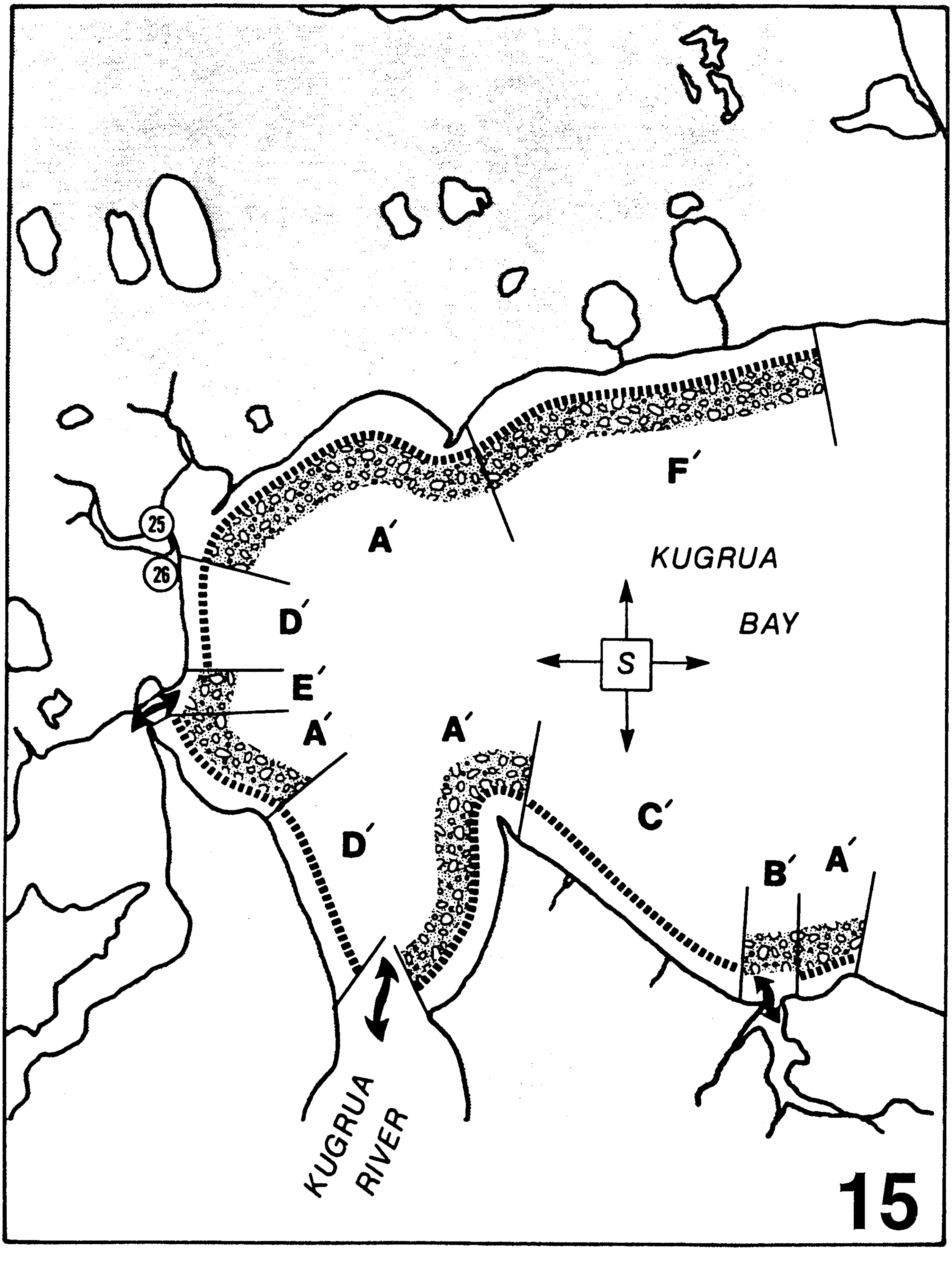
HUMAN USE INDEX



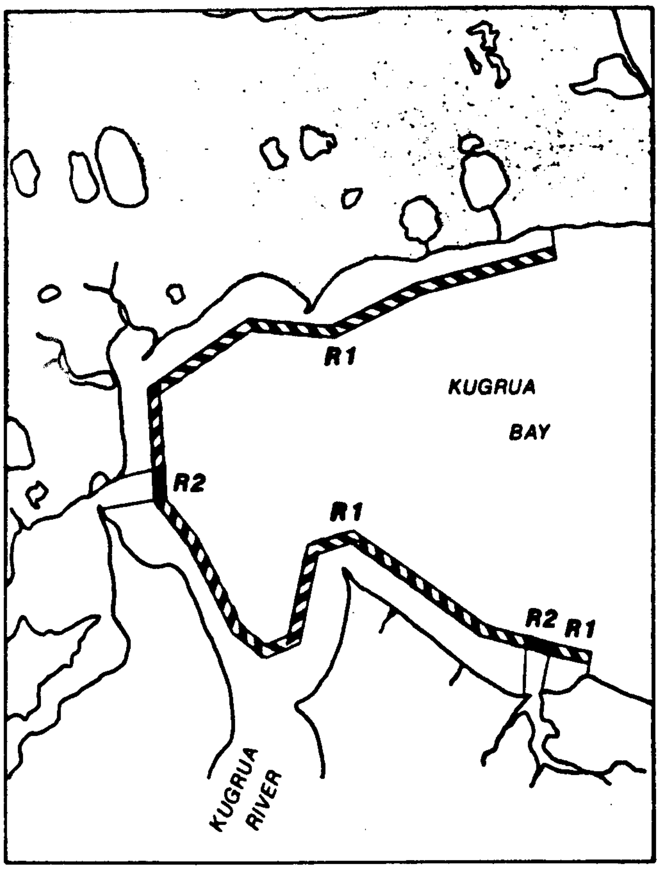
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff				▨	▨	▨		
R2	Low energy beach				■	■	■		
H1	Beluga whale hunting				▨	▨			
	Fishing			▨	▨	▨	▨		

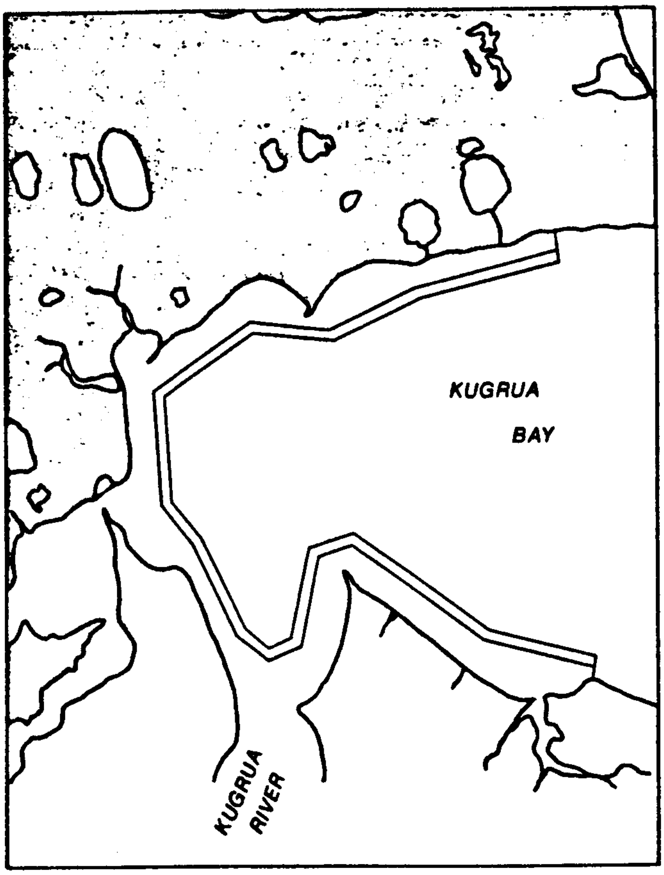
14


15
KUGRUA
BAY
S
A′
F′
25
26
D′
E′
A′
A′
C′
D′
B′
A′
KUGRUA
RIVER

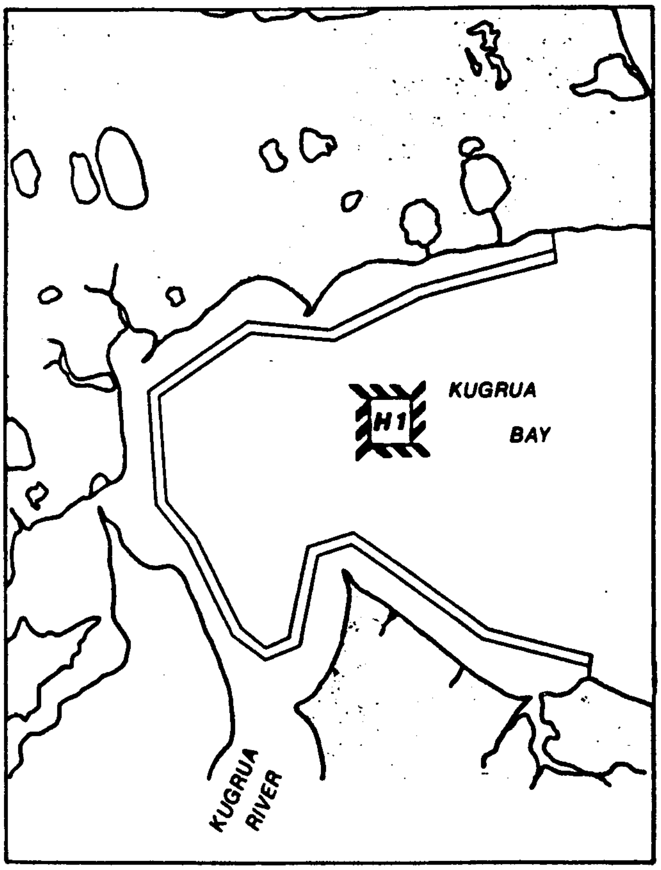
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



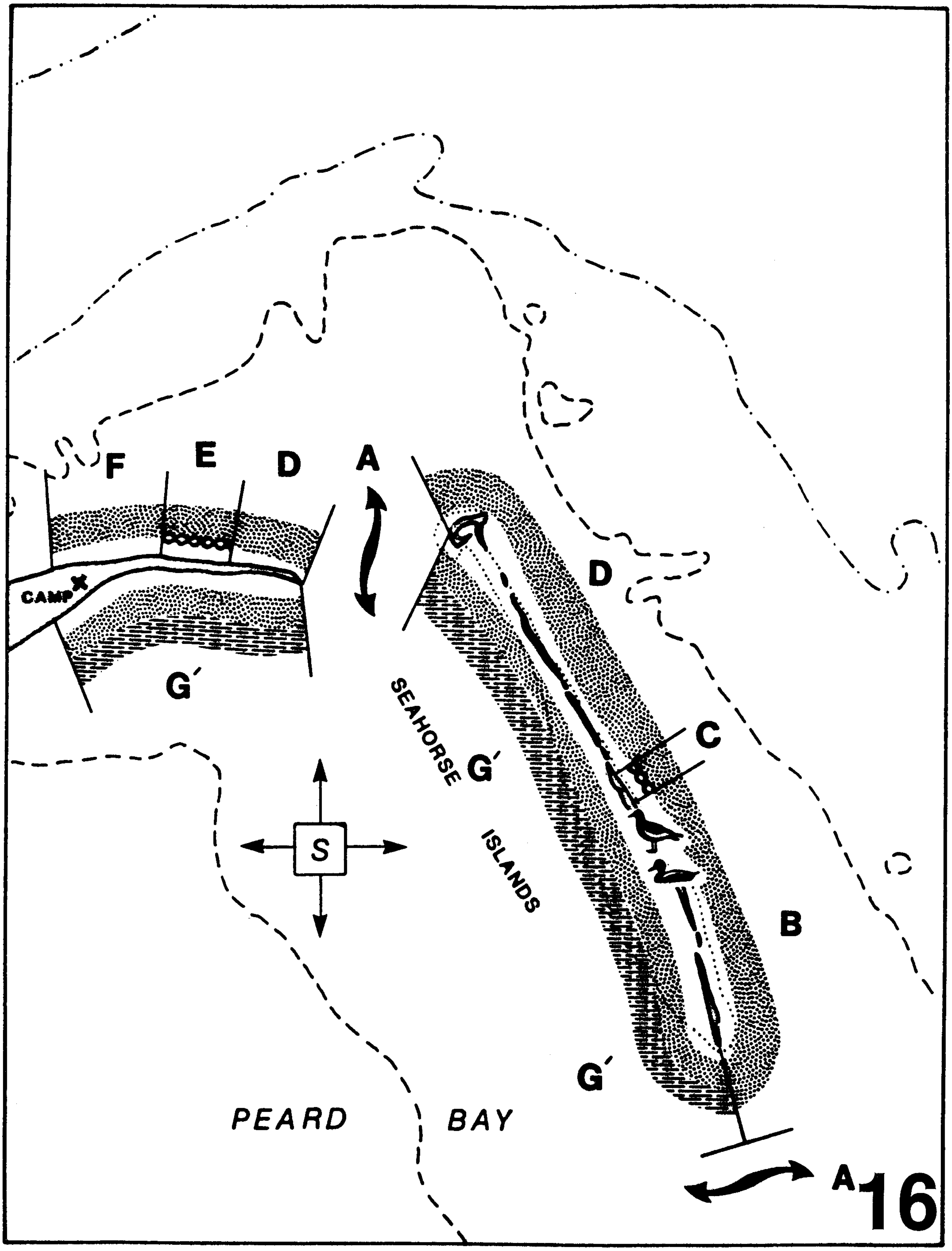
HUMAN USE INDEX



Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff				▨	▨	▨		
R2	Low energy beach				■	■	■		
H1	Spotted seal hunting				▨	▨			
	Fishing				▨	▨	▨		

15


F
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CAMP X
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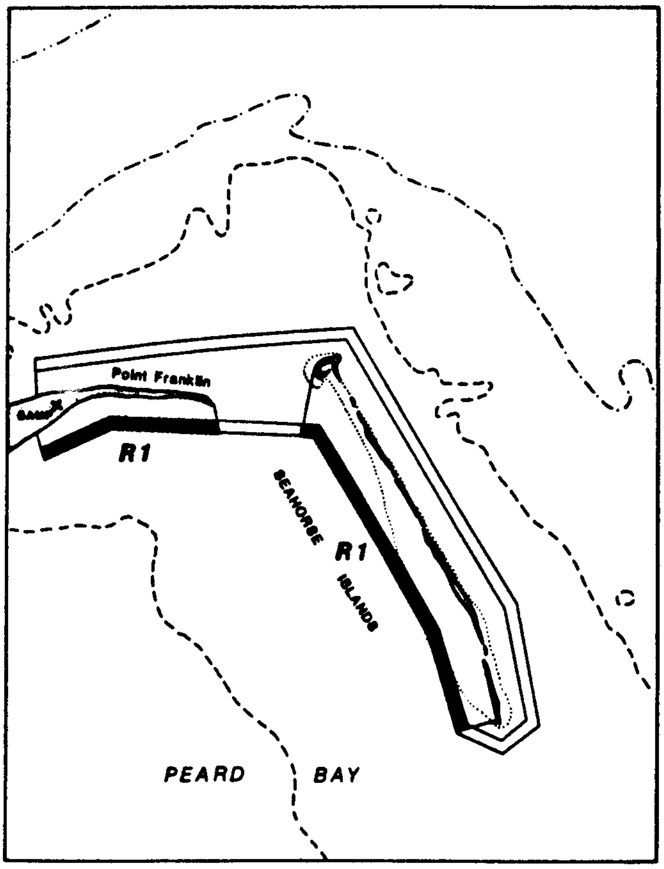
SEAHORSE
ISLANDS
G´
S
B
G´
PEARD
BAY
A
16

OIL RESIDENCE INDEX



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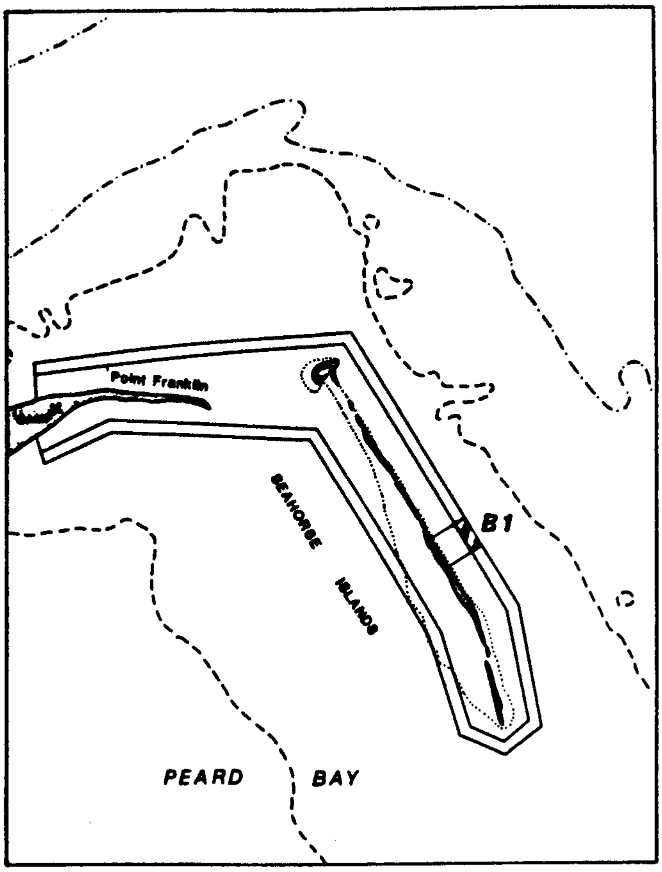
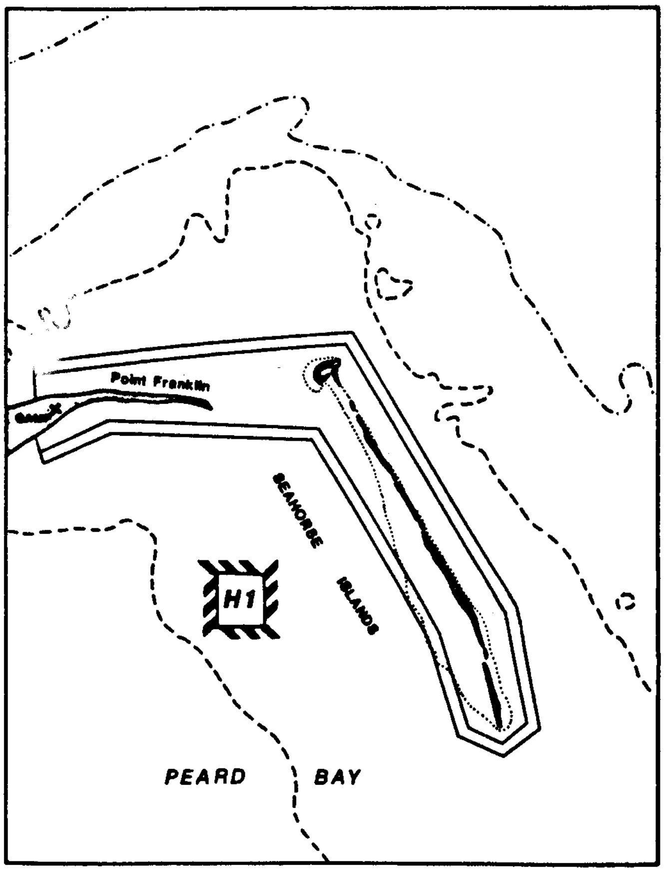


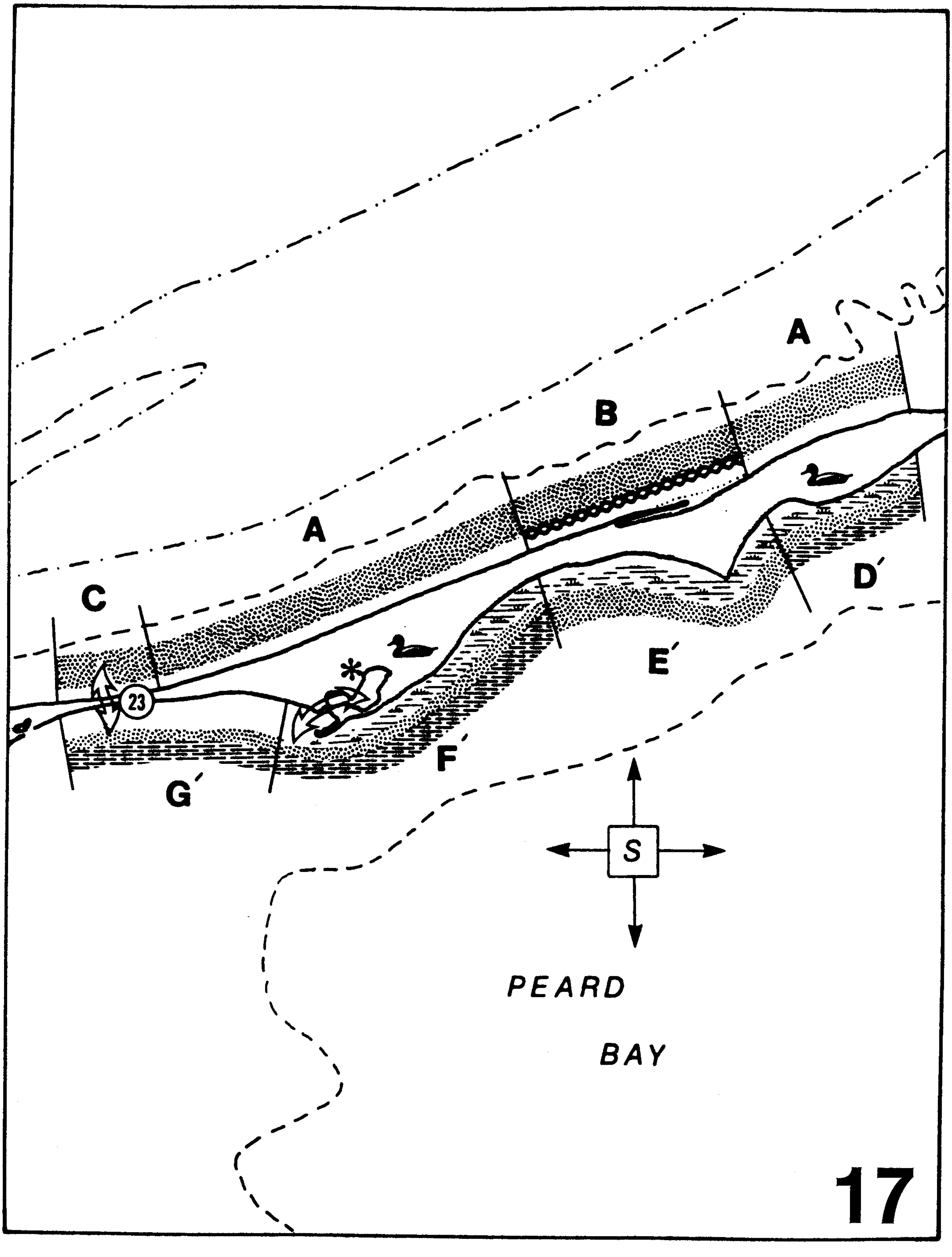
HUMAN USE INDEX



Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach				■	■	■		
B1	Black guillemot (20 pr), eider and arctic tern (20 pr) nesting			▨	▨	▨			
H1	Beluga whale hunting				▨	▨			

16



A
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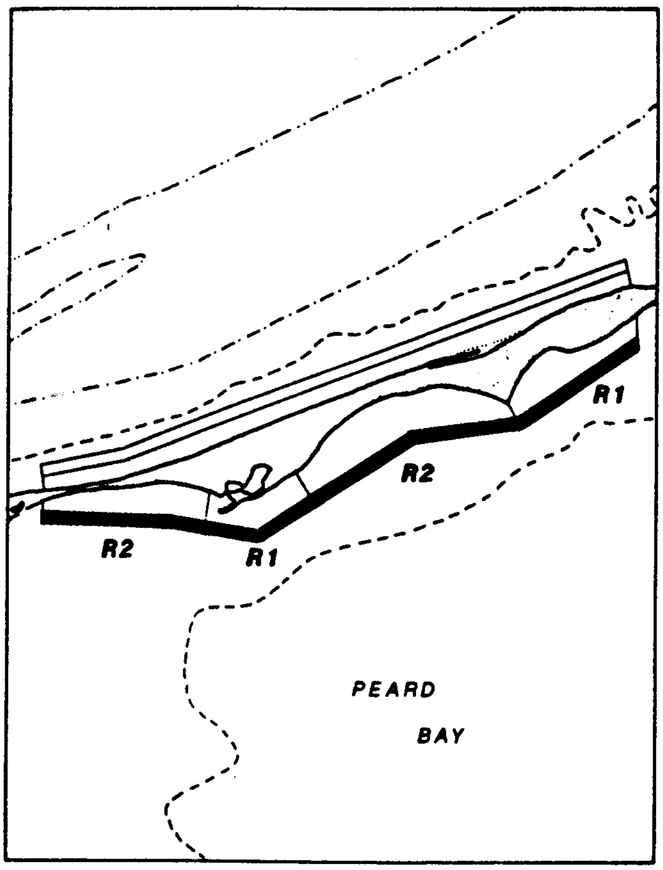
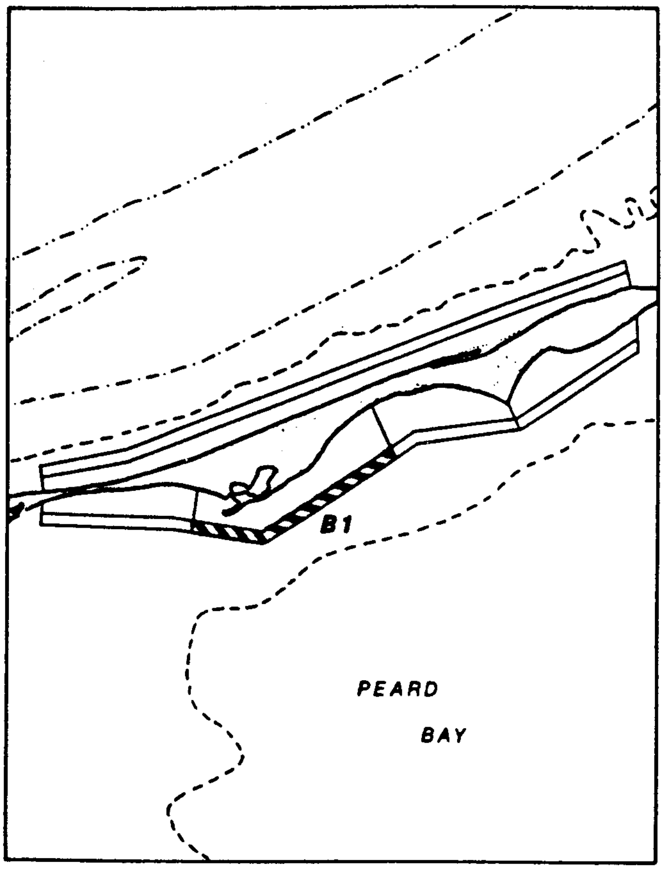
23
D′
E′
F′
G′
S
PEARD
BAY
17

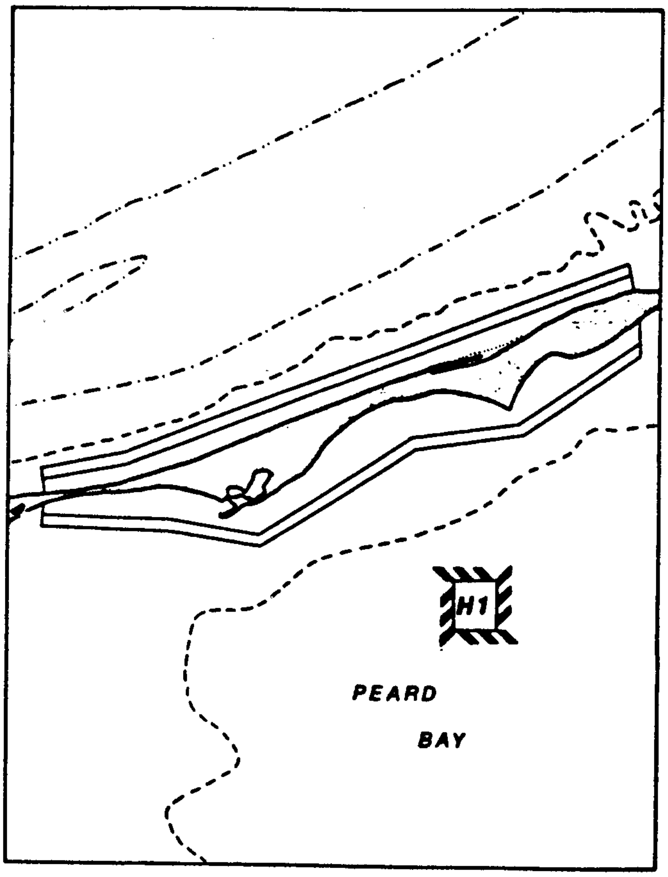
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



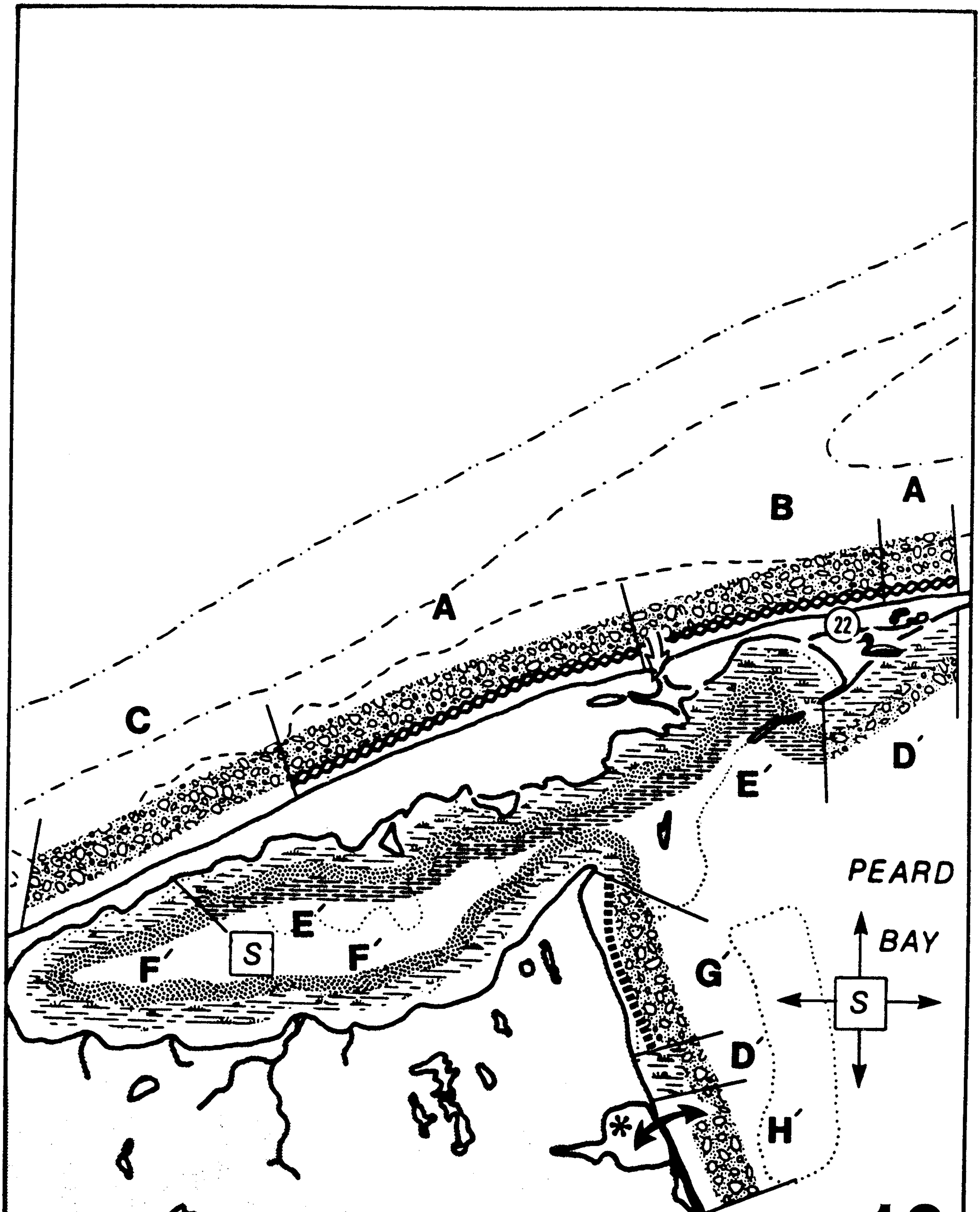
HUMAN USE INDEX



Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach; Wetland				■	■	■		
R2	Low energy beach				■	■	■		
B1	Wetland and eider nesting			▨	▨	▨	▨	▨	
H1	Beluga whale hunting				▨	▨			

17


A
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22
D′
E′
PEARD
BAY
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F′
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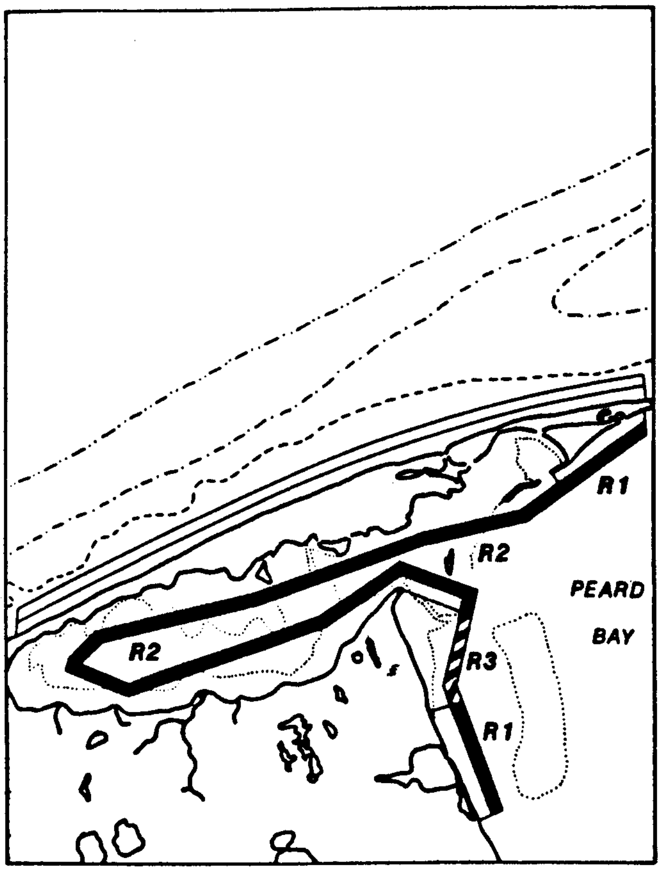
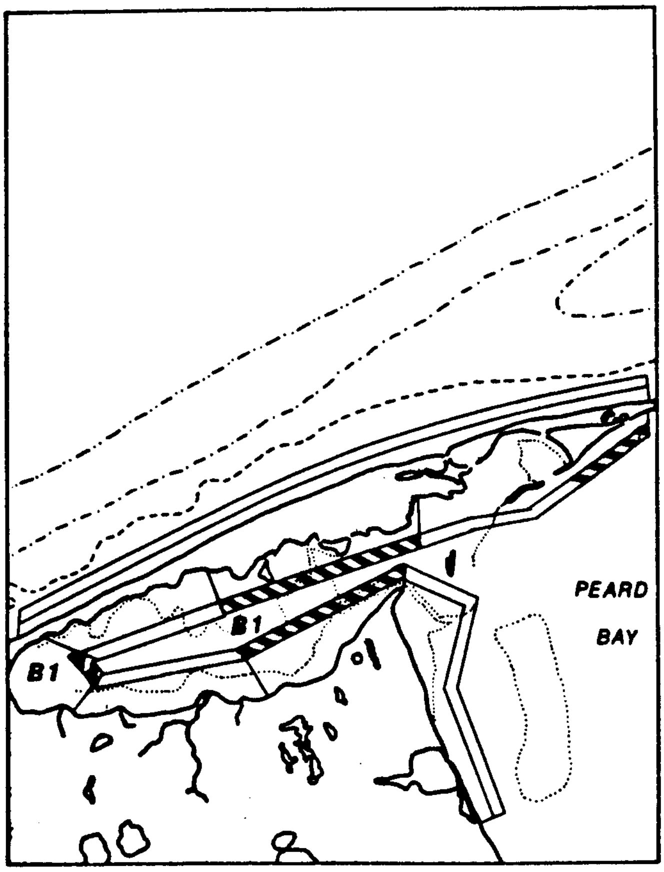
G′
S
D′
H′
18

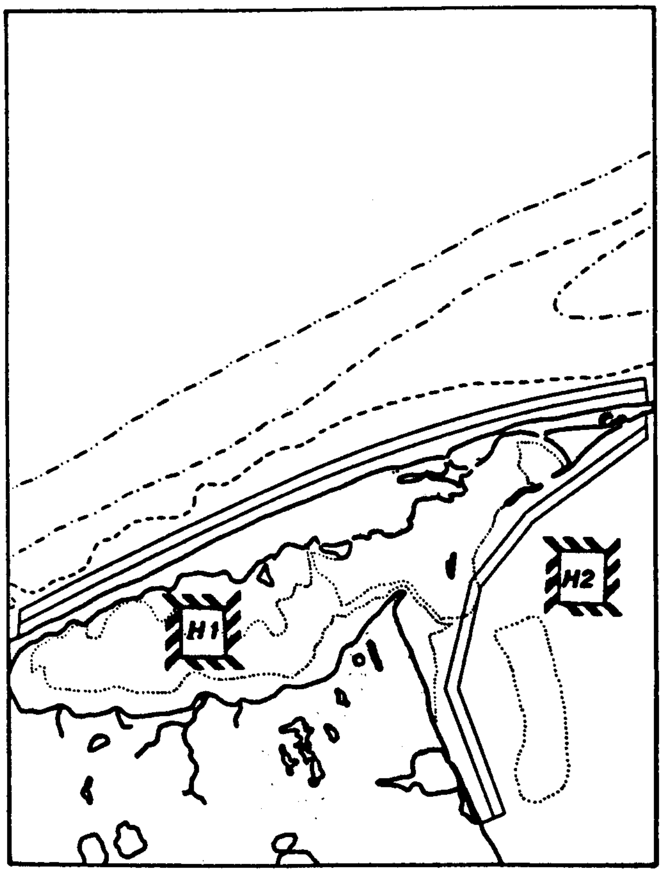
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



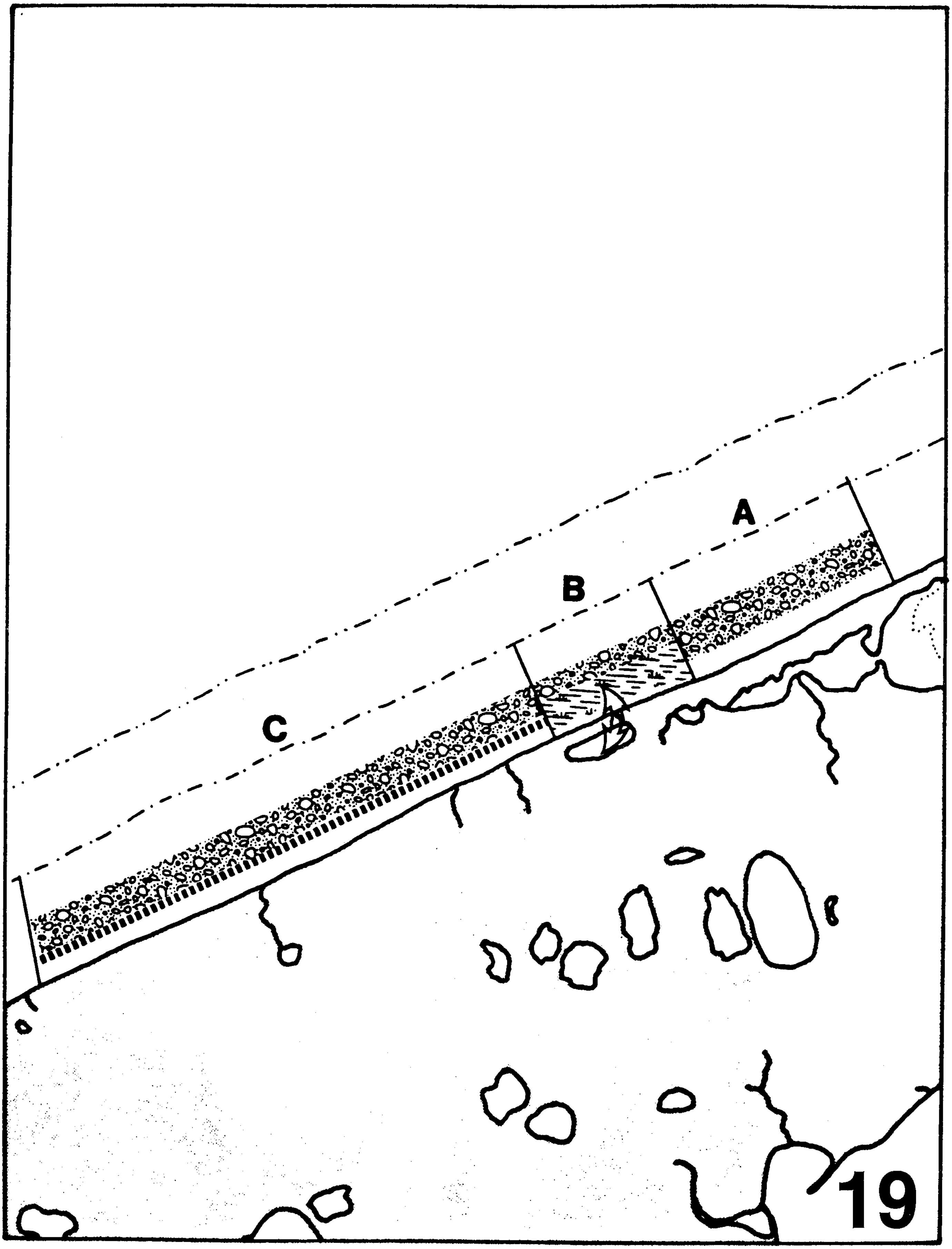
HUMAN USE INDEX



Seasonal Variability of Indices

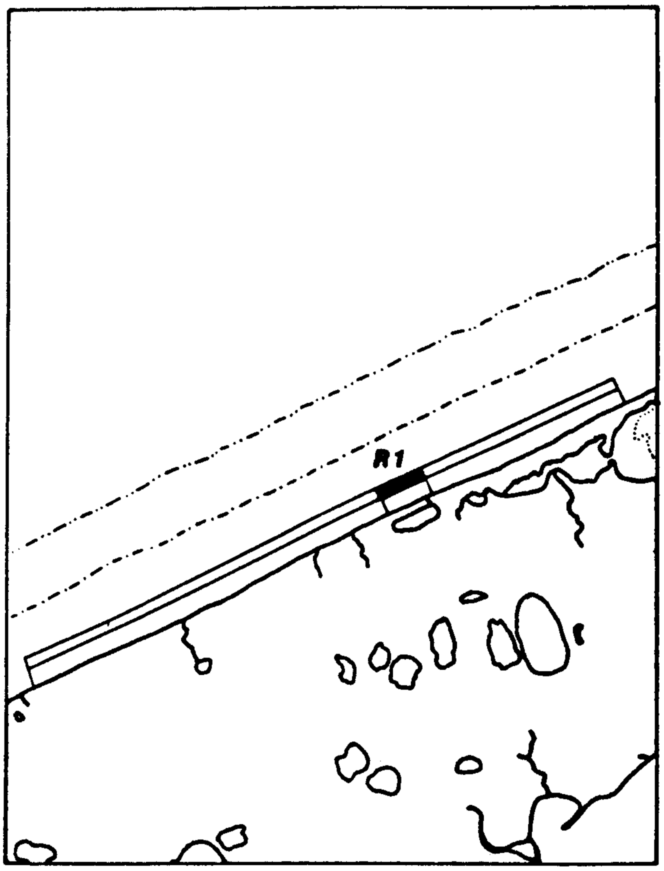
		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach; Wetland				■	■	■		
R2	Low energy beach				■	■	■		
R3	Protected tundra cliff				▨	▨	▨		
B1	Wetland and eider nesting			▨	▨	▨	▨	▨	
H1	Waterfowl hunting					▨	▨		
H2	Beluga whale hunting				▨	▨			

18

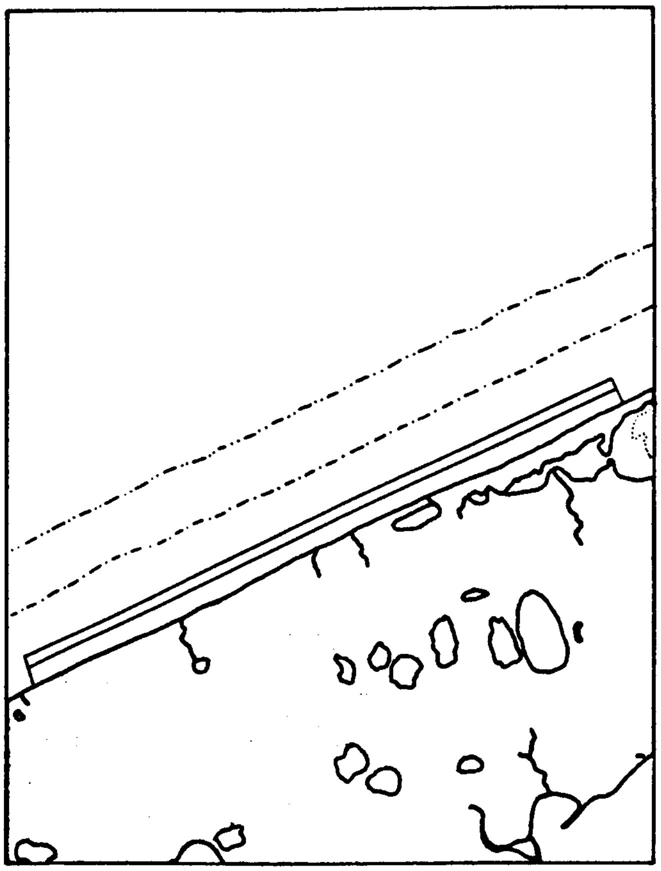


A
B
C
19

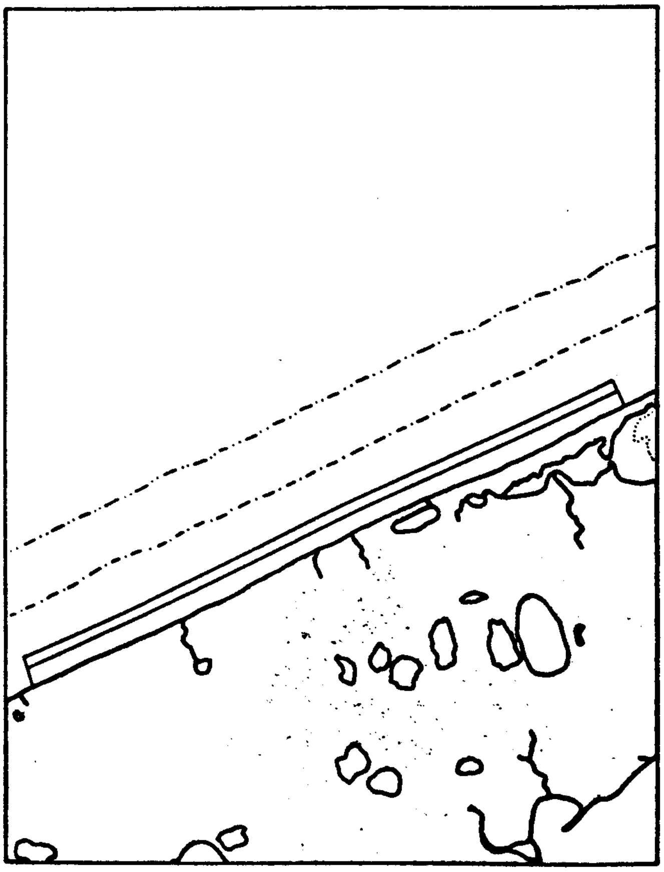
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



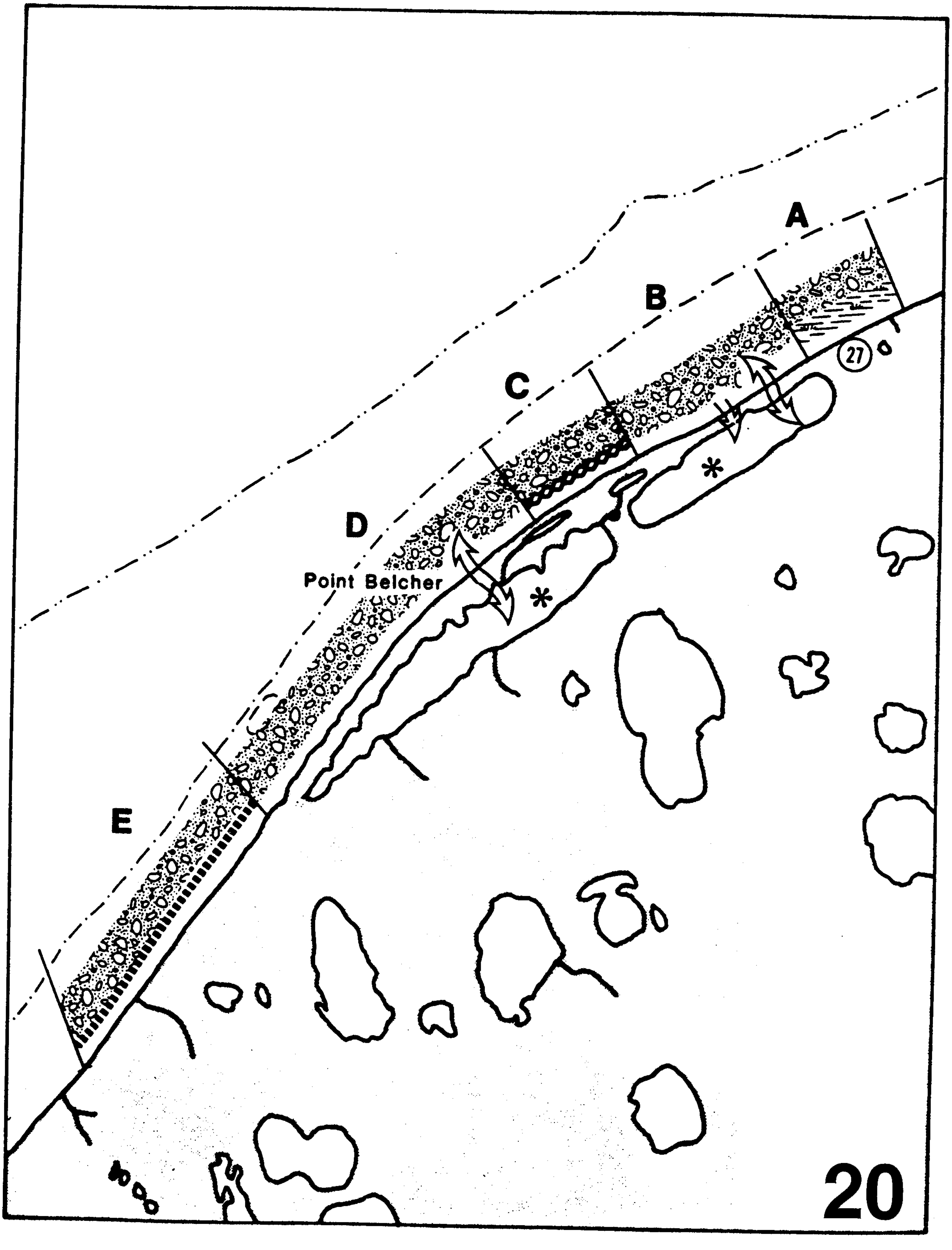
HUMAN USE INDEX



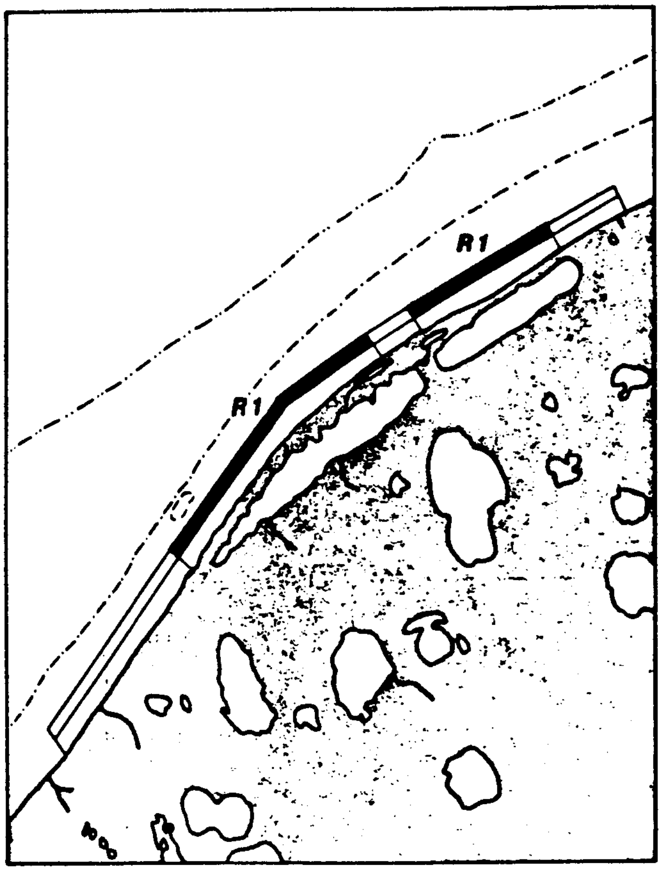
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Ephemeral inlet; Lagoon					■	■		

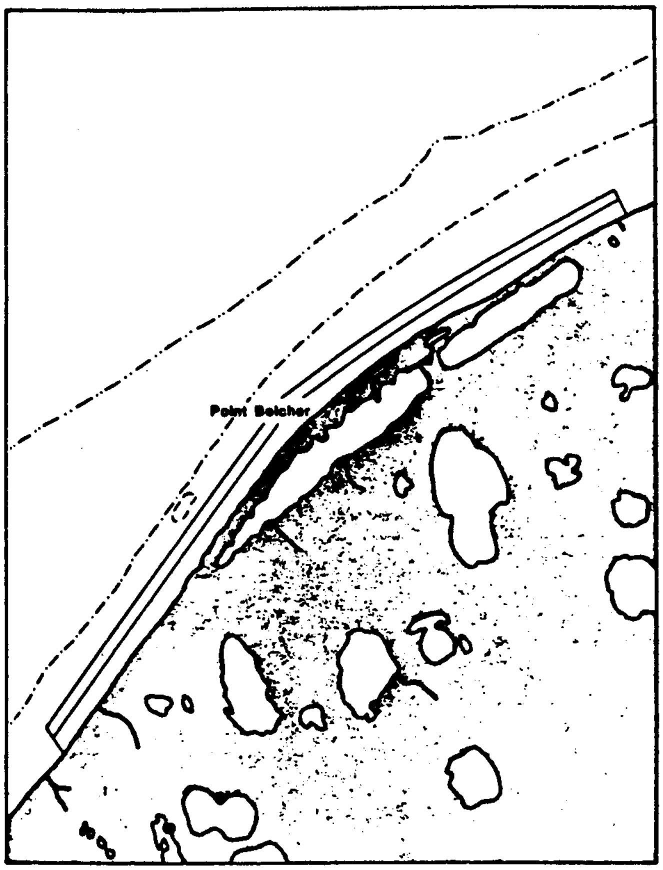
19


A
B
C
D
E
Point Belcher
27
20

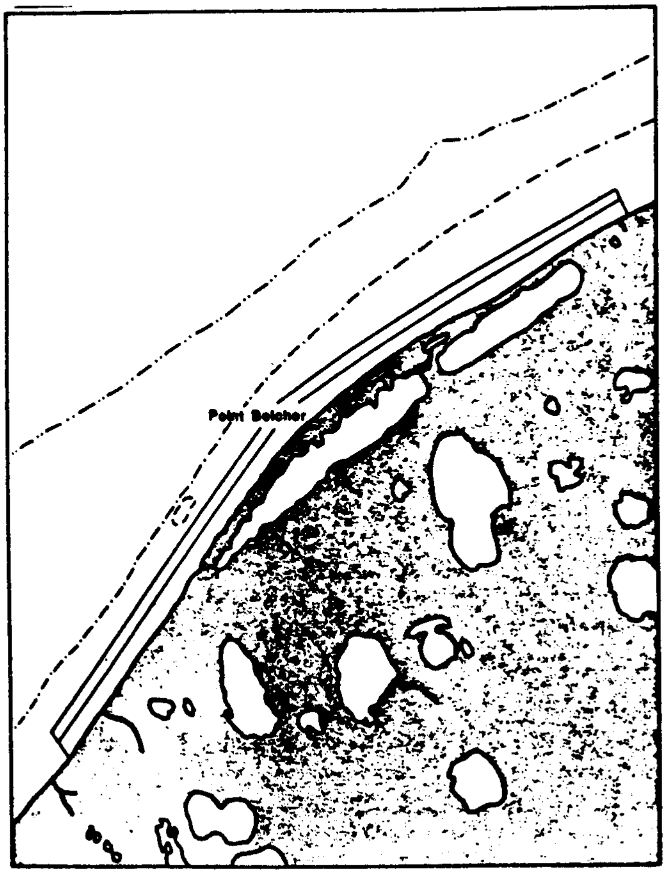
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



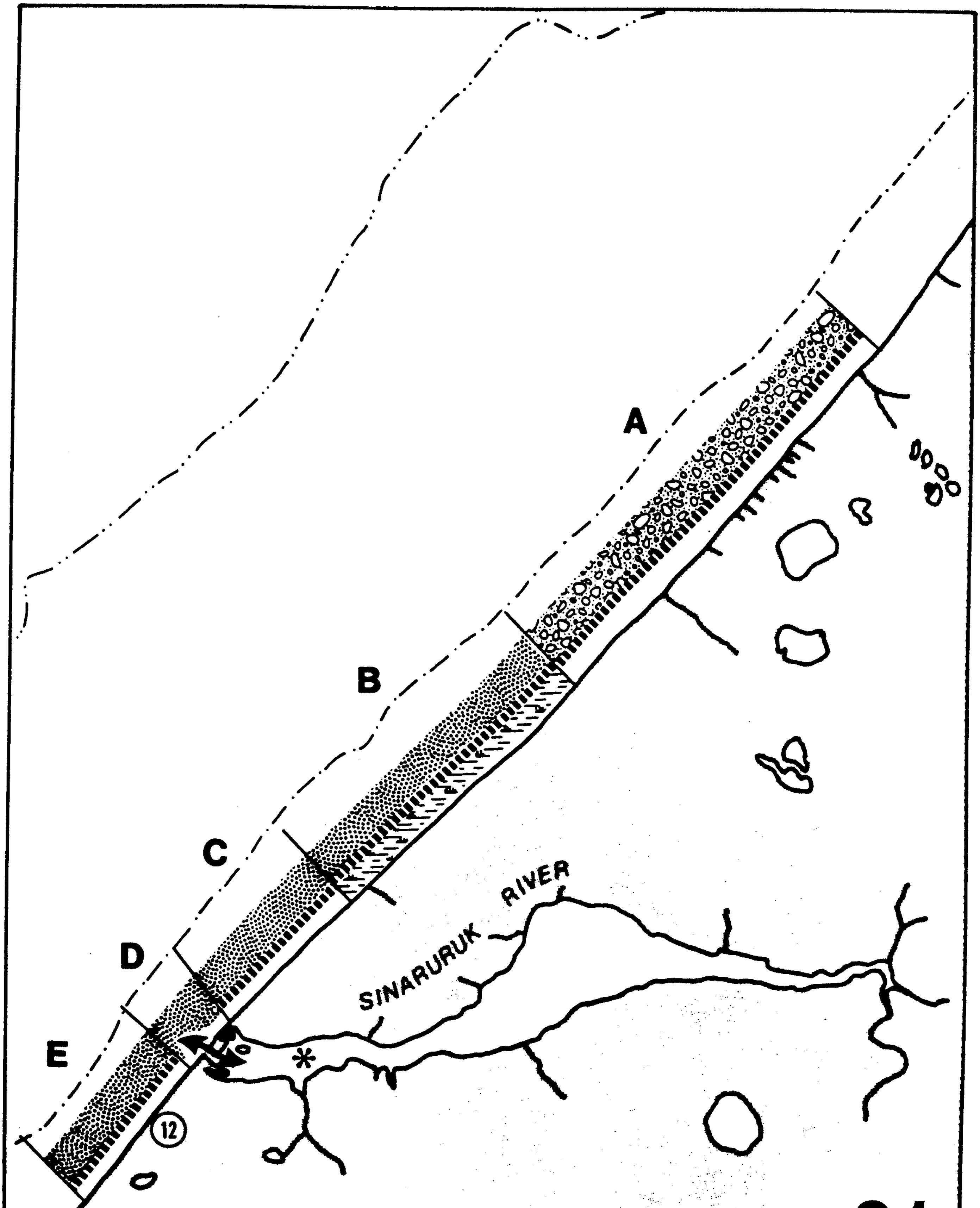
HUMAN USE INDEX



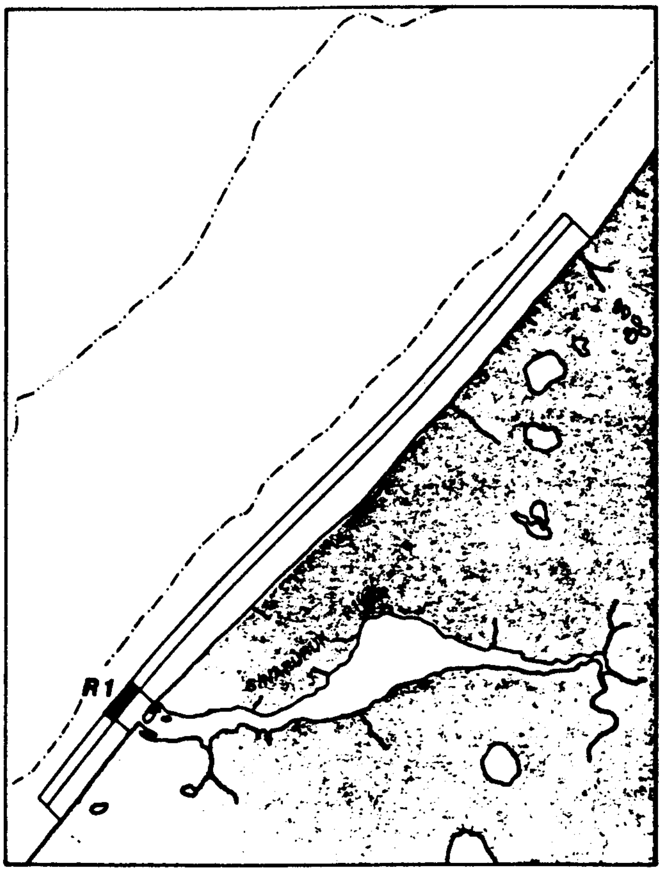
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Ephemeral inlet; Lagoon					■	■		

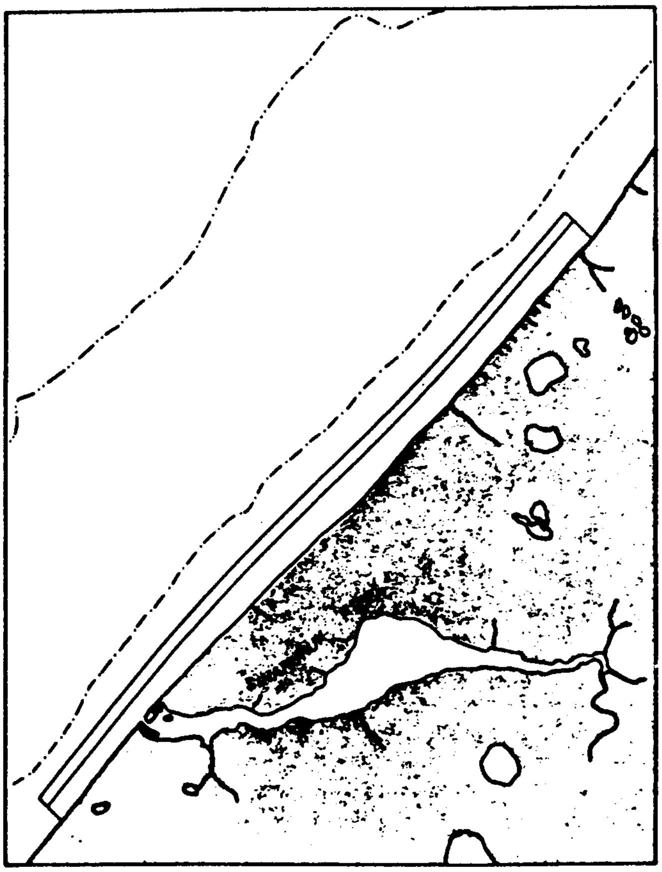
20


A
B
C
D
E
SINARURUK RIVER
12
21

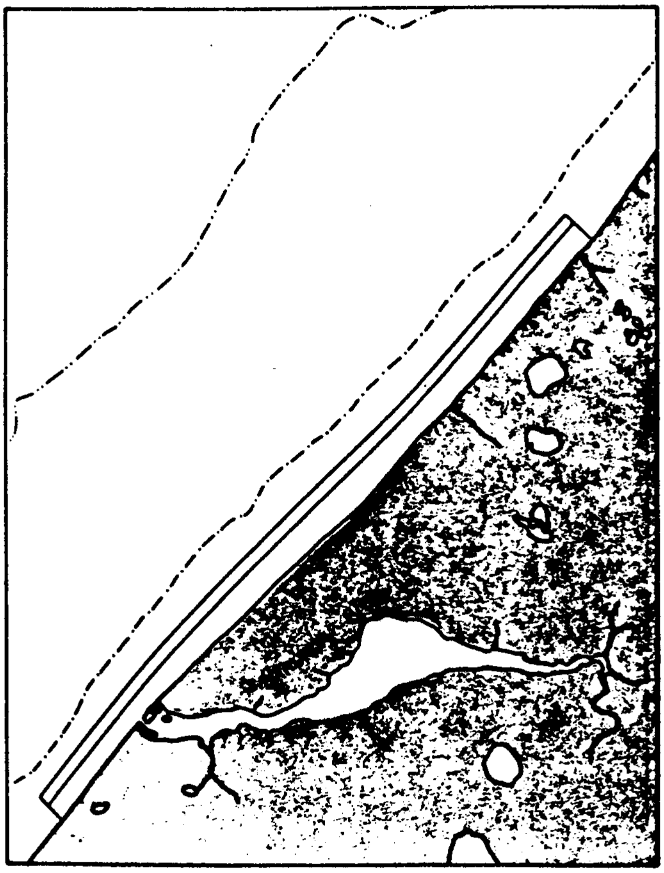
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



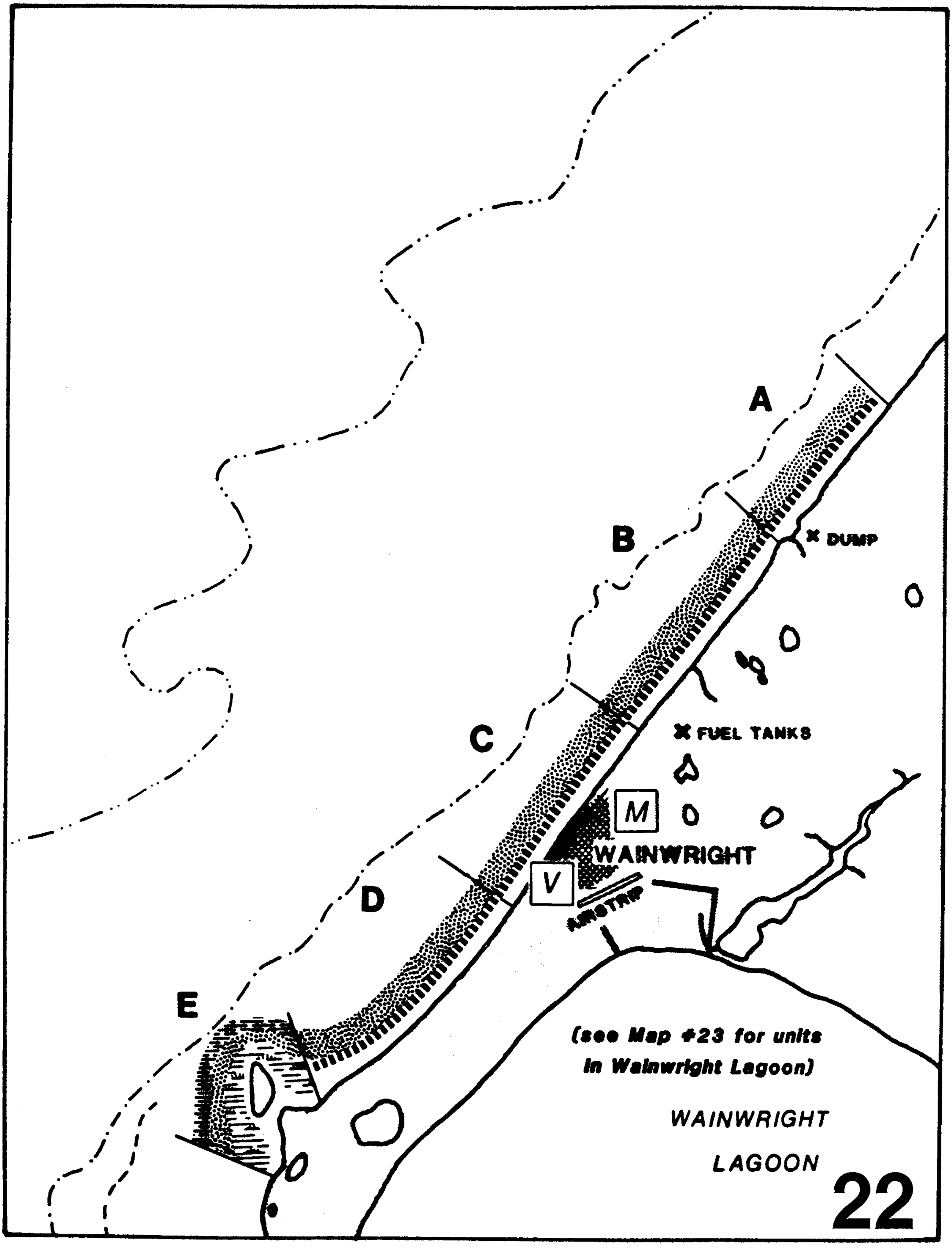
HUMAN USE INDEX



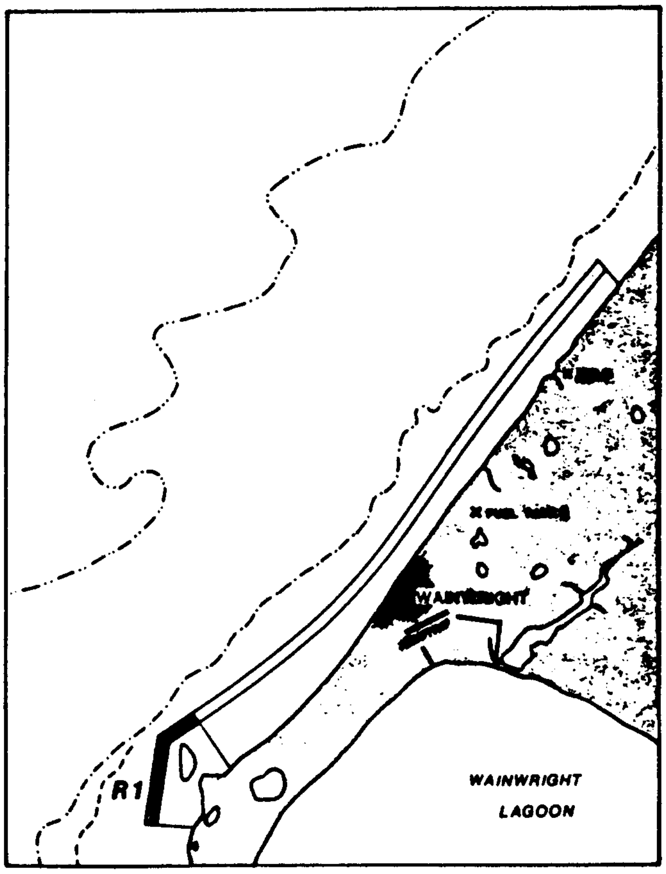
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Permanent inlet; Lagoon					■	■		

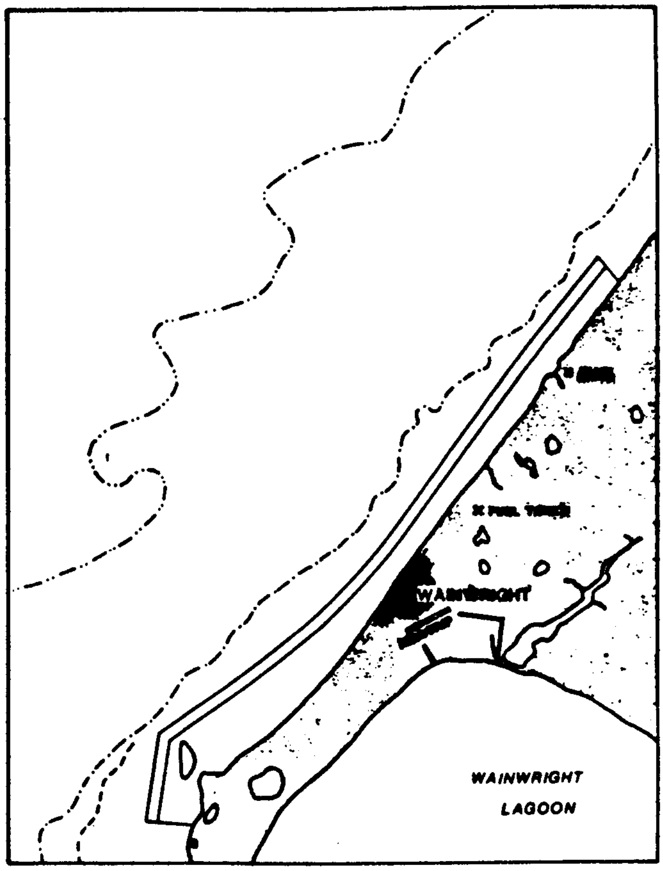
21


A
B
C
D
E
DUMP
FUEL TANKS
M
V
WAINWRIGHT
AIRSTRIP
(see Map #23 for units
in Wainwright Lagoon)
WAINWRIGHT
LAGOON
22

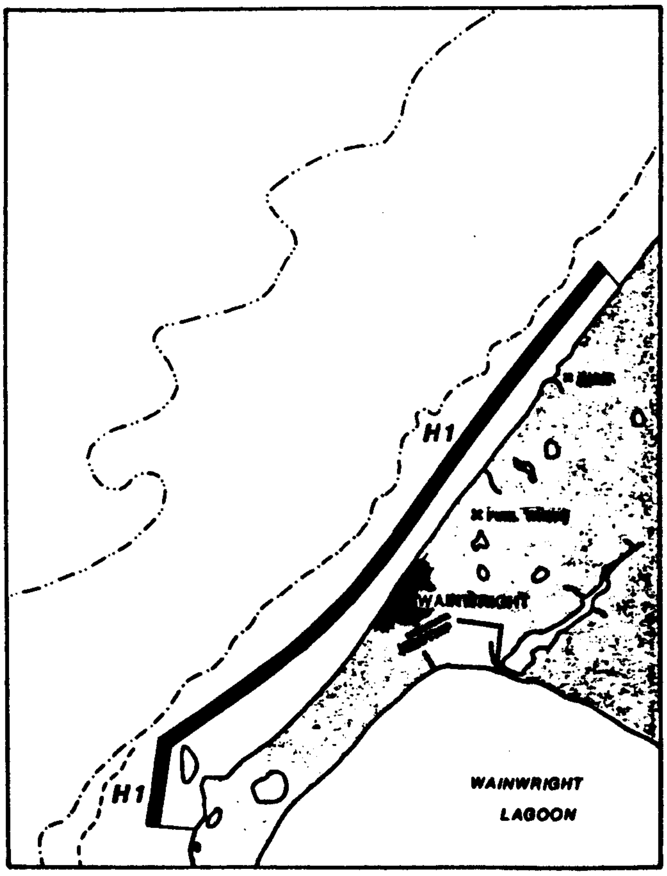
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



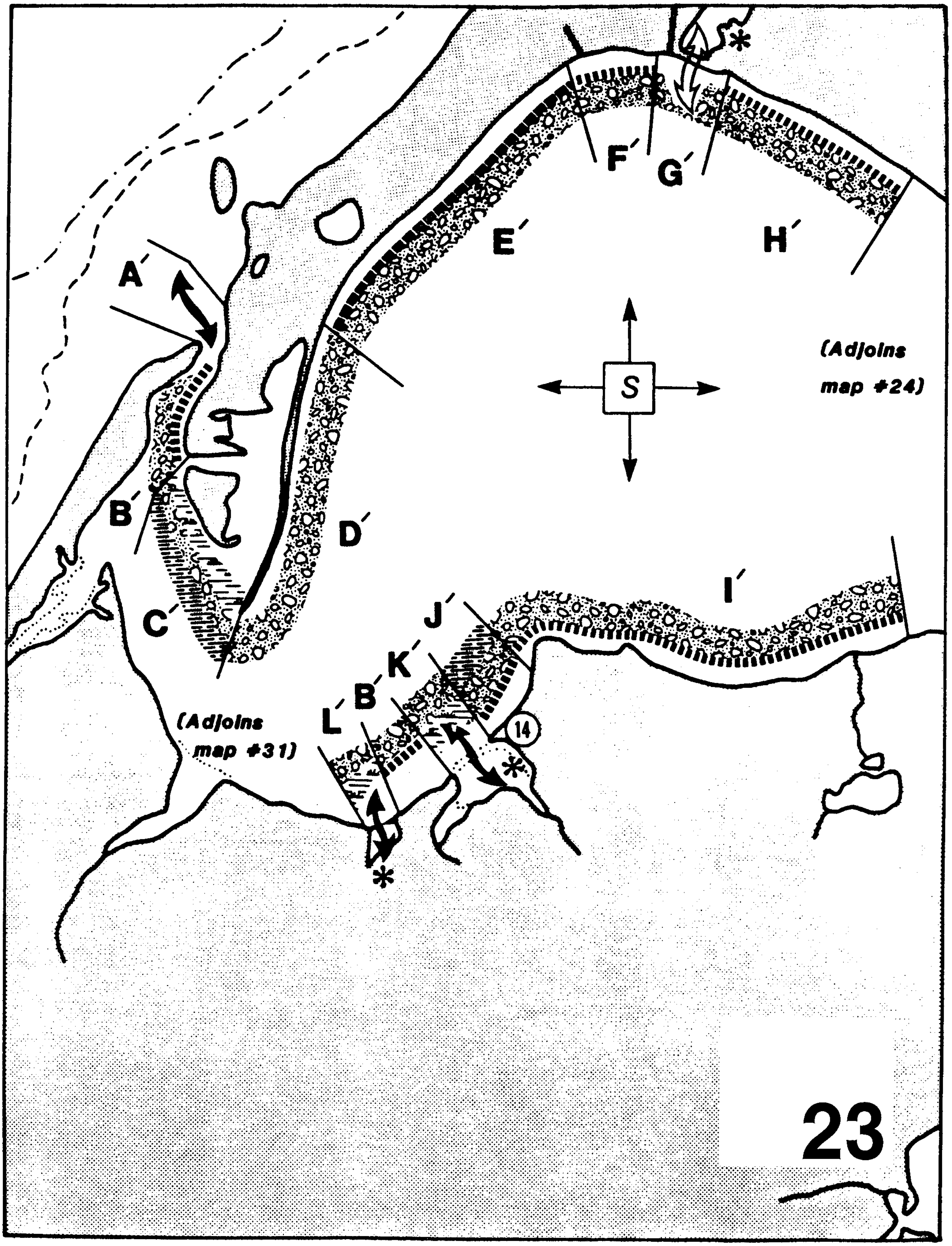
HUMAN USE INDEX



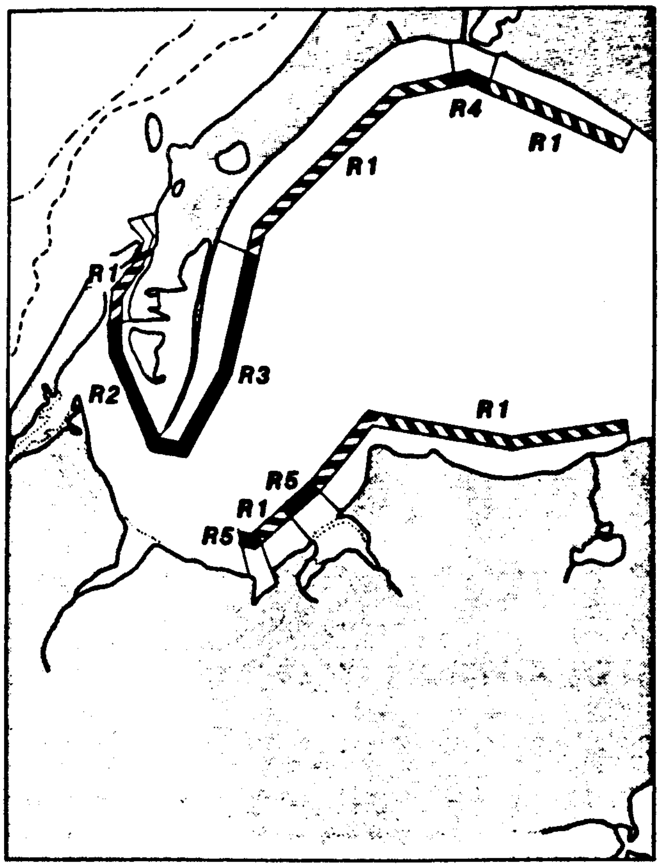
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Wetland				■	■	■	■	
H1	Community of Wainwright			■	■	■	■	■	
	Subsistence access			■	■	■	■	■	
	Resident recreation			■	■	■	■	■	

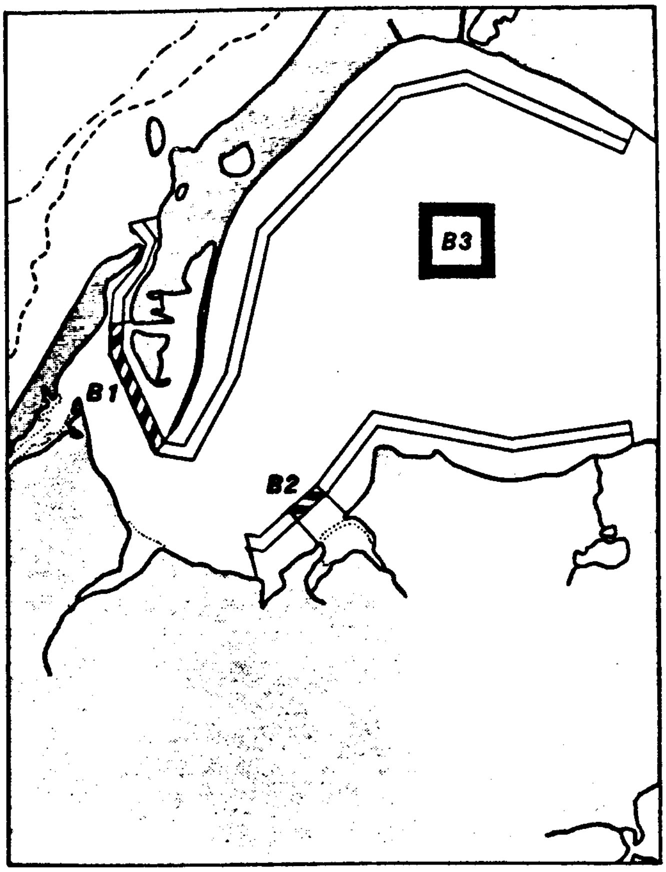
22


A'
B'
C'
D'
E'
F'
G'
H'
I'
J'
K'
B
L'
S
(Adjoins map #24)
(Adjoins map #31)
14
23

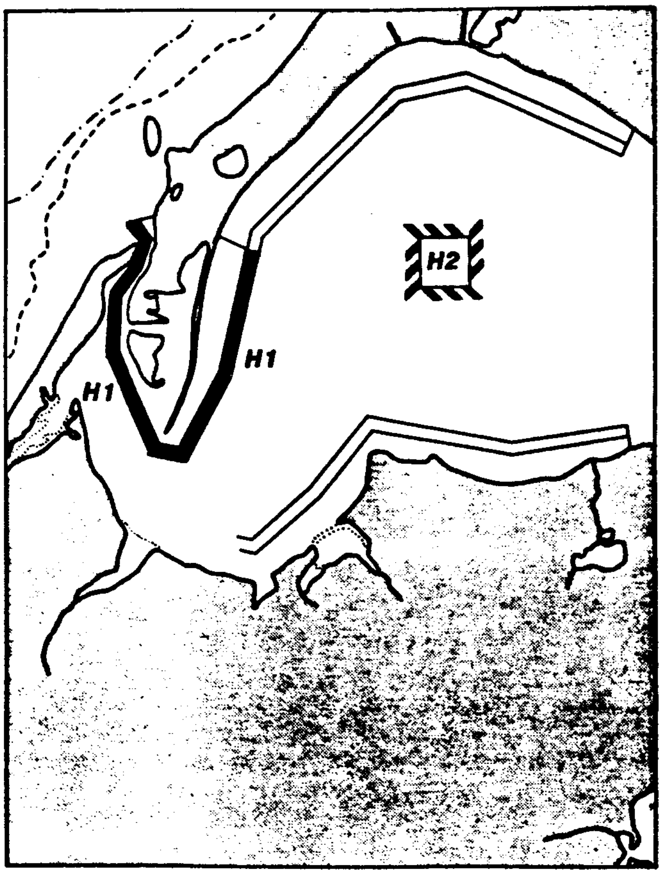
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



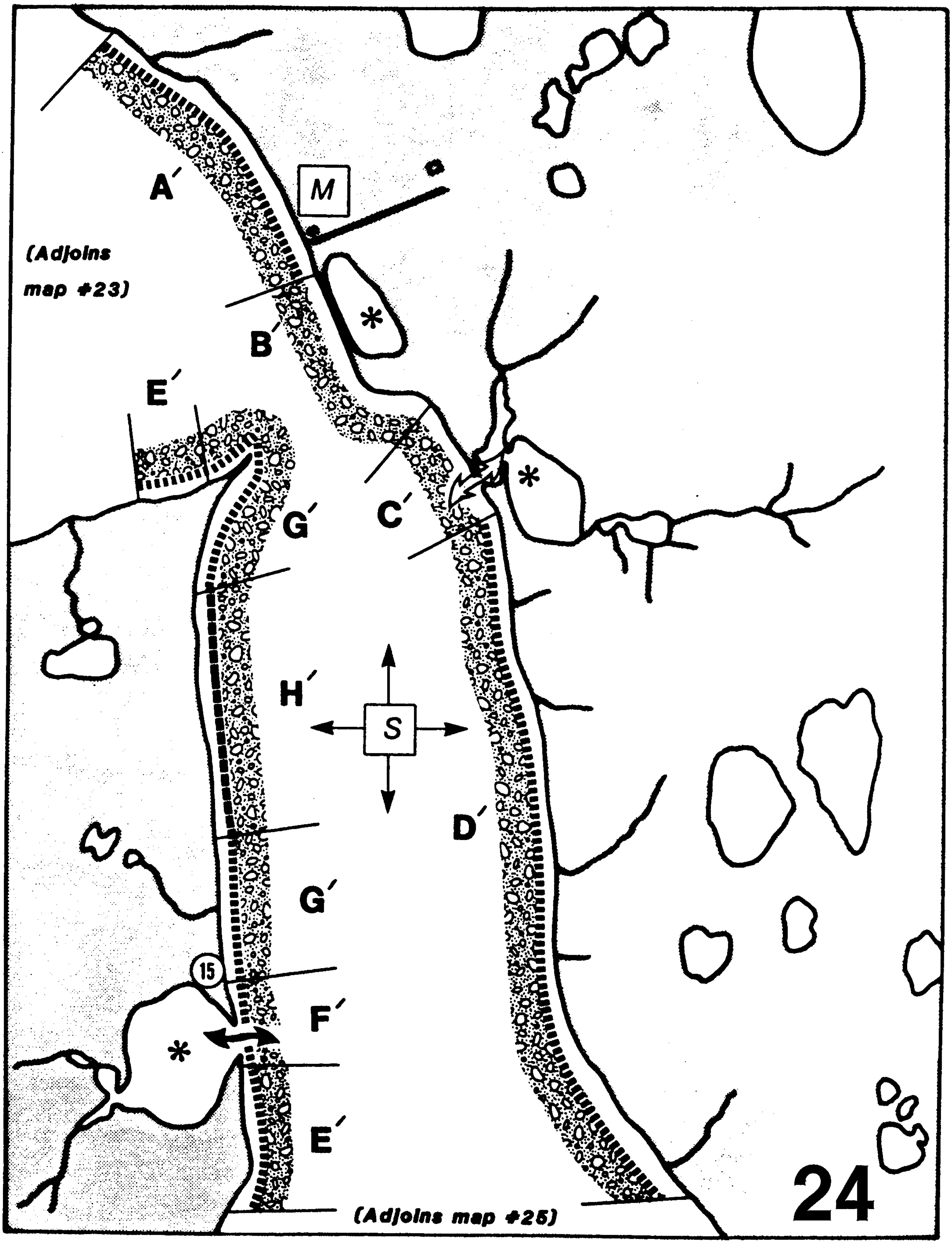
HUMAN USE INDEX



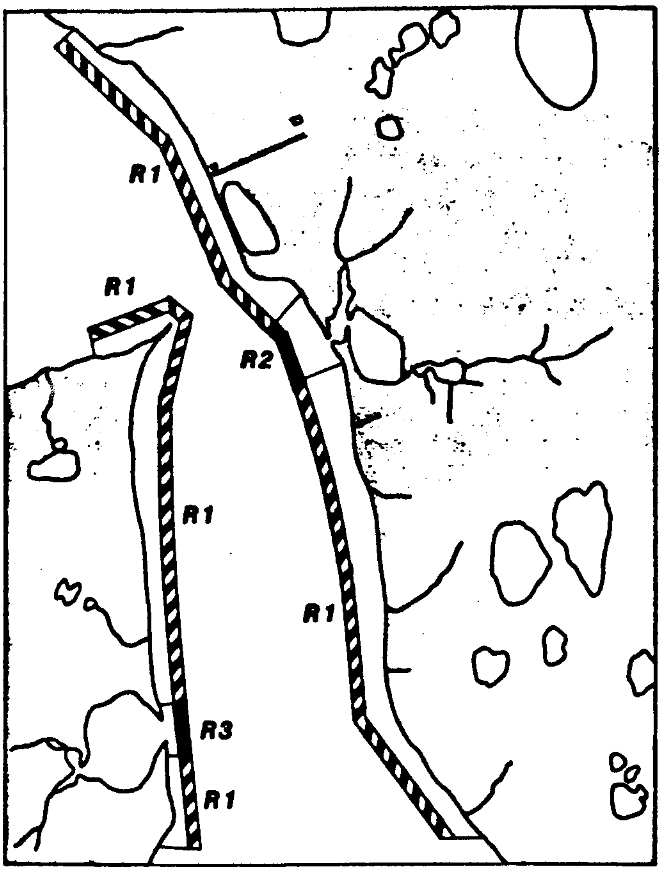
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff				▨	▨	▨		
R2	Low energy beach; Wetland				▬	▬	▬		
R3	Low energy beach				▬	▬	▬		
R4	Ephemeral inlet; Lagoon				▬	▬	▬		
R5	Permanent inlet; Lagoon				▬	▬	▬		
B1	Wetland and mudflat			▨	▨	▨	▨	▨	
B2	Wetland and lagoon			▨	▨	▨	▨	▨	
B3	Wainwright Inlet Whales, seals, Fish			▬	▬	▬	▬		
H1	Subsistence access Resident recreation			▬ ▬	▬ ▬	▬ ▬	▬ ▬	▬ ▬	
H2	Beluga whale hunting Fishing			 ▨	▨ ▨	▨ ▨	 ▨		

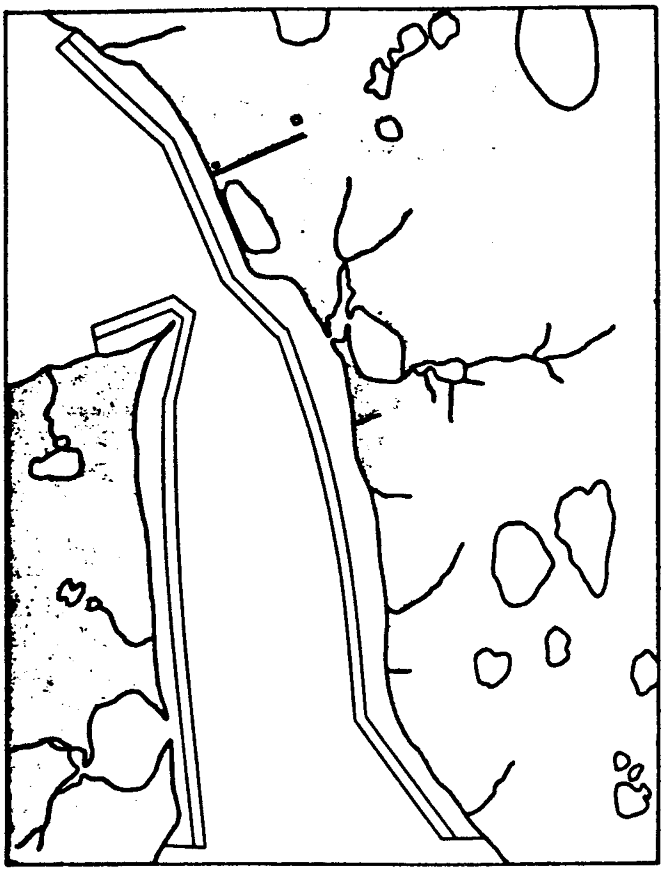
23


A´
M
(Adjoins map #23)
*
B´
E´
*
G´
C´
H´
S
D´
G´
15
F´
*
E´
(Adjoins map #25)
24

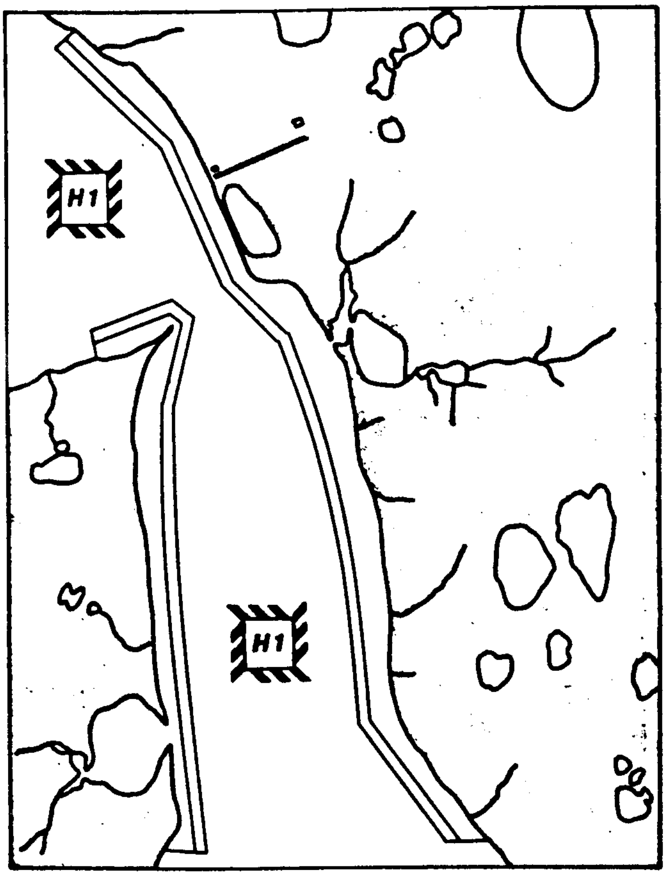
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



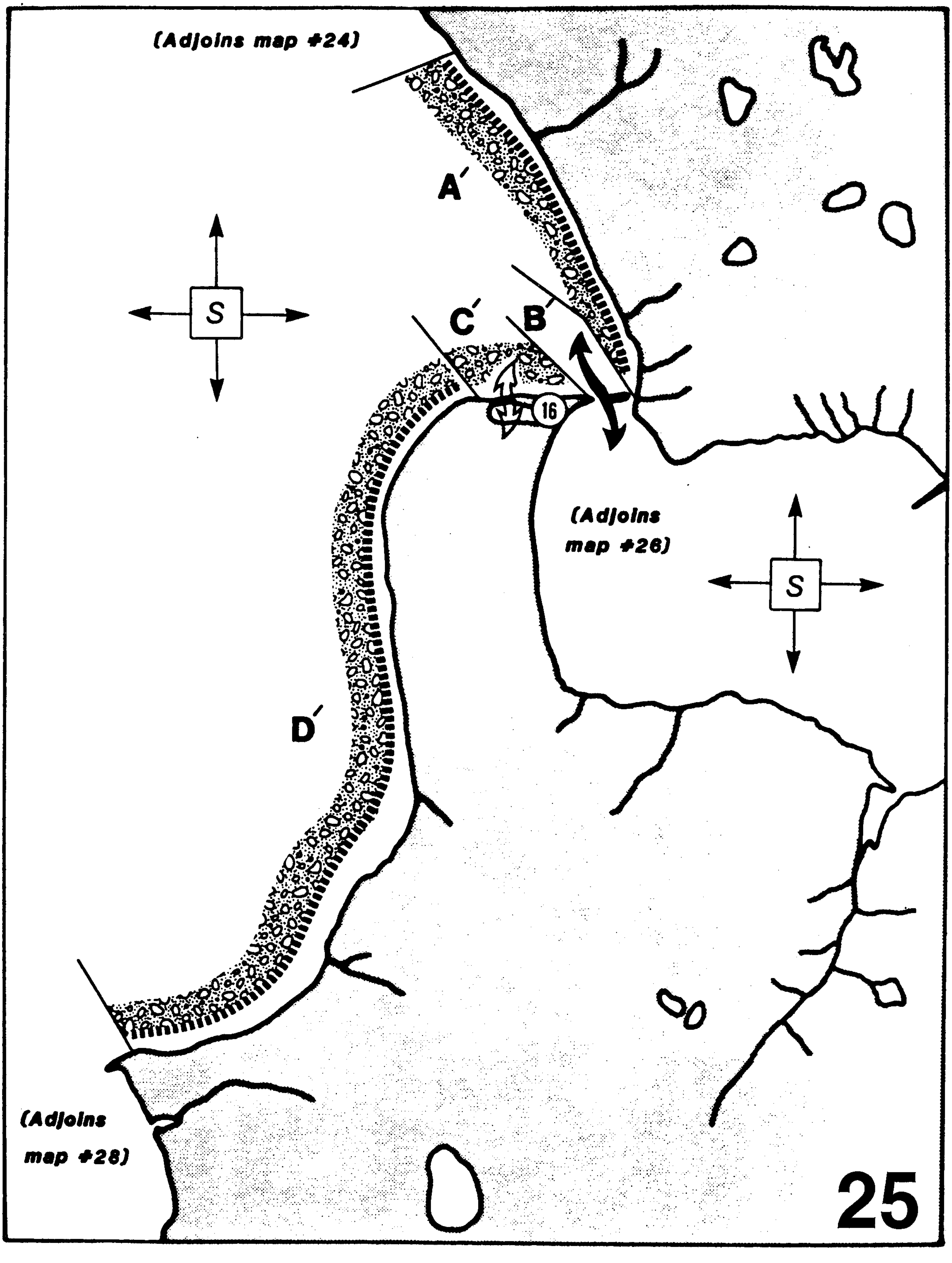
HUMAN USE INDEX



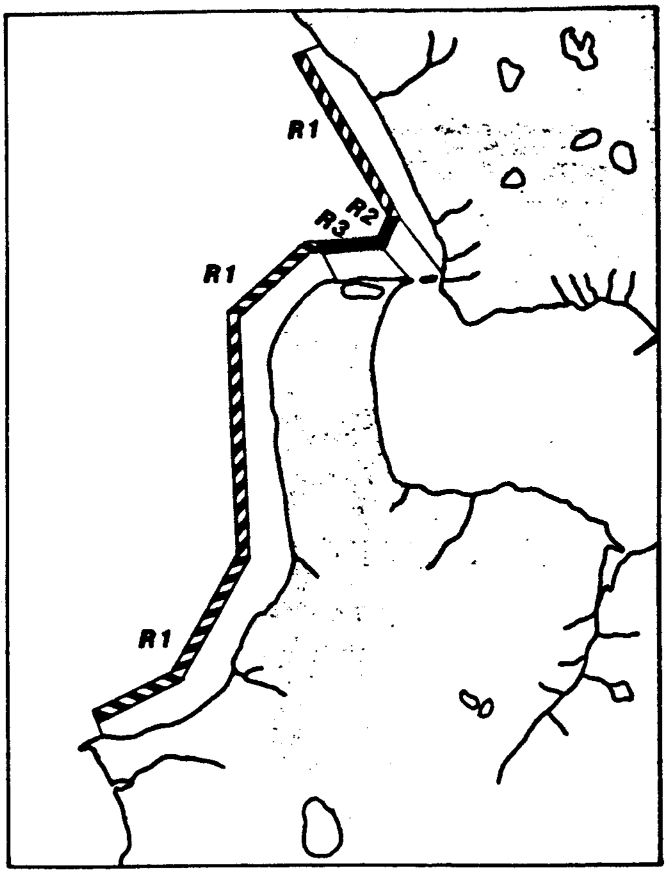
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff				▨	▨	▨		
R2	Ephemeral inlet; Lagoon				■	■	■		
R3	Permanent inlet; Lagoon				■	■	■		
H1	Fishing			▨	▨	▨	▨		

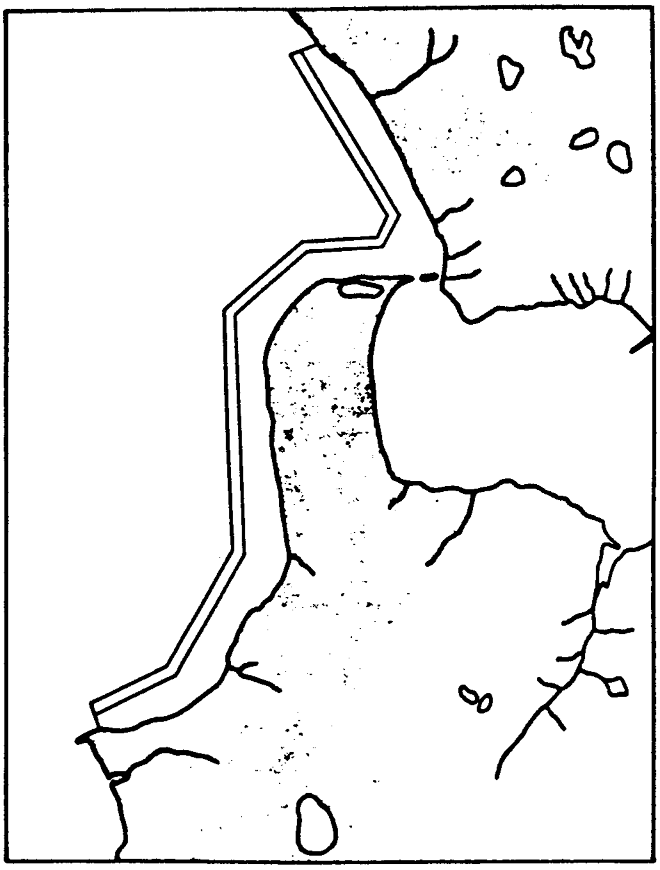
24


(Adjoins map #24)
A´
C´
B´
S
16
(Adjoins map #26)
S
D´
(Adjoins map #28)
25

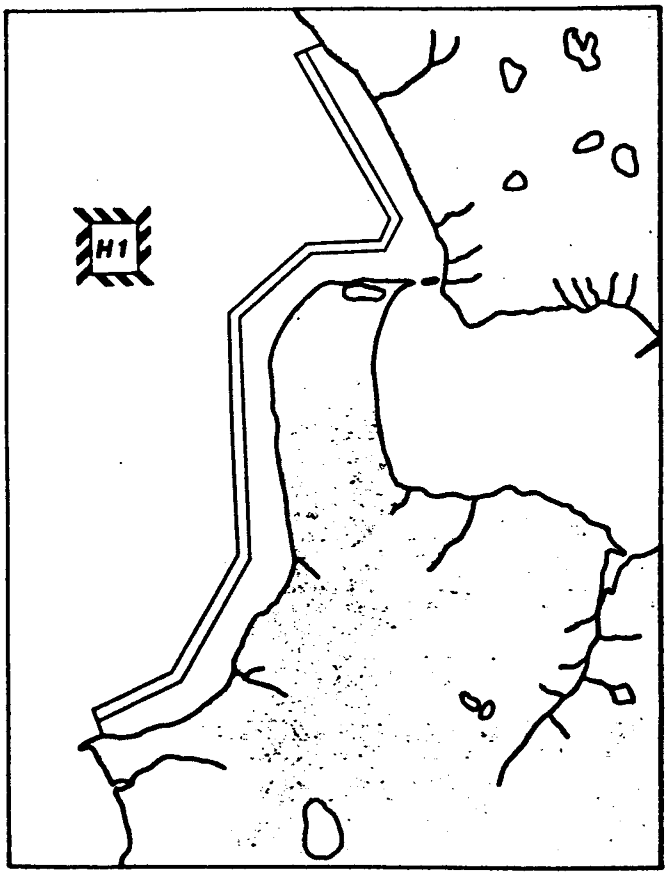
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



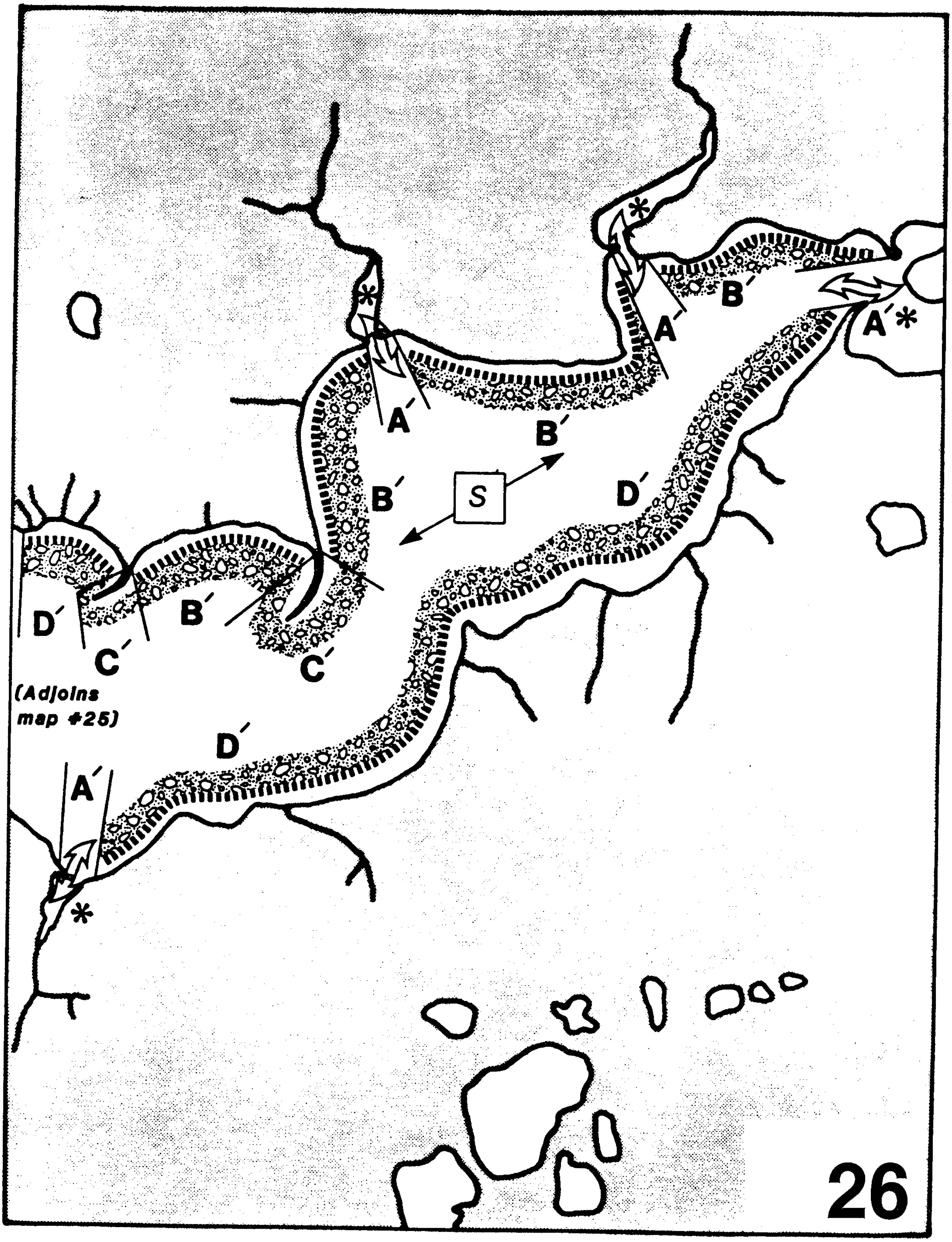
HUMAN USE INDEX



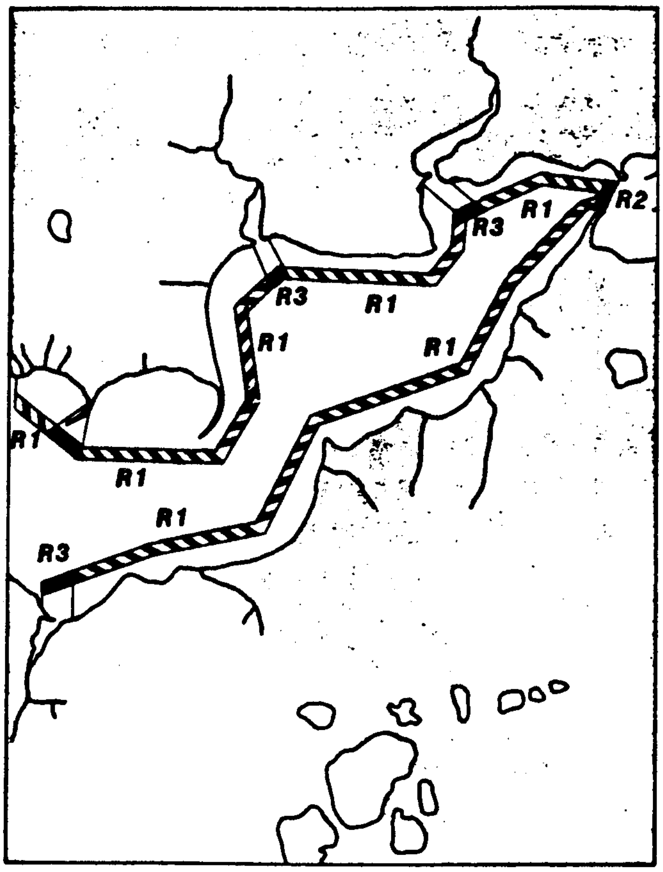
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff				▨	▨	▨		
R2	Permanent inlet; Lagoon				■	■	■		
R3	Ephemeral inlet; Lagoon				■	■	■		
H1	Fishing			▨	▨	▨	▨		

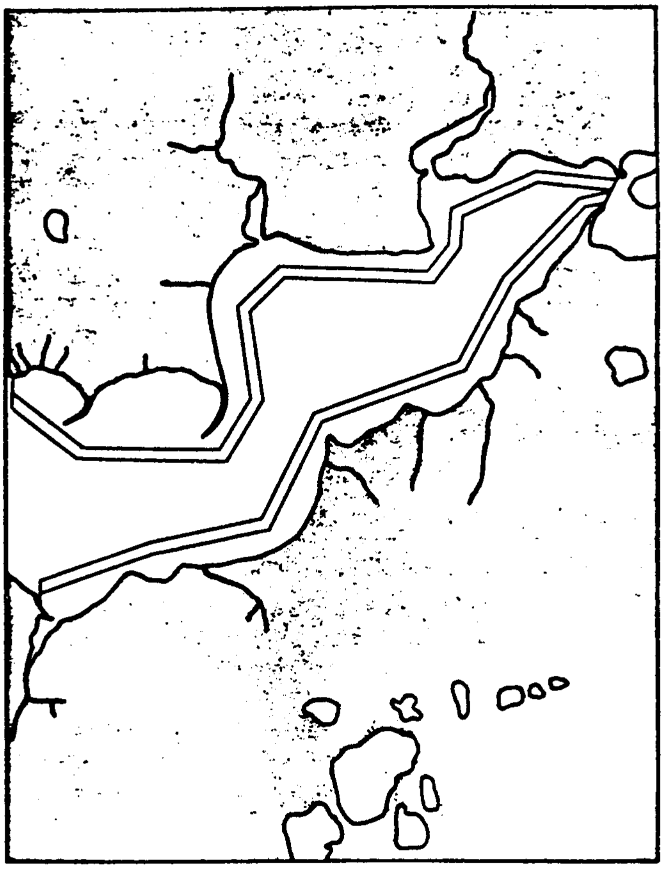
25


A´
*
B´
A´*
*
A´
B´
S
B´
D´
D´
B´
C´
C´
(Adjoins map #25)
D´
A´
*
26

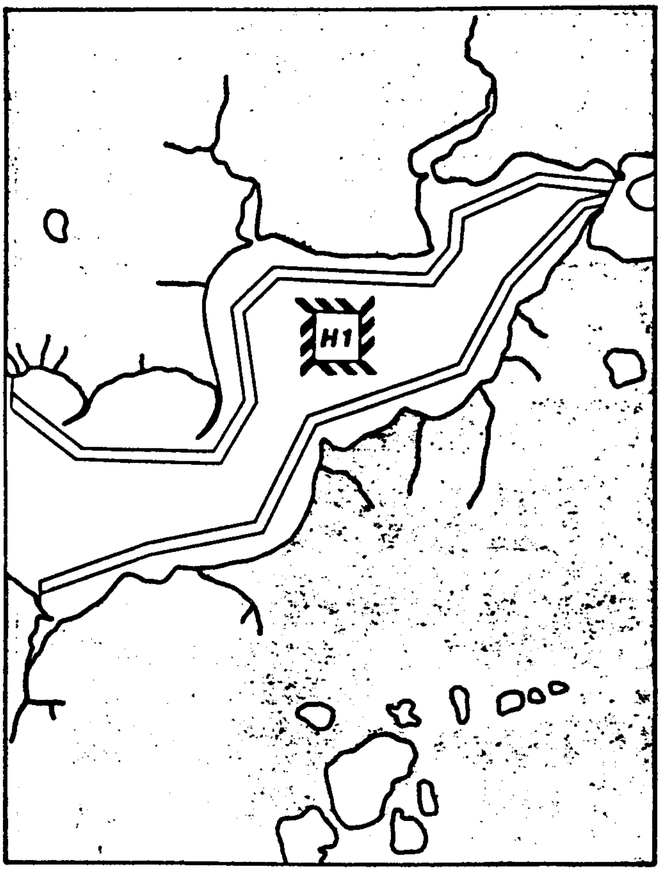
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



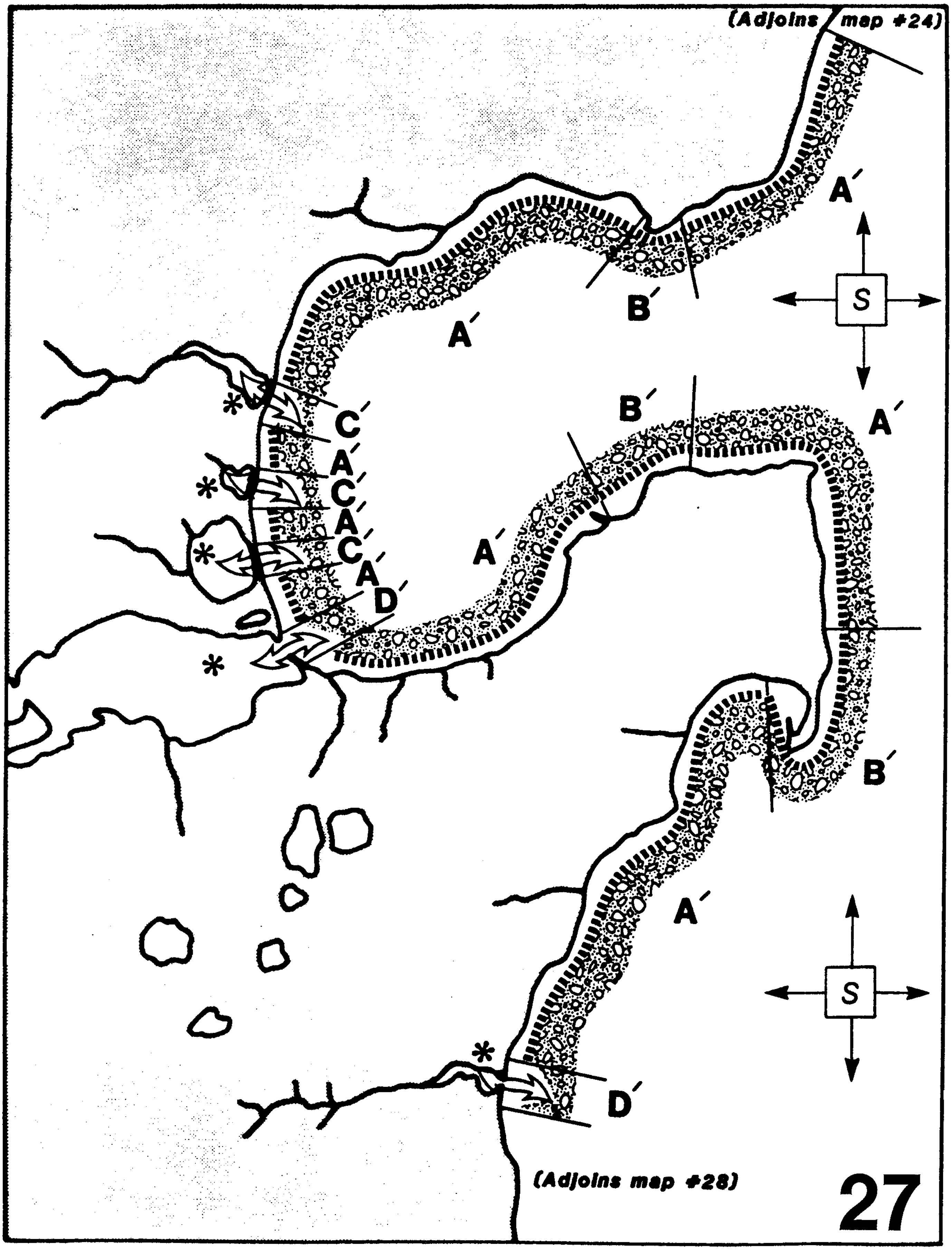
HUMAN USE INDEX

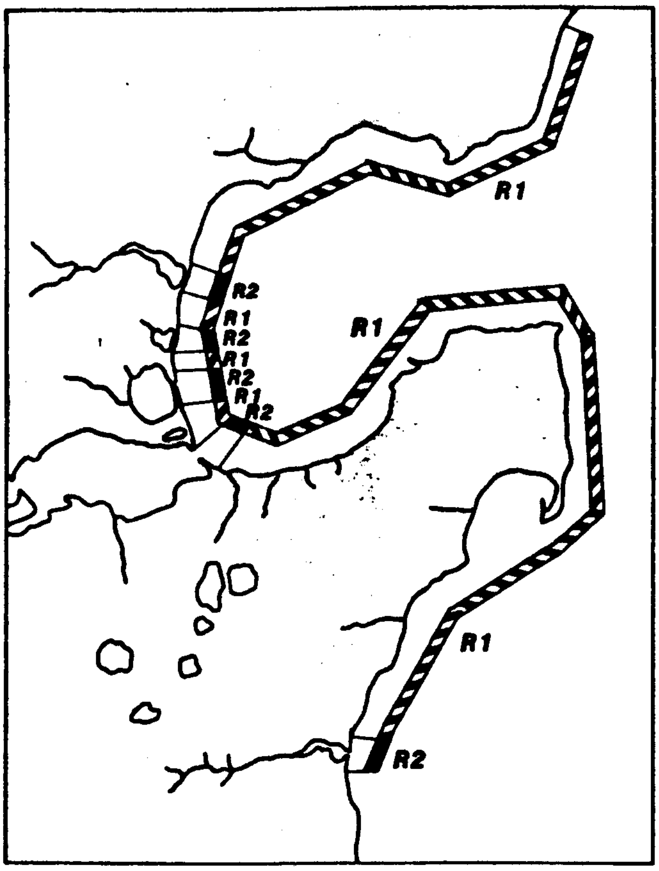


Seasonal Variability of Indices

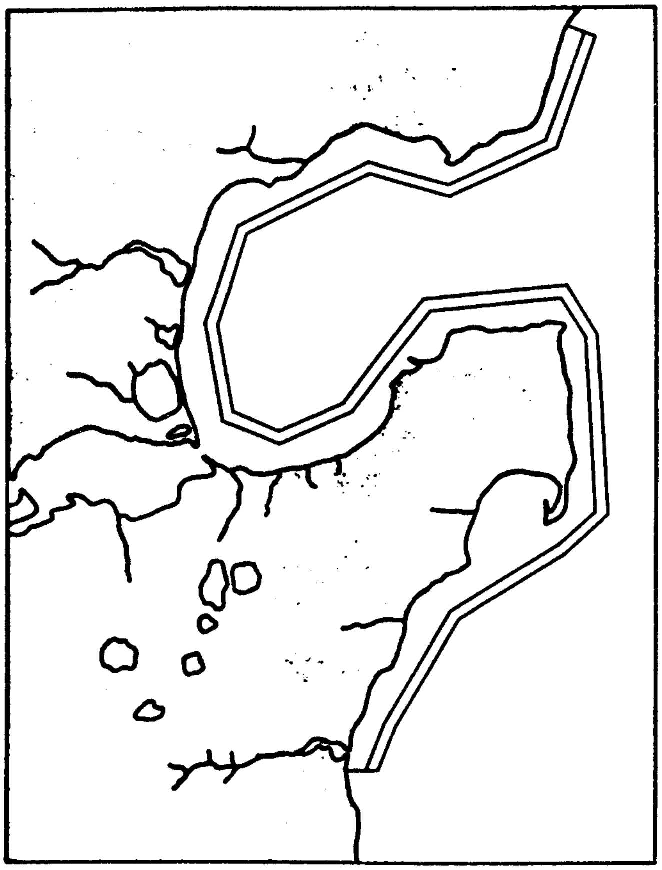
		SEASON							
			Break-Up/Summer/Freeze-Up						
Identifier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Ephemeral inlet; Lagoon				▨	▨	▨		
R2	Protected tundra cliff				■	■	■		
R3	Low energy beach				■	■	■		
H1	Fishing			▨	▨	▨	▨		

26

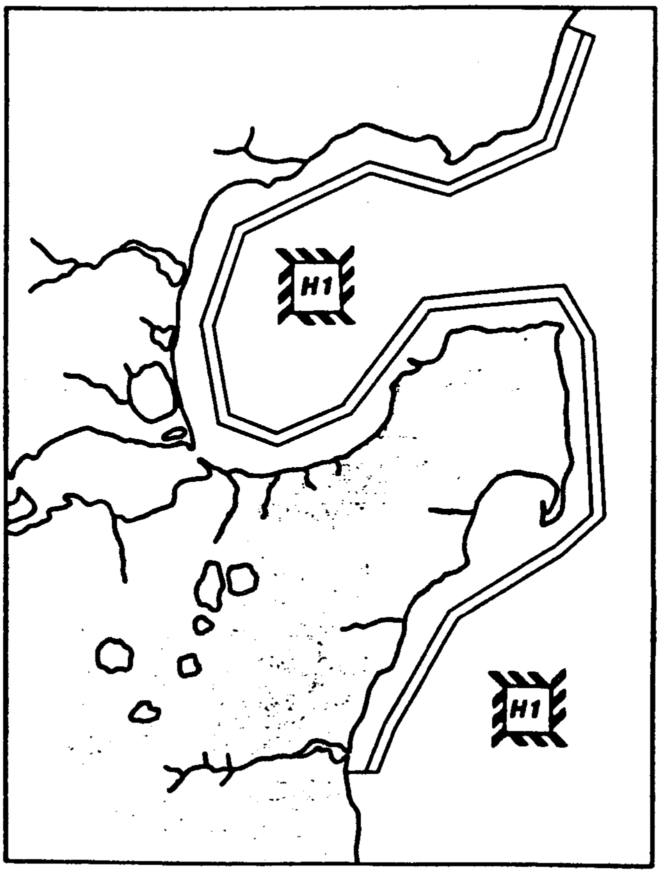

(Adjoins map #24)
A´
S
A´
B´
B´
A´
C´
A´
C´
A´
C´
A´
D´
A´
B´
A´
S
D´
(Adjoins map #28)
27



OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX

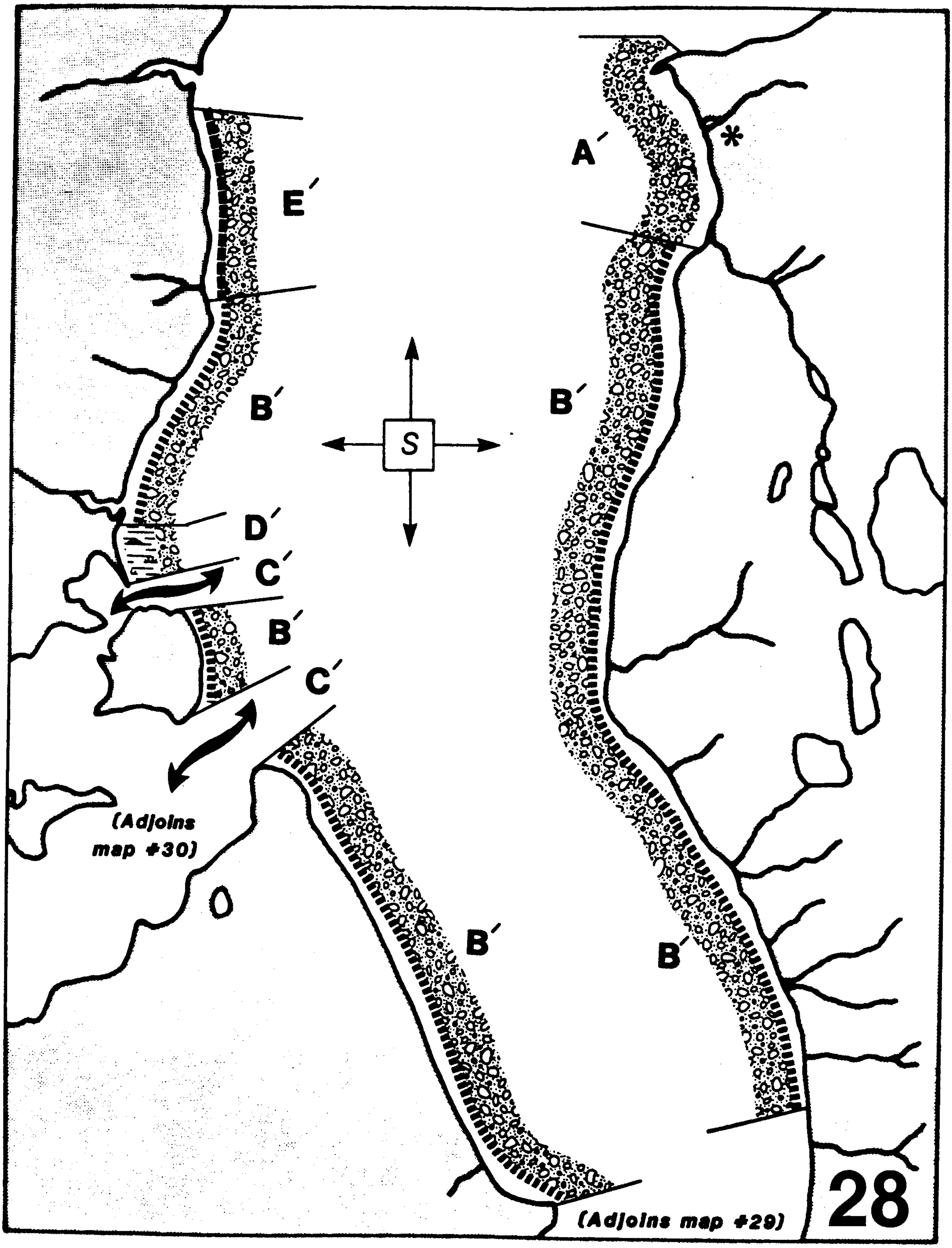


HUMAN USE INDEX

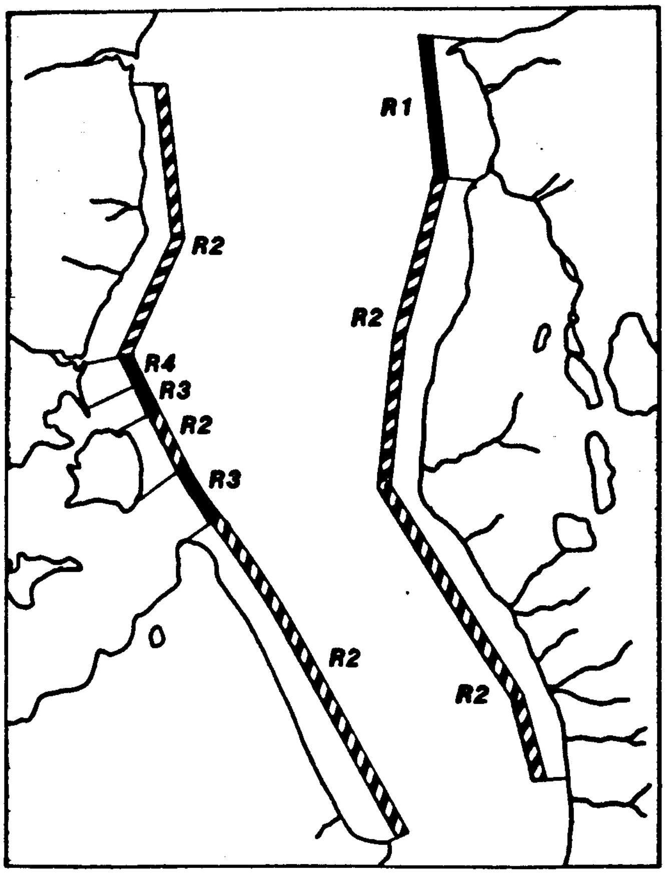
Seasonal Variability of Indices

		SEASON							
			Break-Up/Summer/Freeze-Up						
Identifier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Protected tundra cliff				▨	▨	▨		
R2	Ephemeral inlet; Lagoon				■	■	■		
H1	Fishing			▨	▨	▨	▨		

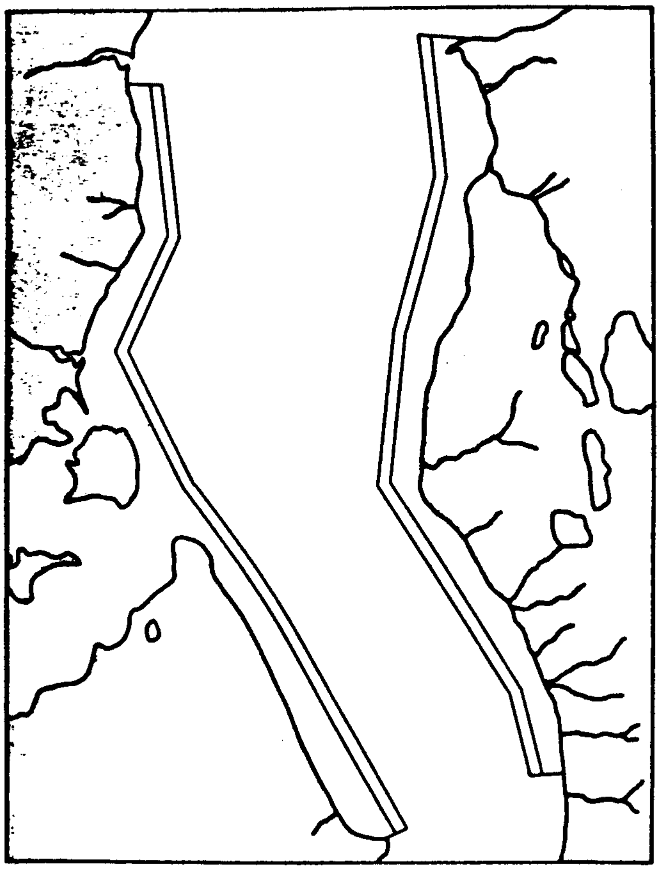
27


A´
*
E´
B´
B´
S
D´
C´
B´
C´
(Adjoins map #30)
B´
B´
(Adjoins map #29)
28

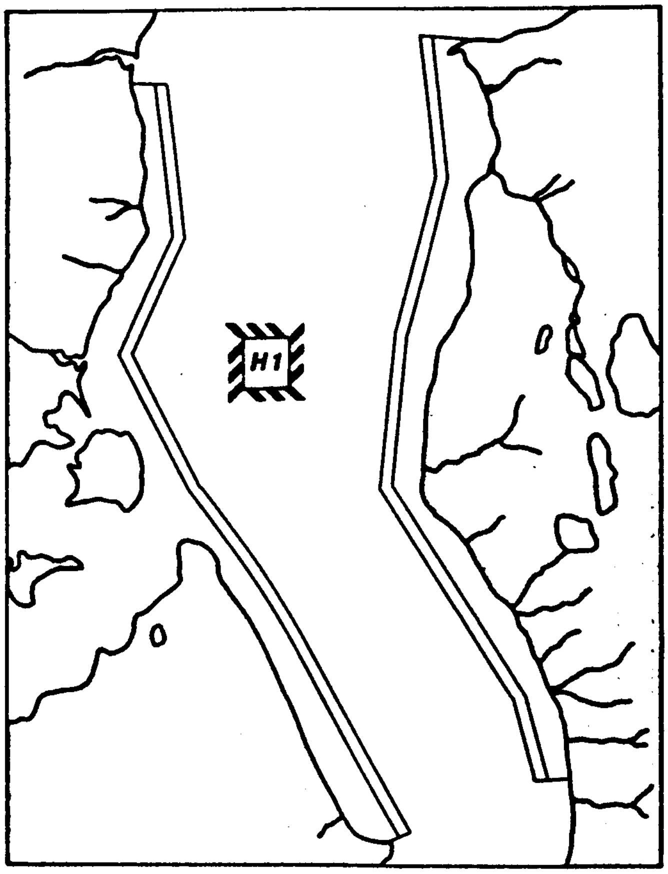
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



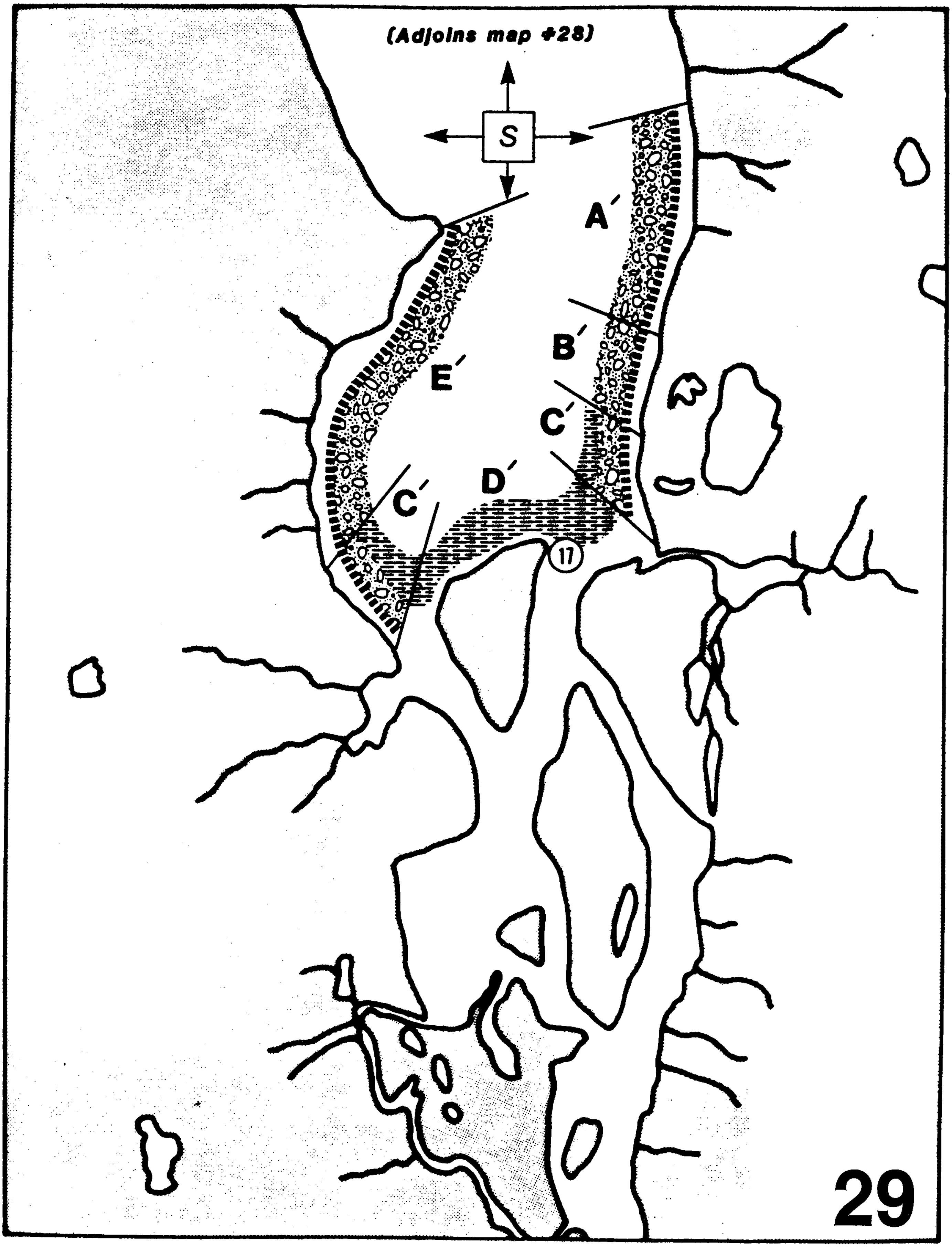
HUMAN USE INDEX



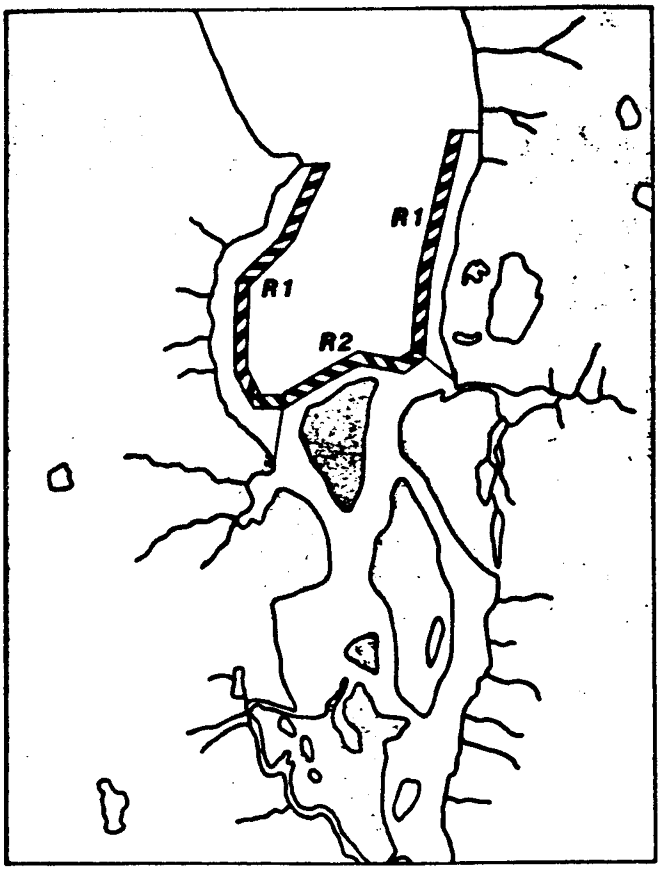
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach				■	■	■		
R2	Protected tundra cliff				▨	▨	▨		
R3	Permanent inlet; Lagoon				■	■	■		
R4	Low energy beach; Wetland				■	■	■		
H1	Fishing			▨	▨	▨	▨		

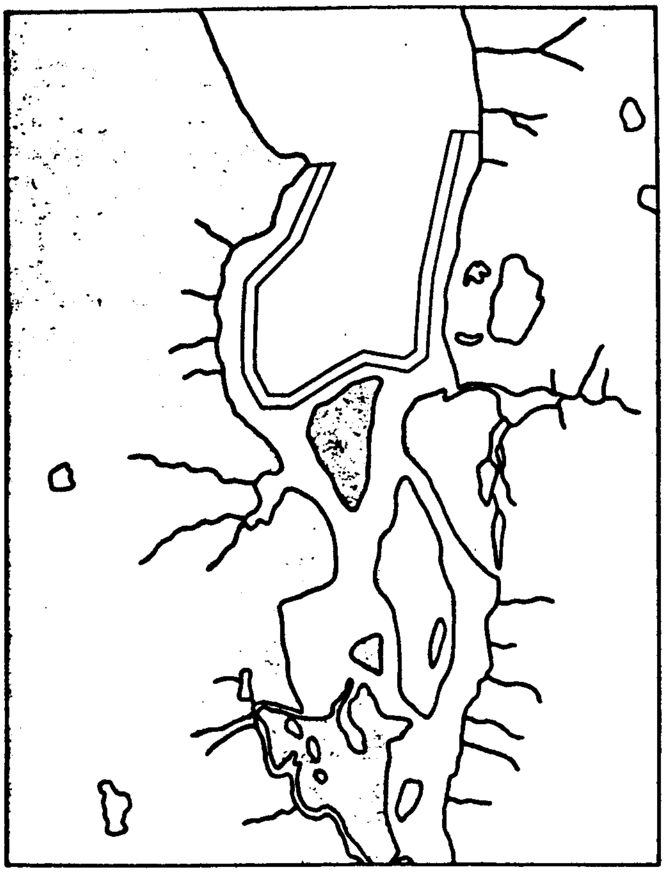
28


(Adjoins map #28)
S
A´
B´
C´
E´
D´
C´
⑰
29

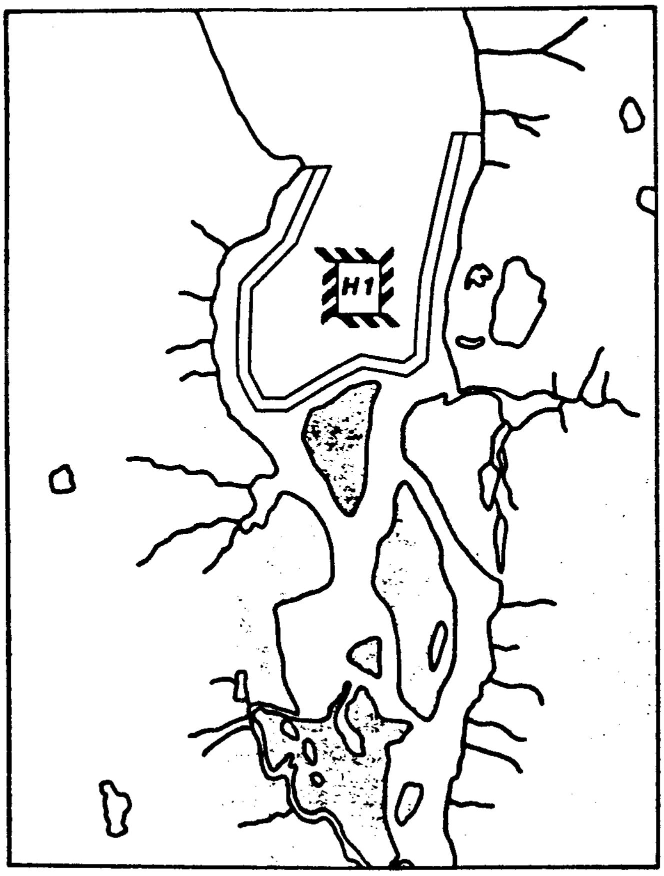
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



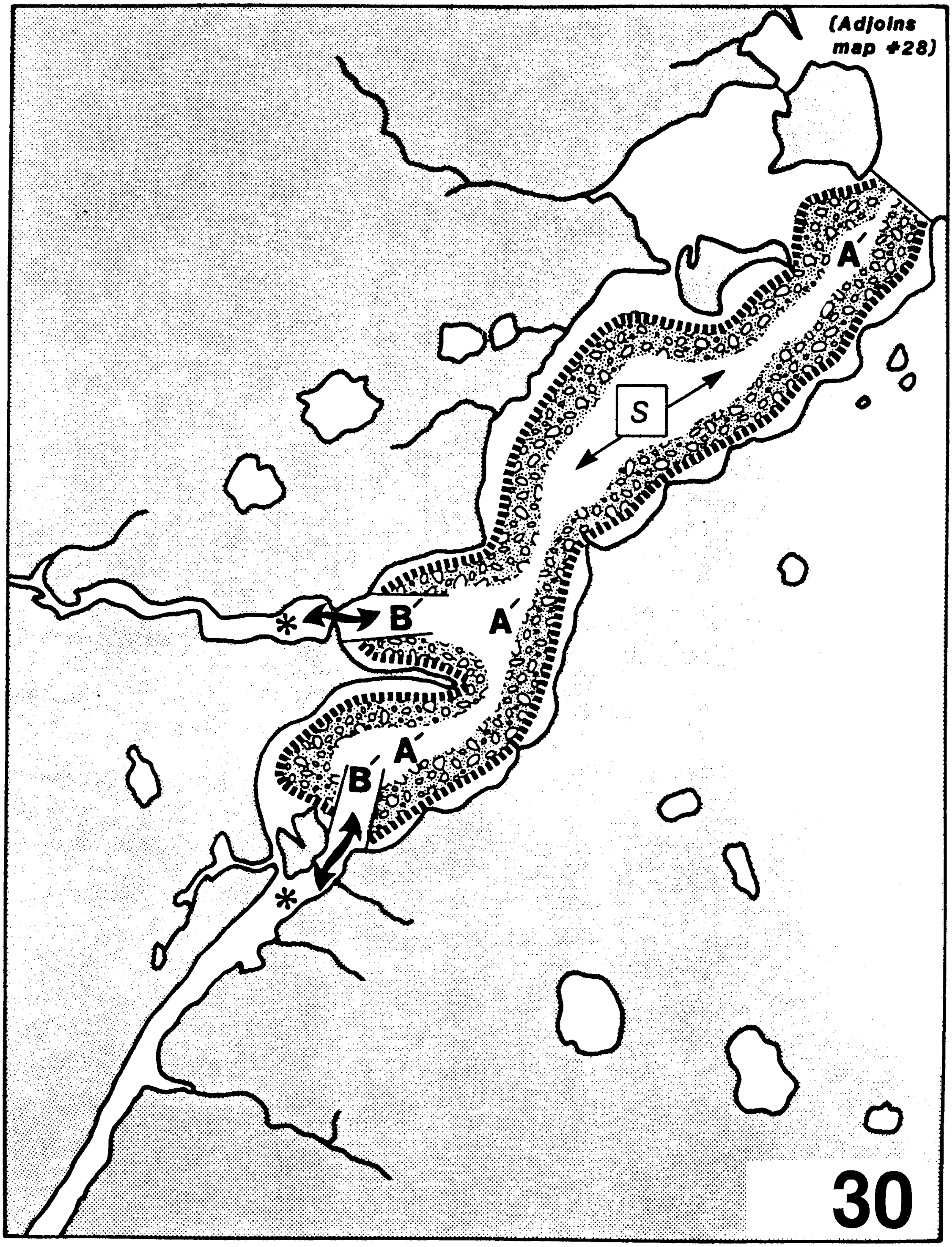
HUMAN USE INDEX



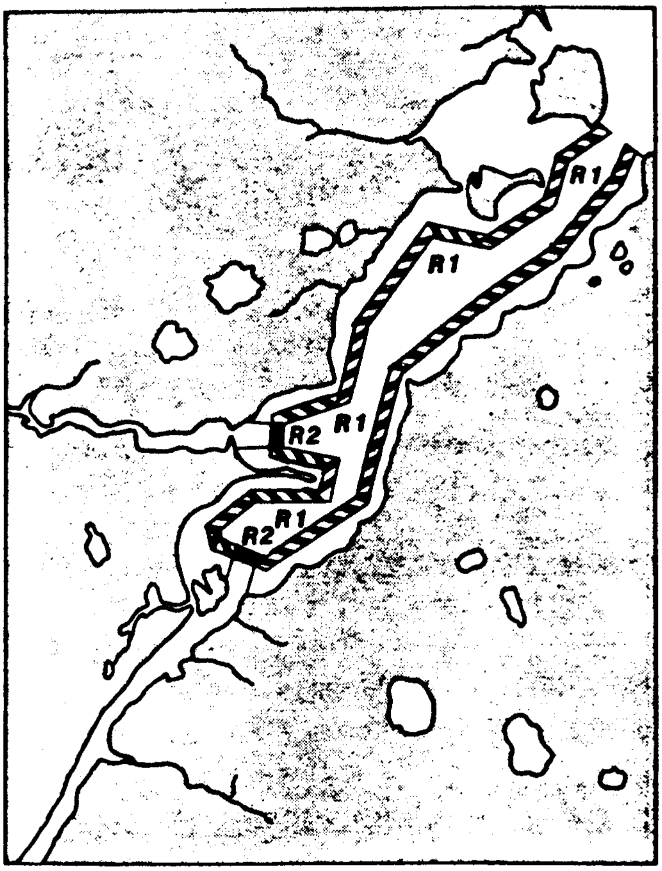
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff				▨	▨	▨		
R2	Delta flats				▨	▨	▨		
H1	Fishing			▨	▨	▨	▨		

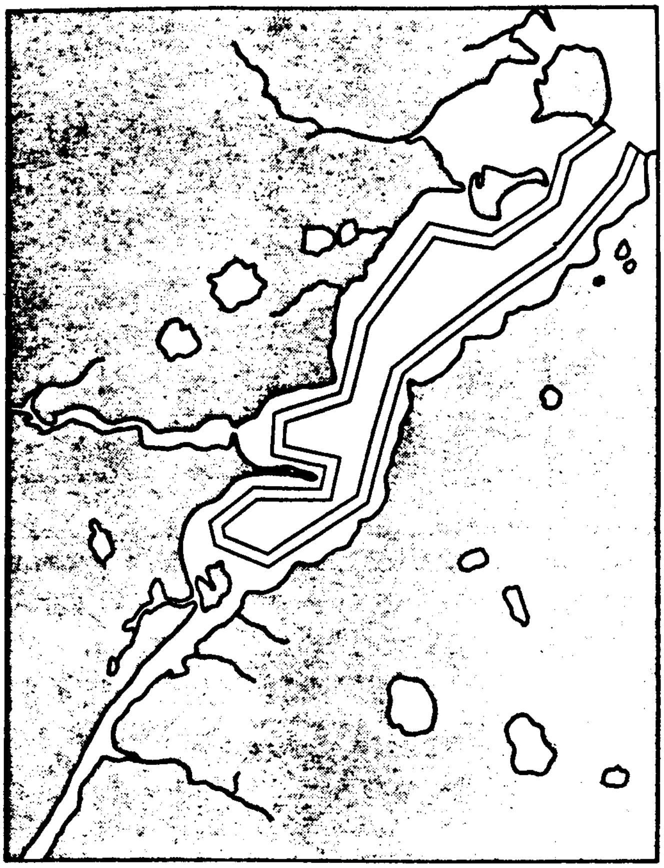
29


(Adjoins map #28)
A´
S
A´
B´
*
B´
A´
*
30

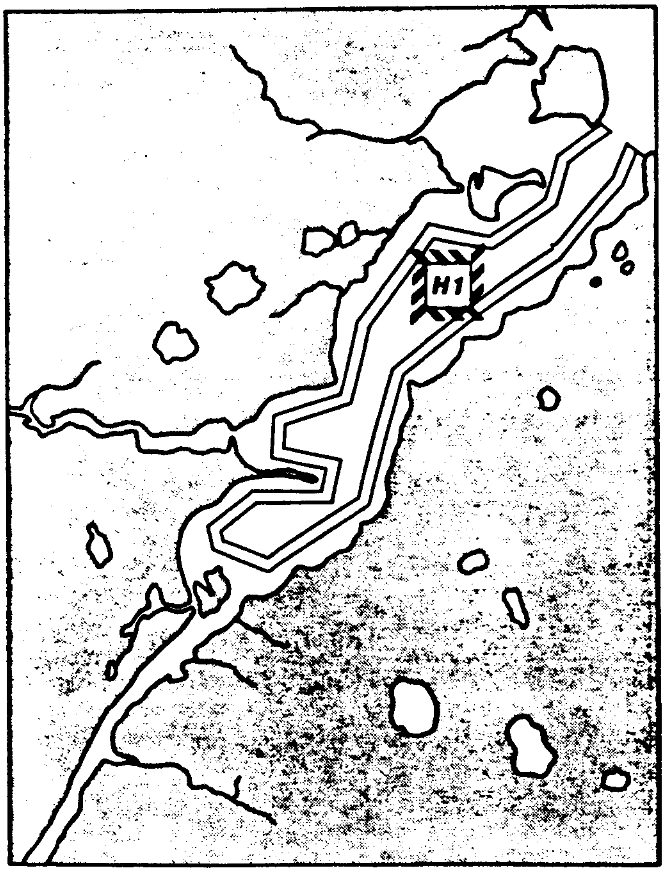
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



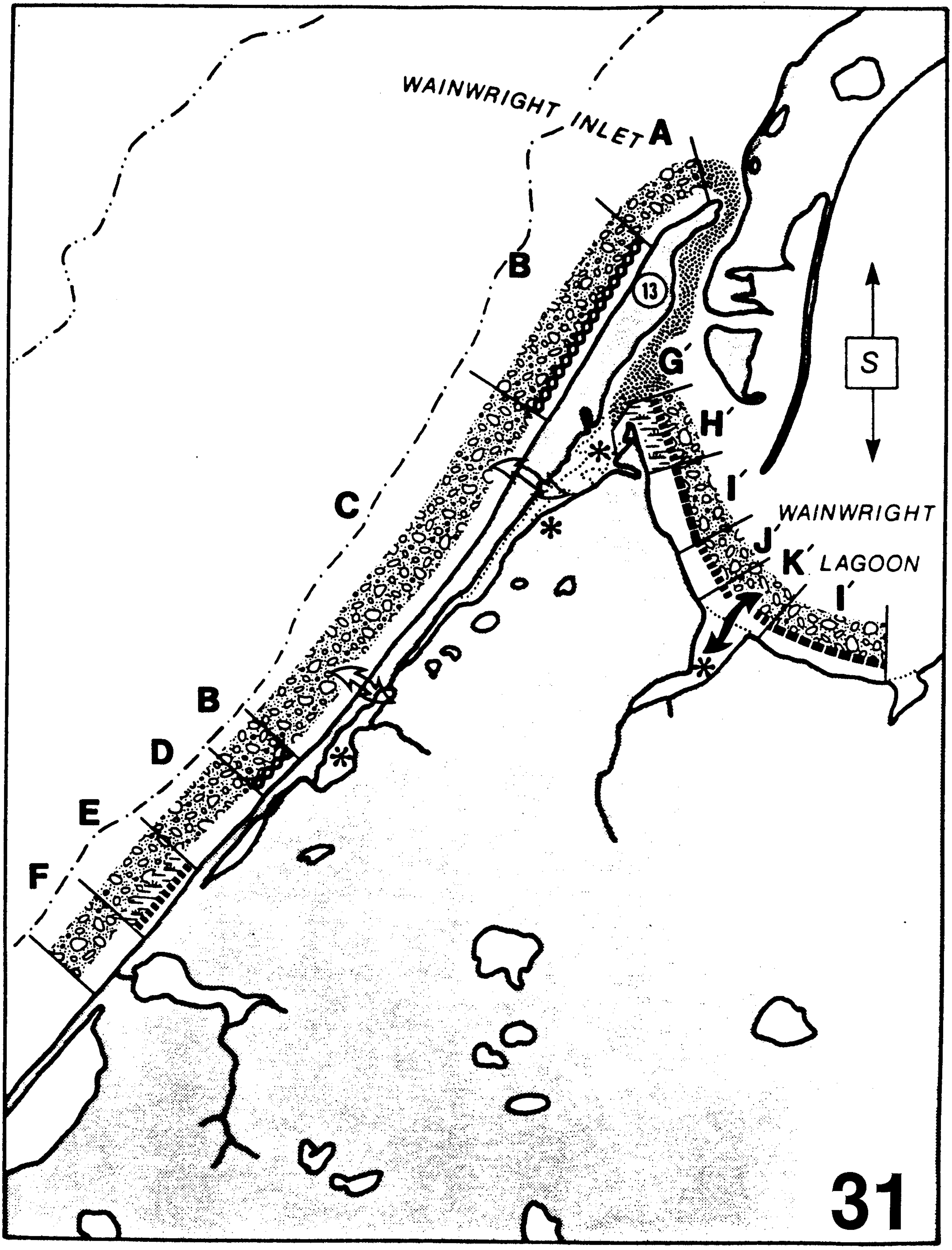
HUMAN USE INDEX

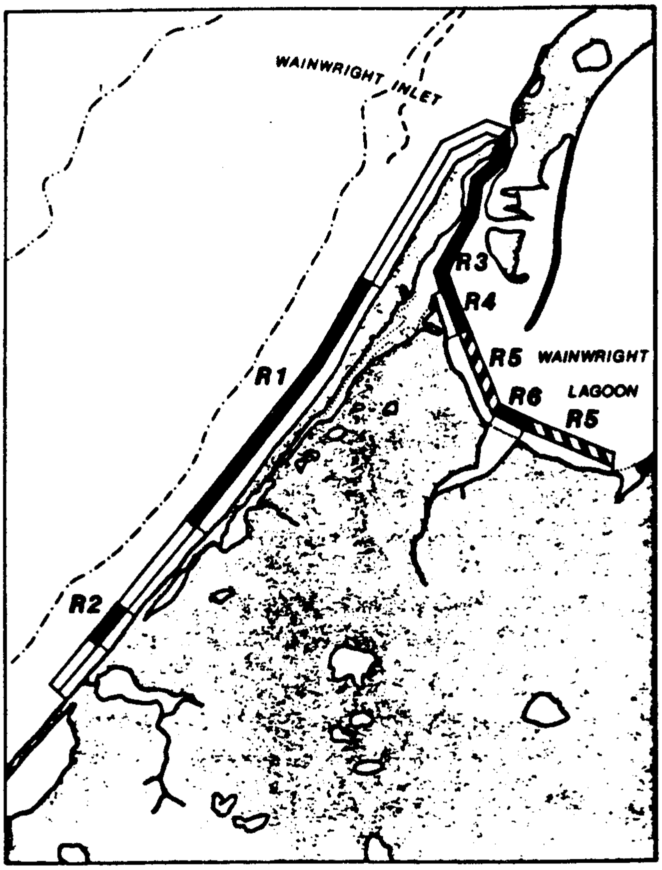


Seasonal Variability of Indices

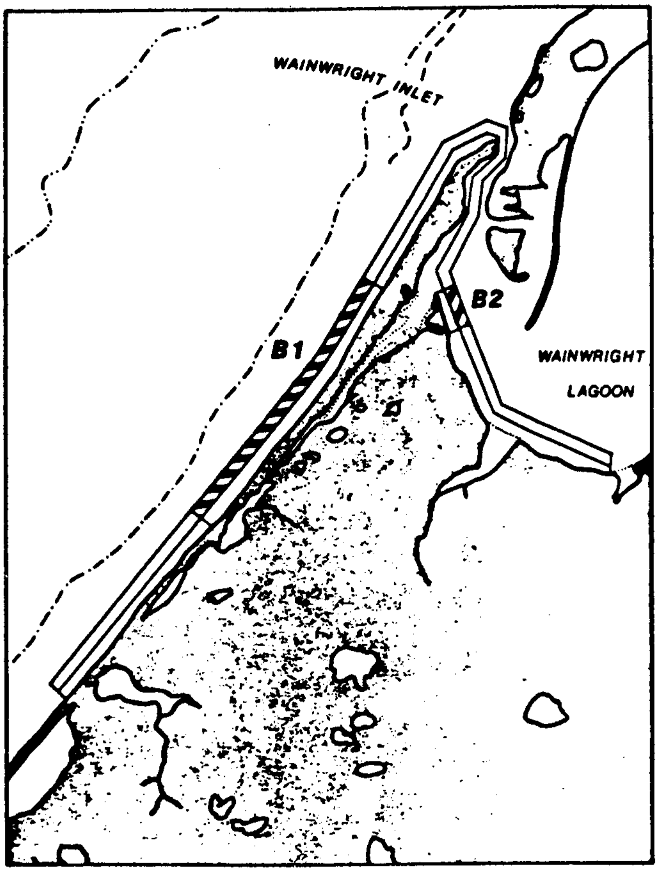
Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff				▨	▨	▨		
R2	Stable inlet; Estuary				■	■	■		
H1	Fishing			▨	▨	▨	▨		

30

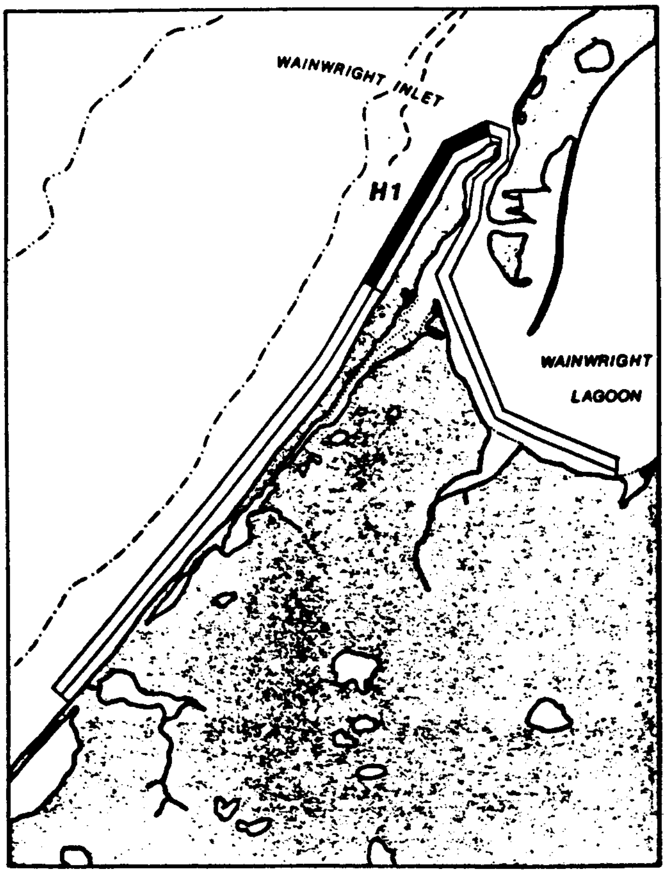

WAINWRIGHT INLET
A
B
13
G
H
S
I
C
WAINWRIGHT
J
K
LAGOON
I
B
D
E
F
31



OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX

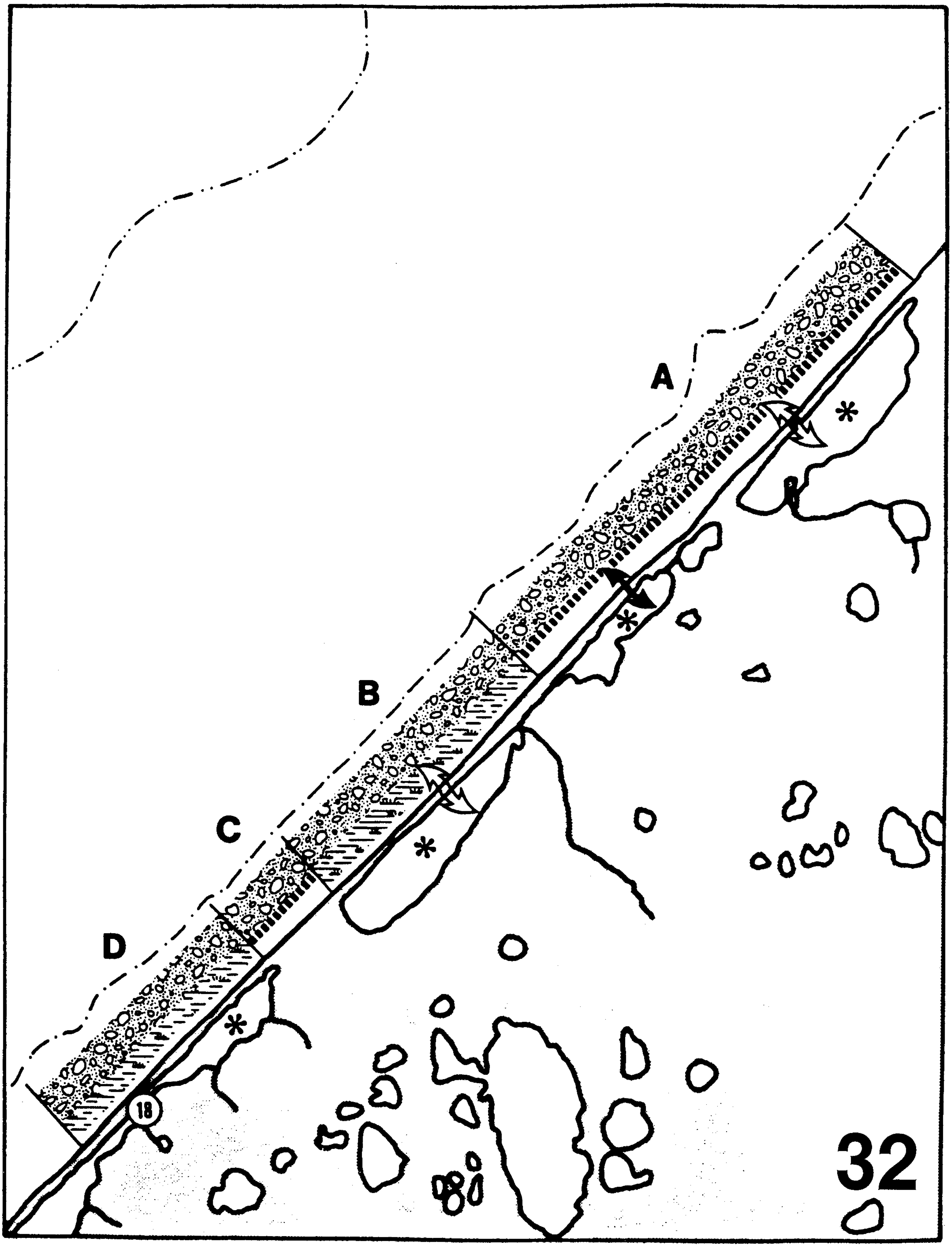


HUMAN USE INDEX

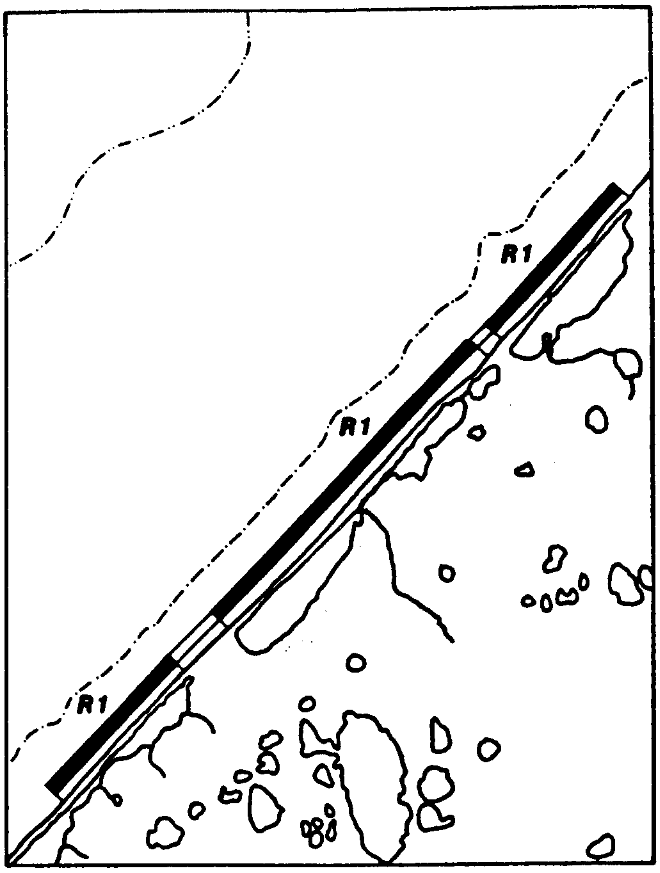
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Washover channels; Lagoon				■	■	■	■	
R2	Wetland				■	■	■	■	
R3	Low energy beach				■	■	■		
R4	Low energy beach; Wetland				■	■	■		
R5	Protected tundra cliff				▨	▨	▨		
R6	Stable inlet; Estuary				■	■	■		
B1	Wetland and lagoon			▨	▨	▨	▨	▨	
B2	Wetland			▨	▨	▨	▨	▨	
H1	Egg gathering			■	■				
	Waterfowl hunting					■	■		

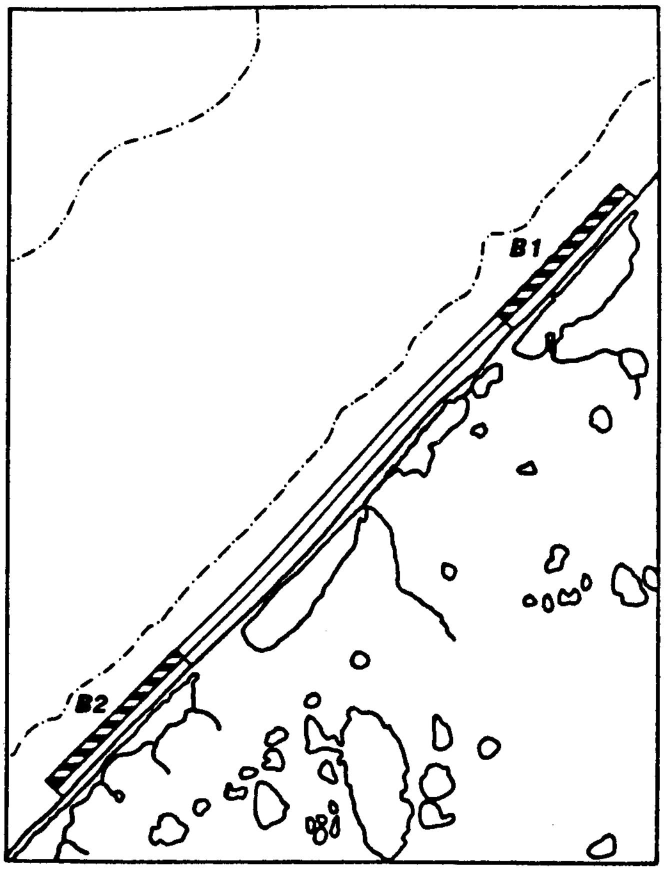
31


A
B
C
D
18
32

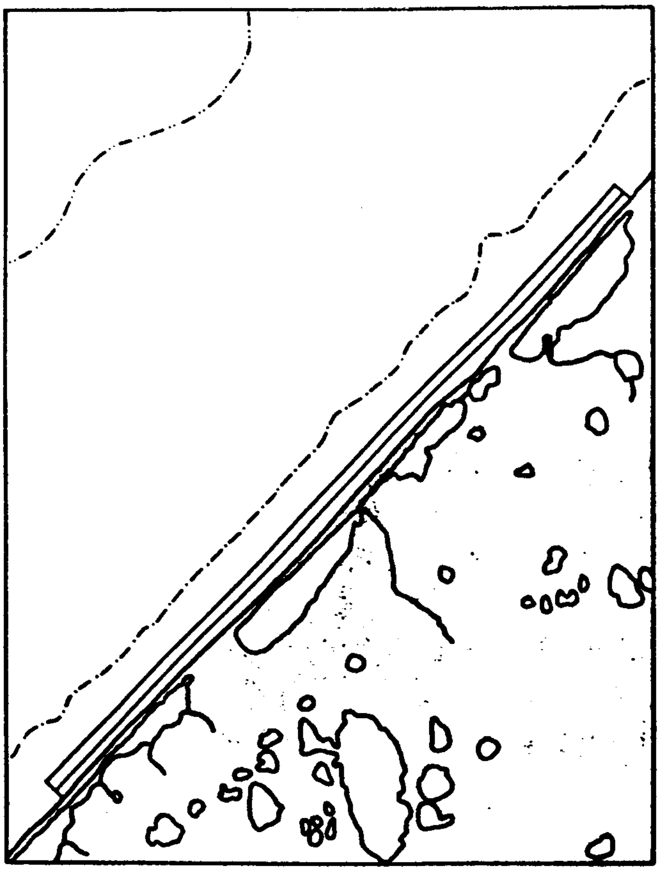
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



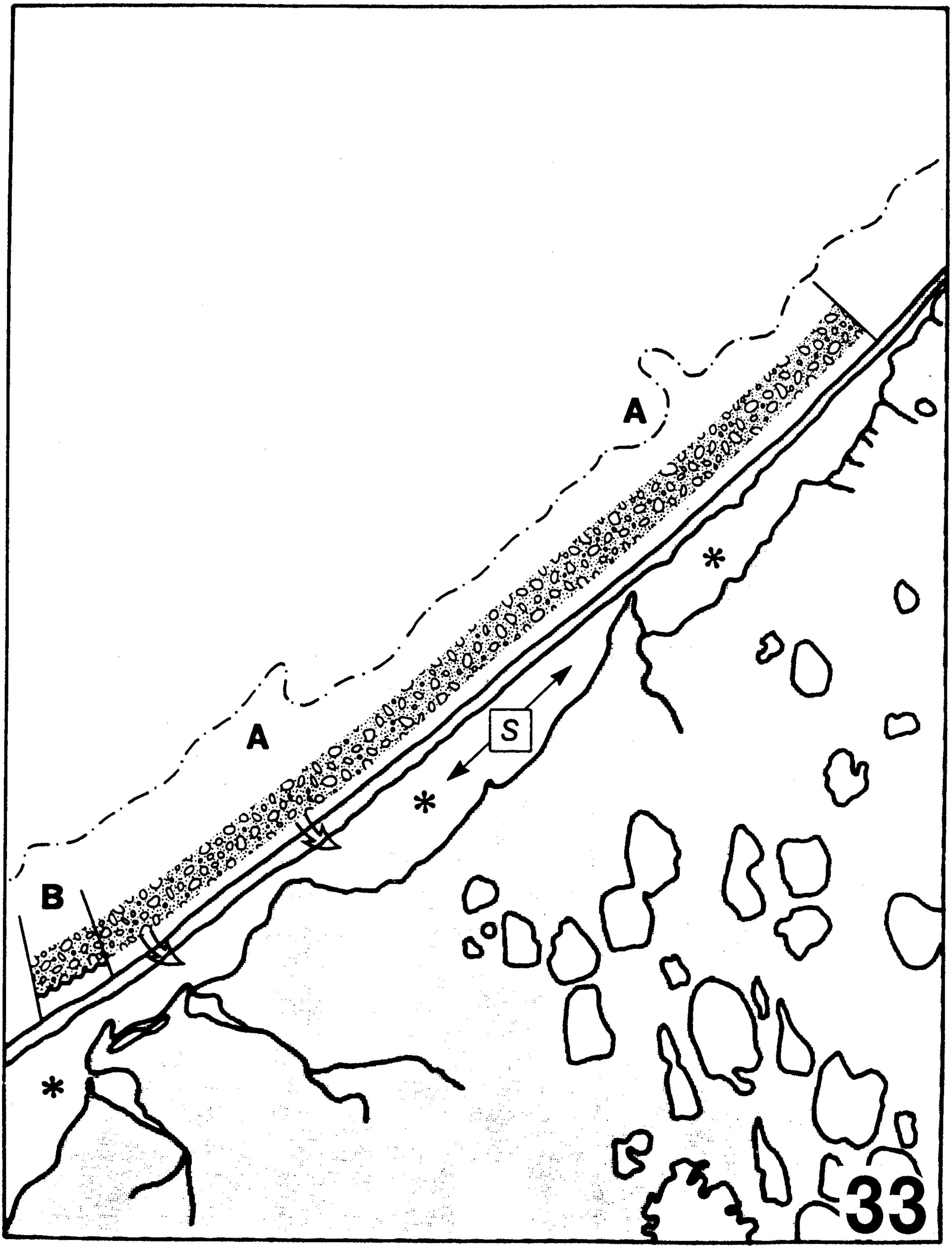
HUMAN USE INDEX



Seasonal Variability of Indices

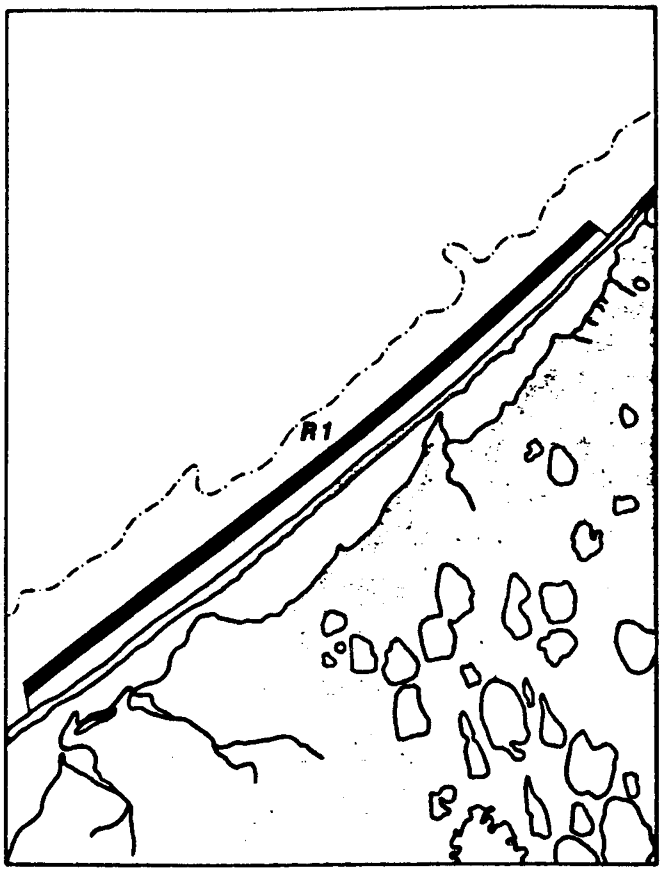
		SEASON							
Identi-fier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Washover fan or inlet; estuary				▬	▬	▬	▬	
B1	Lagoon and wetland			▨	▨	▨	▨	▨	
B2	Lagoon and wetland			▨	▨	▨	▨	▨	

32

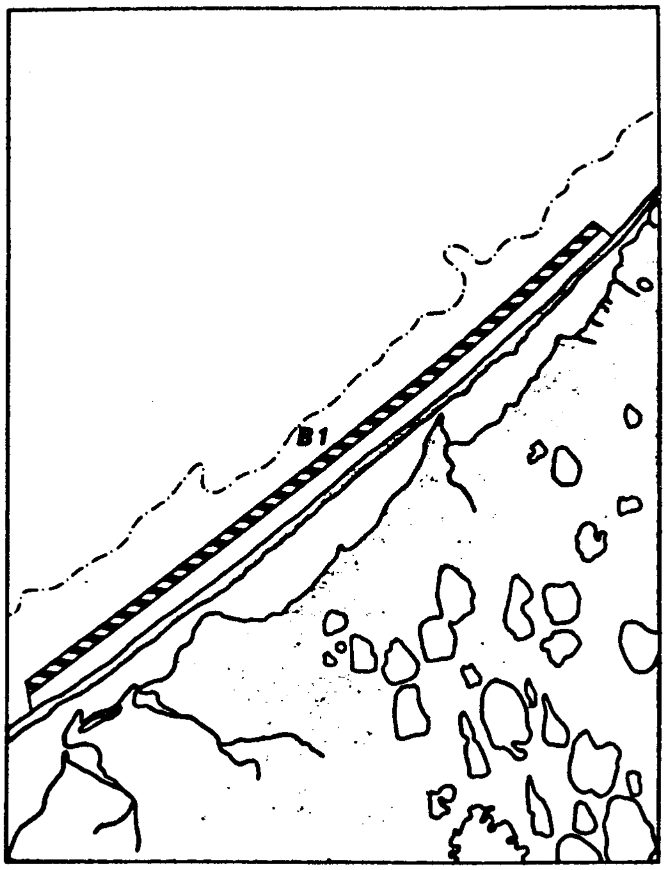


A
A
B
S
*
*
*
33

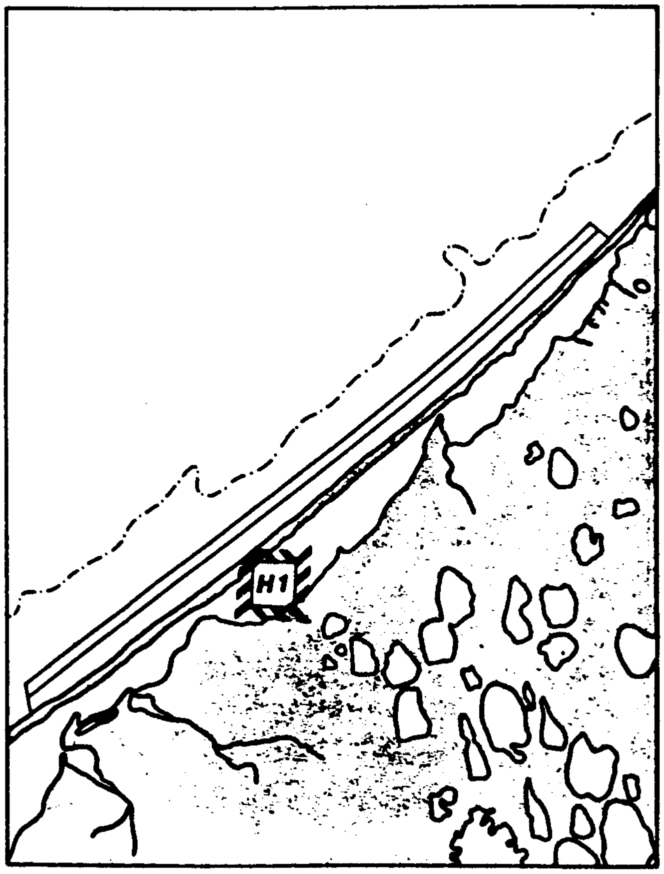
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



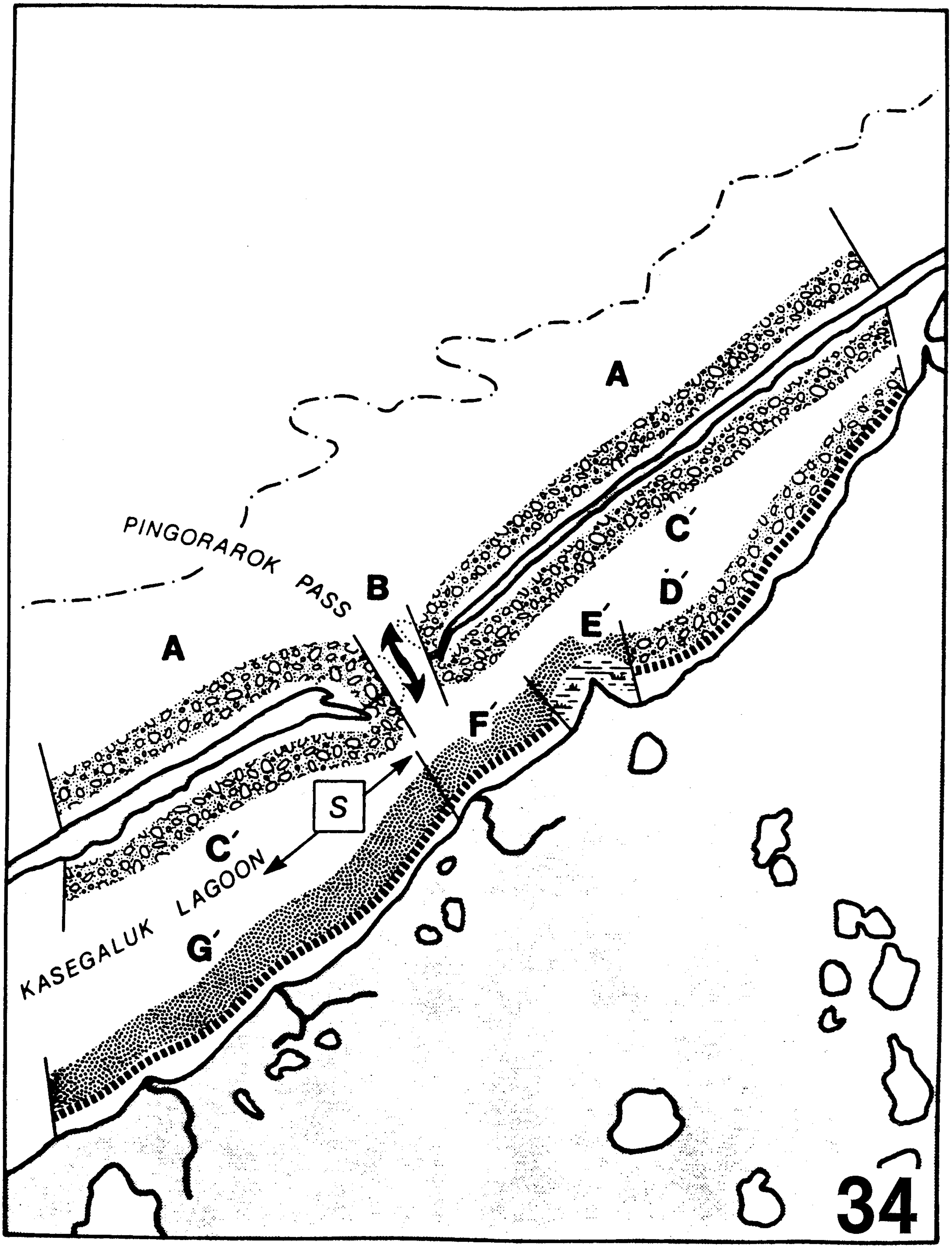
HUMAN USE INDEX



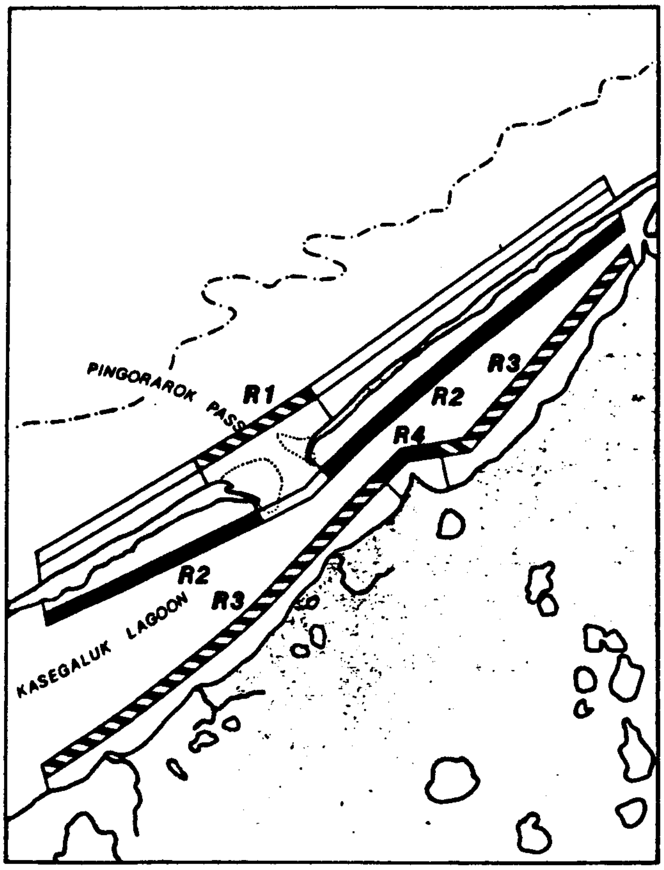
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Washover fan; lagoon				■	■	■	■	
B1	Lagoon and wetland			▨	▨	▨	▨	▨	
H1	Beluga whale hunting				▨	▨			
	Spotted seal hunting				▨	▨			

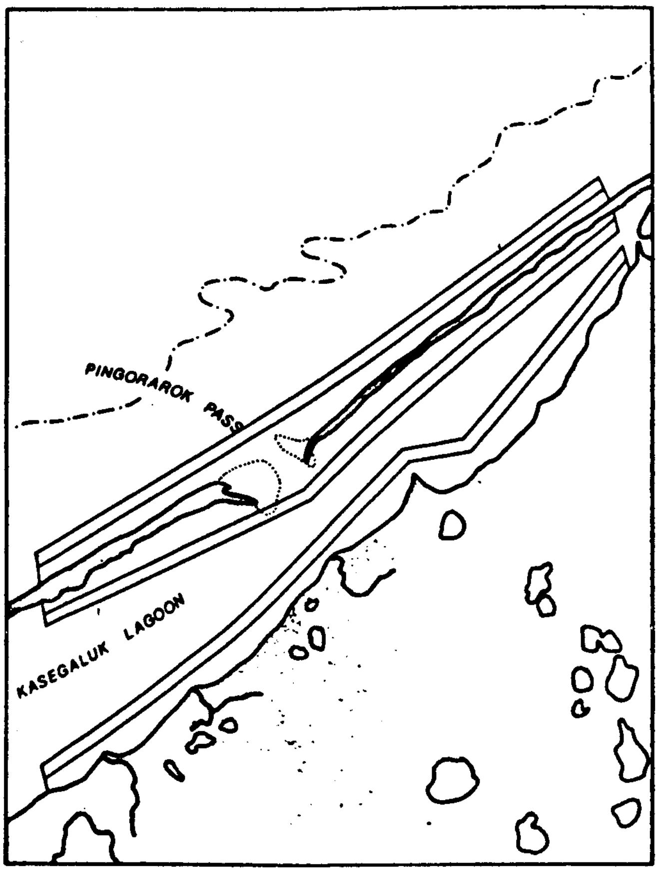
33


A
PINGORAROK PASS
B
A
C´
D´
E´
F´
S
C´
KASEGALUK LAGOON
G´
34

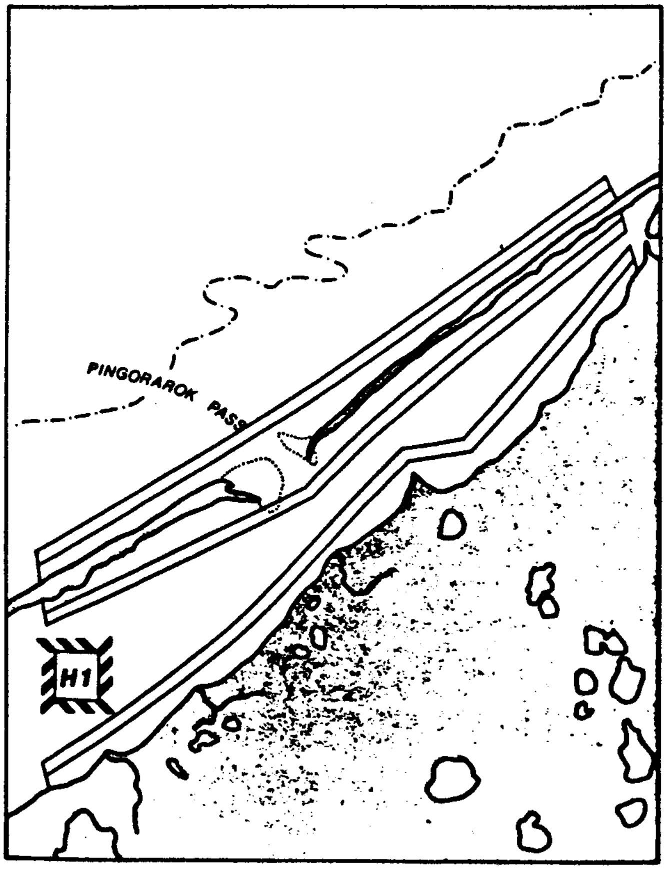
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



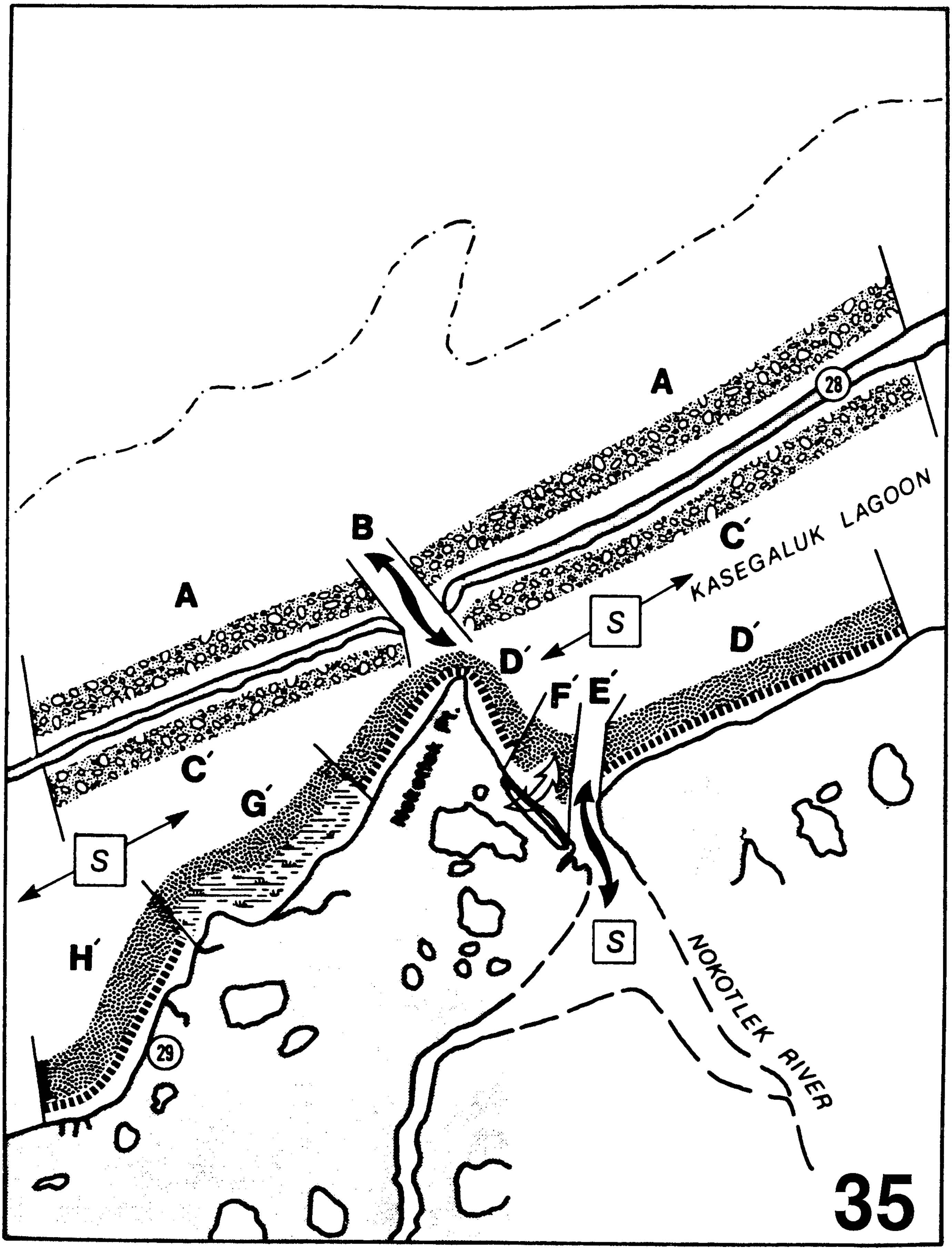
HUMAN USE INDEX



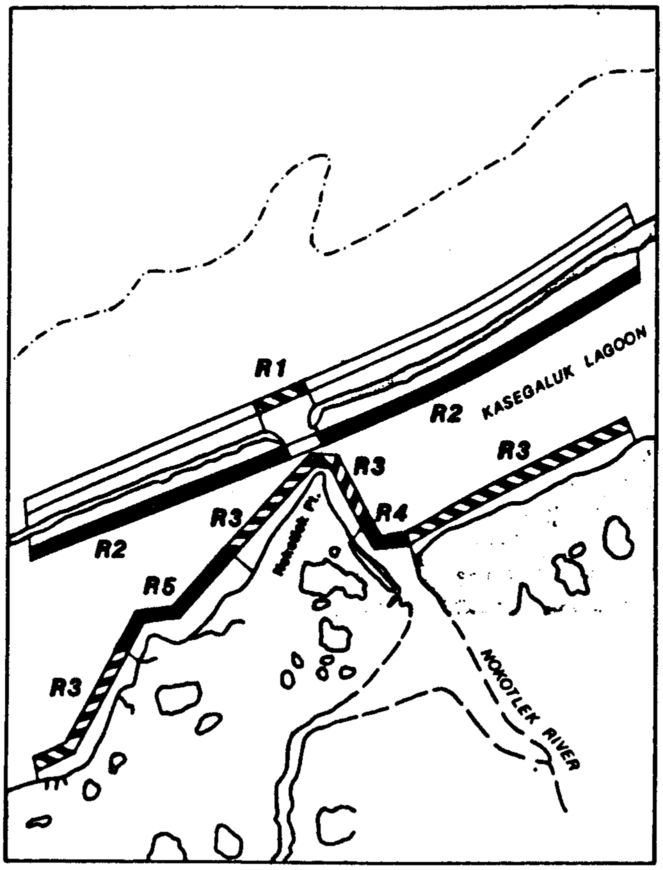
Seasonal Variability of Indices

		SEASON							
			Break-Up/Summer/Freeze-Up						
Identifier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Stable inlet; Recurve spits				▨	▨	▨	▨	
R2	Low energy beach				■	■	■		
R3	Protected tundra cliff				▨	▨	▨		
R4	Low energy beach; Wetland				■	■	■		
H1	Beluga whale hunting				▨	▨			
	Spotted seal hunting				▨	▨			

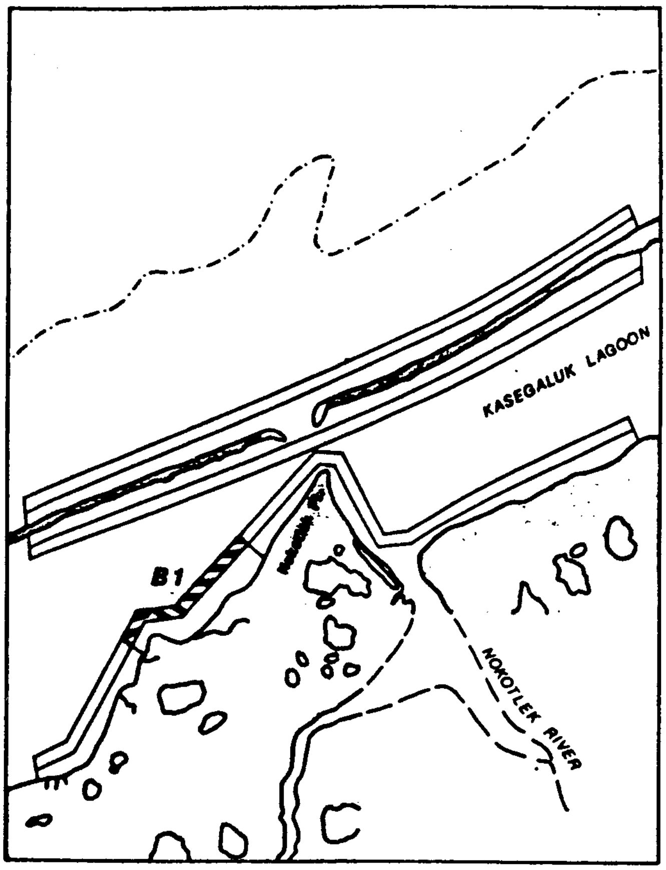
34


A
A
B
C′
C′
KASEGALUK LAGOON
S
D′
D′
F′
E′
G′
S
H′
28
29
S
NOKOTLEK RIVER
35

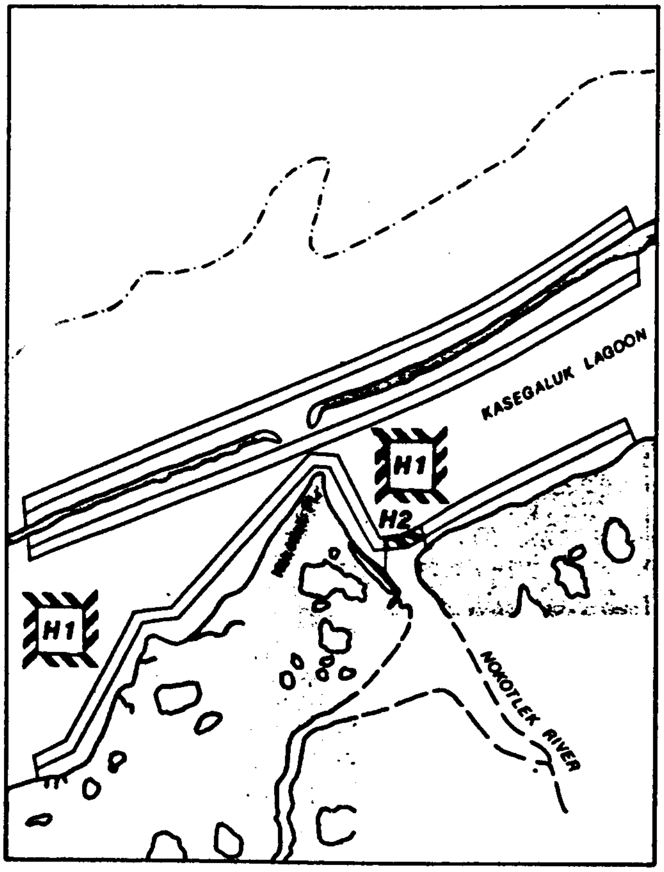
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



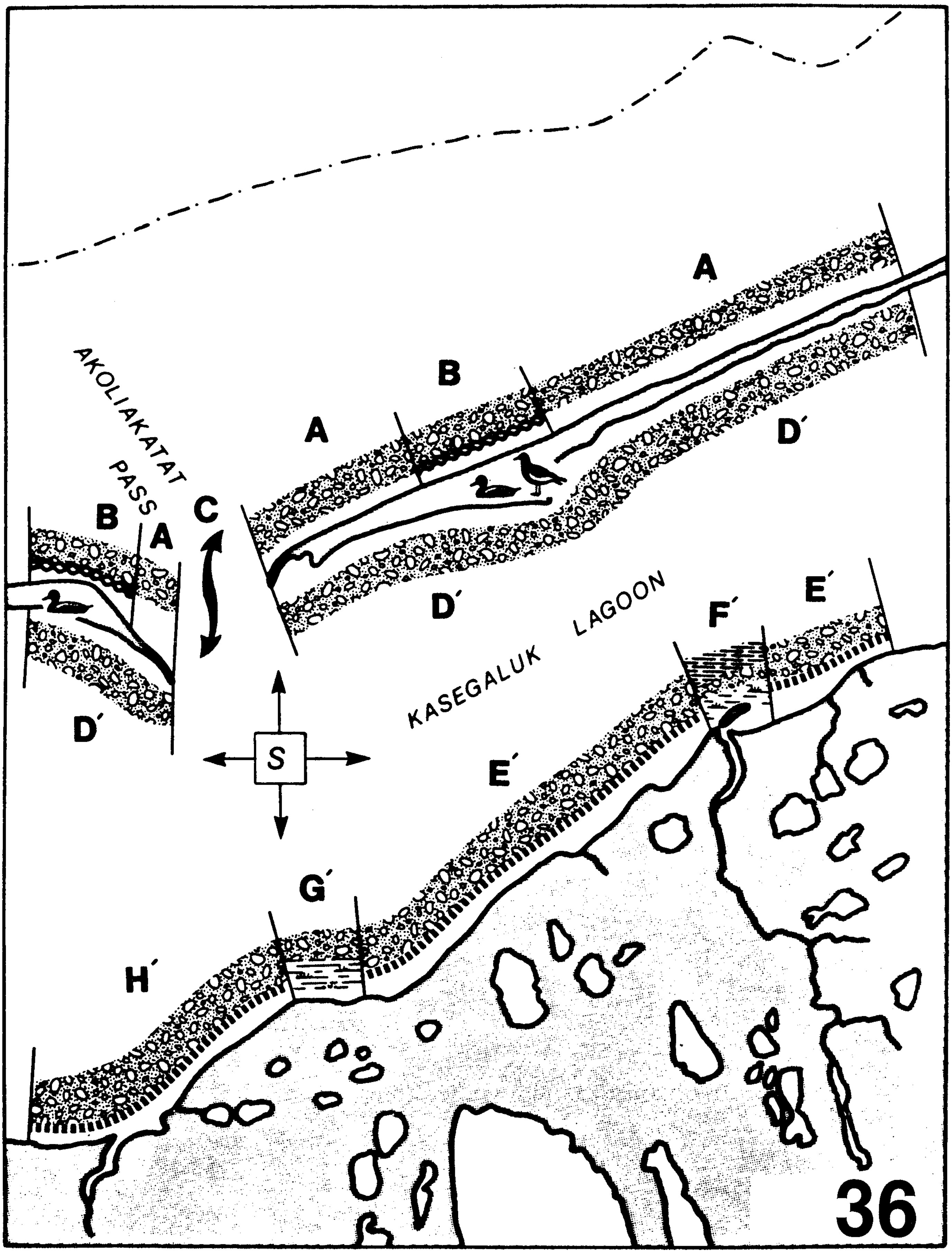
HUMAN USE INDEX



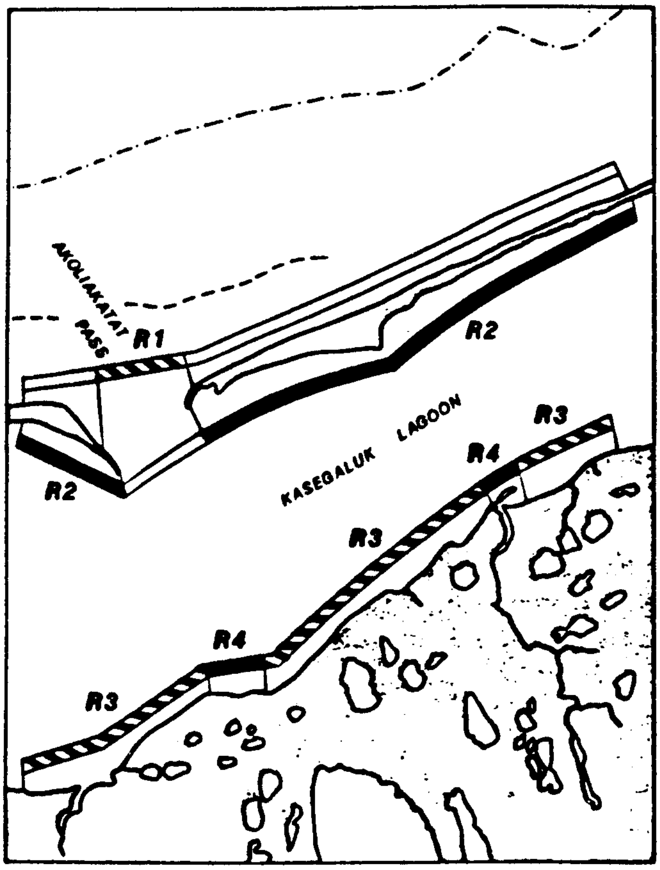
Seasonal Variability of Indices

		SEASON							
			Break-Up/Summer/Freeze-Up						
Identifier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Stable inlet; Recurve spits				▨	▨	▨	▨	
R2	Low energy beach				■	■	■		
R3	Protected tundra cliff				▨	▨	▨		
R4	Inlets; lagoon/ river				■	■	■		
R5	Low energy beach; Wetland				■	■	■		
B1	Wetland			▨	▨	▨	▨	▨	
H1	Beluga whale hunting				▨	▨			
	Spotted seal hunting				▨	▨			
H2	Fishing			▨	▨	▨	▨		

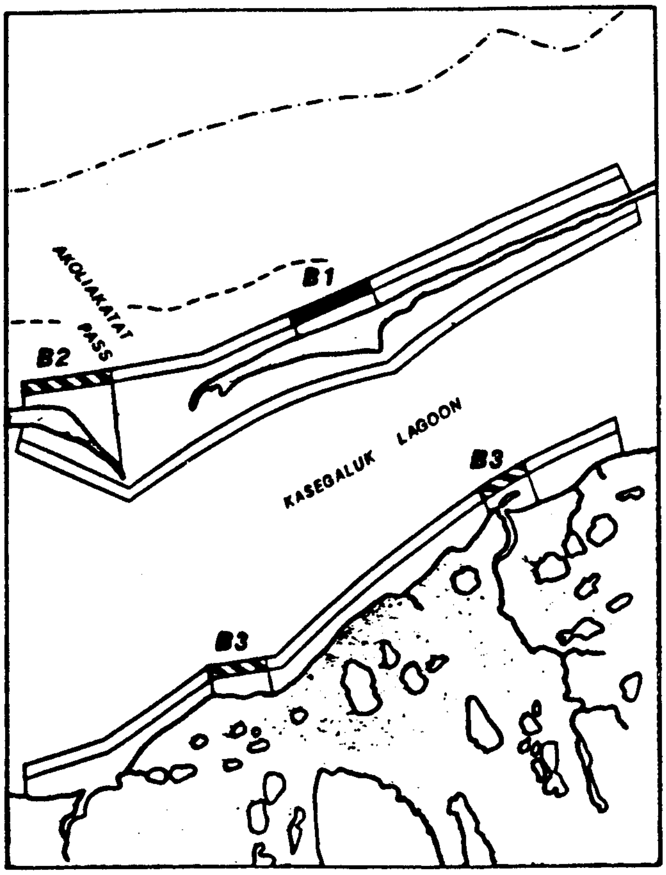
35


AKOLIAKATAT PASS
A
B
A
B
A
A
B
C
D´
D´
D´
KASEGALUK LAGOON
S
F´
E´
E´
G´
H´
36

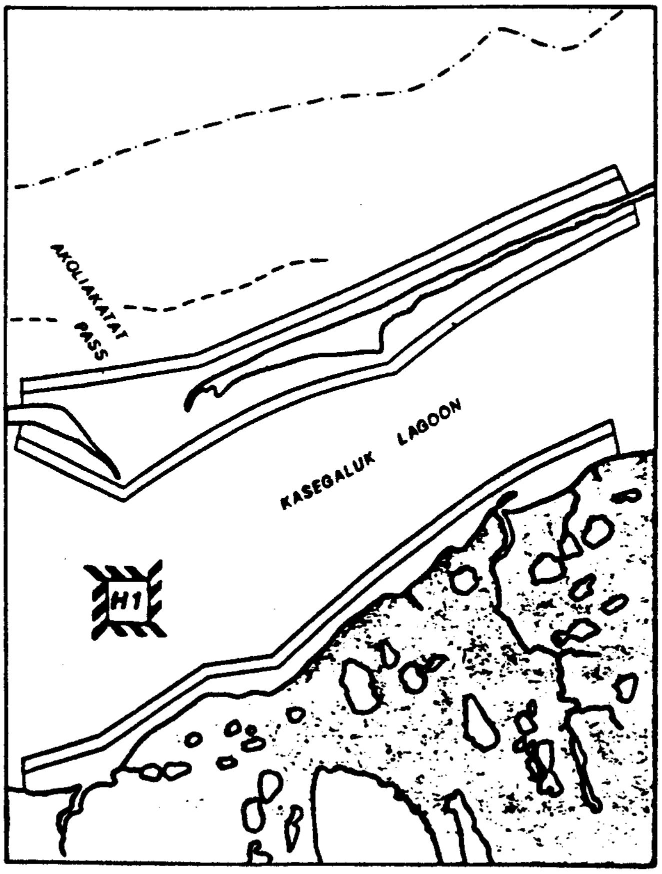
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



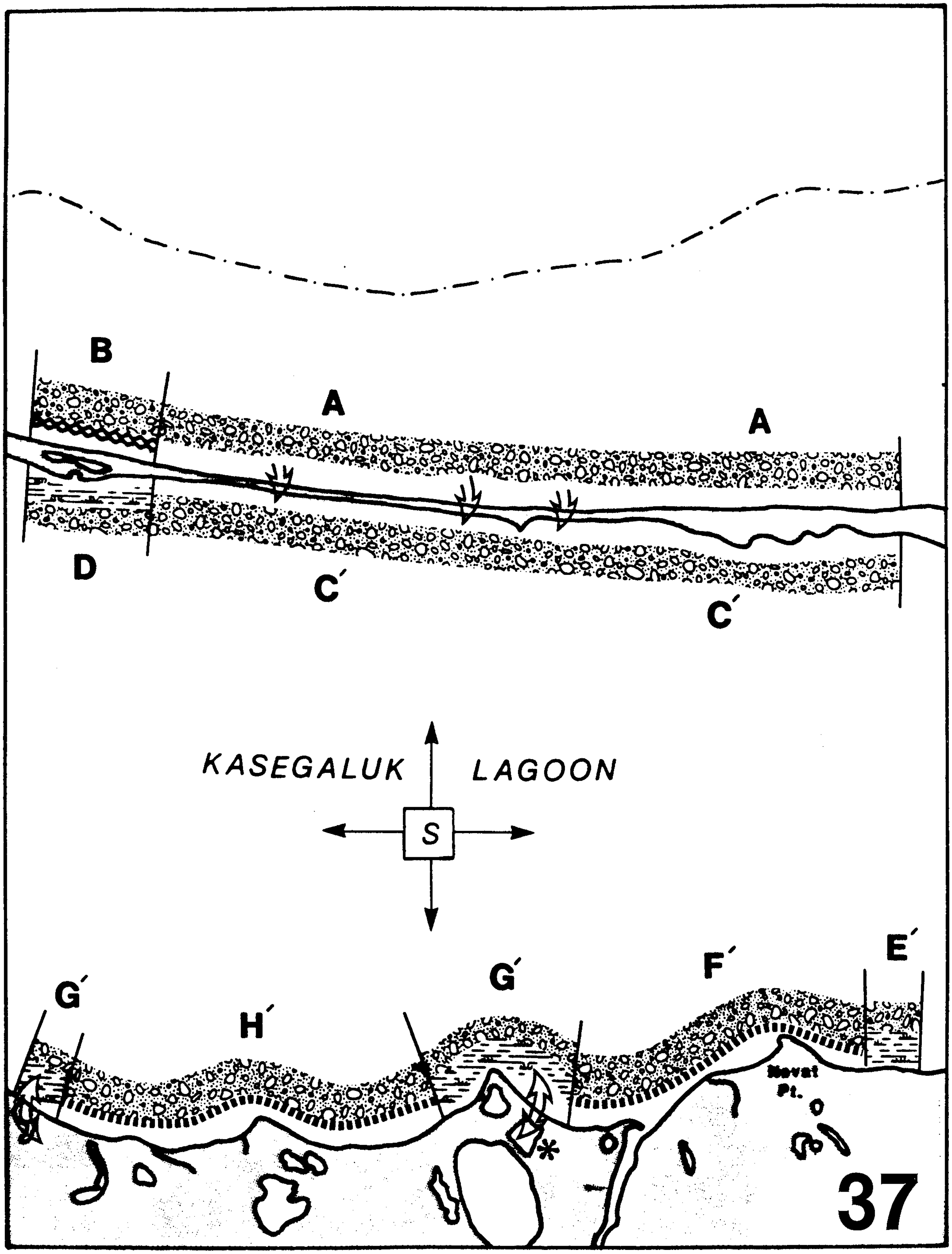
HUMAN USE INDEX



Seasonal Variability of Indices

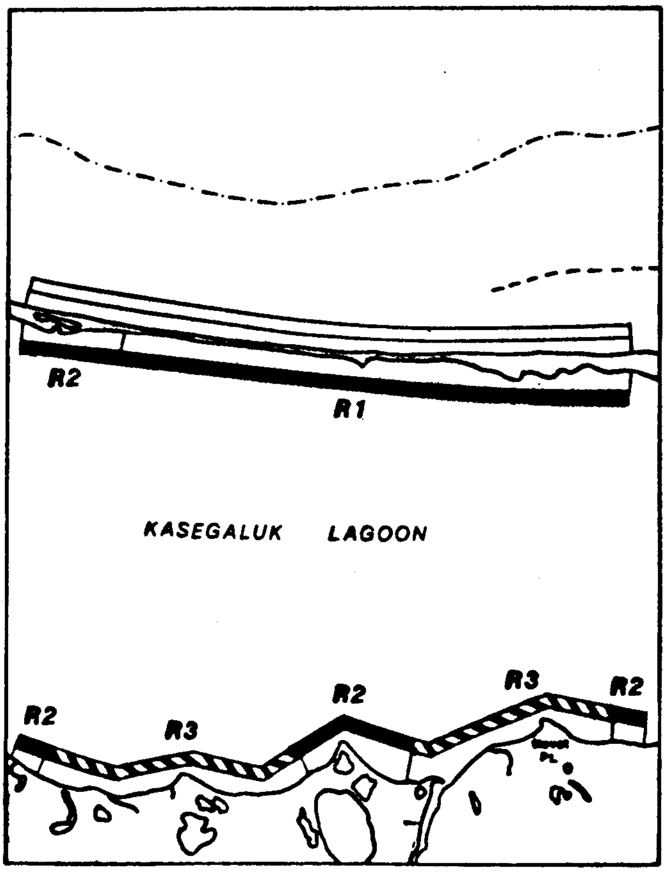
Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Stable inlet; Recurve spits				▨	▨	▨	▨	
R2	Low energy beach				■	■	■		
R3	Protected tundra cliff				▨	▨	▨		
R4	Inlets; lagoon/ river				■	■	■		
B1	Eider (450 pr), gull (10 pr) and arctic tern (42 pr) nesting			■	■				
B2	Eider nesting			▨	▨				
B3	Wetland			▨	▨	▨	▨		
H1	Beluga whale hunting				▨	▨			
	Spotted seal hunting				▨	▨			
	Fishing			▨	▨	▨	▨		

36

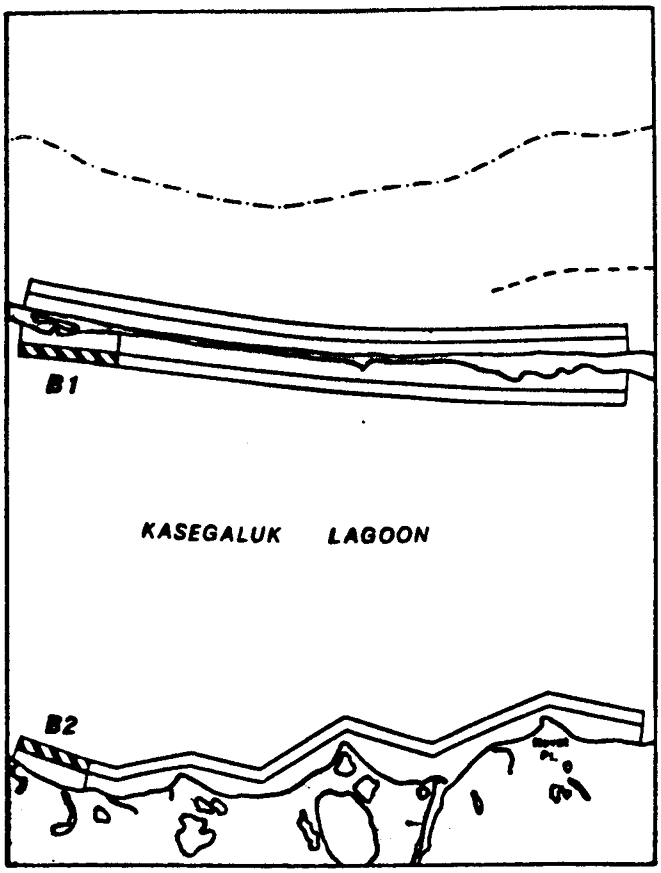


37

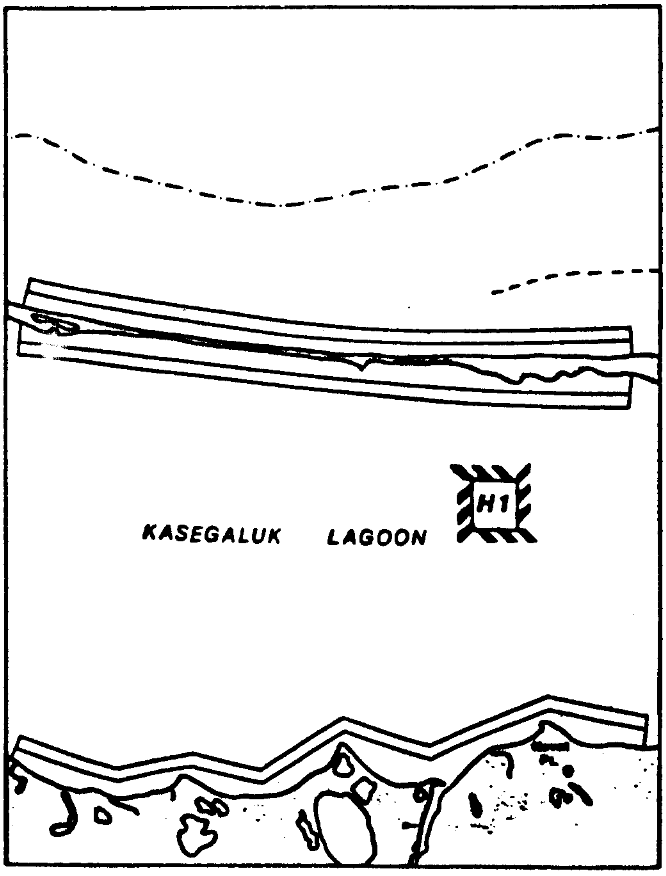
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



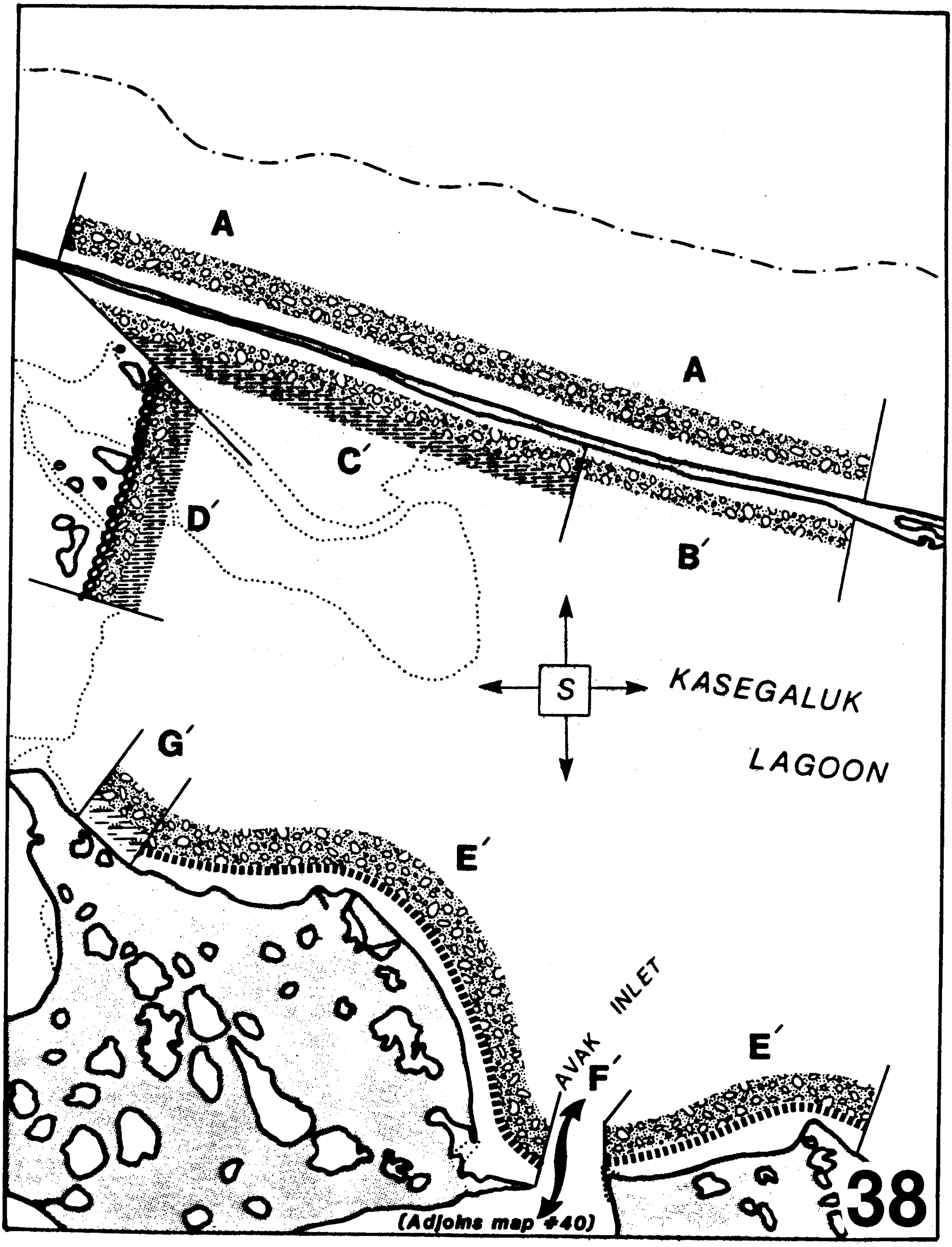
HUMAN USE INDEX



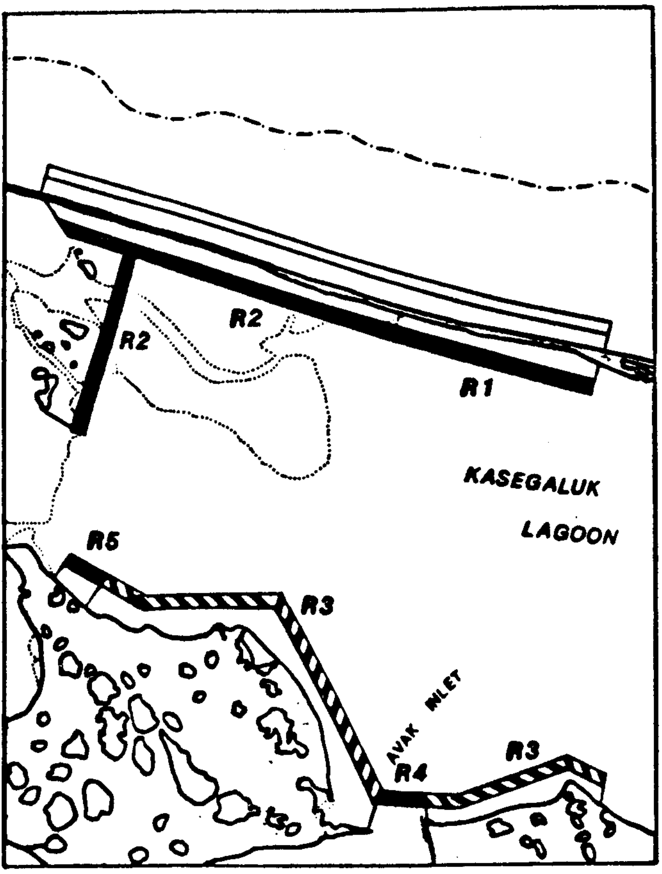
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach				■	■	■		
R2	Low energy beach; Wetland				■	■	■		
R3	Protected tundra cliff				▨	▨	▨		
B1	Wetland use by brant			▨	▨	▨	▨	▨	
B2	Wetland and mudflat			▨	▨	▨	▨	▨	
H1	Beluga whale hunting				▨	▨			
	Spotted seal hunting				▨	▨			

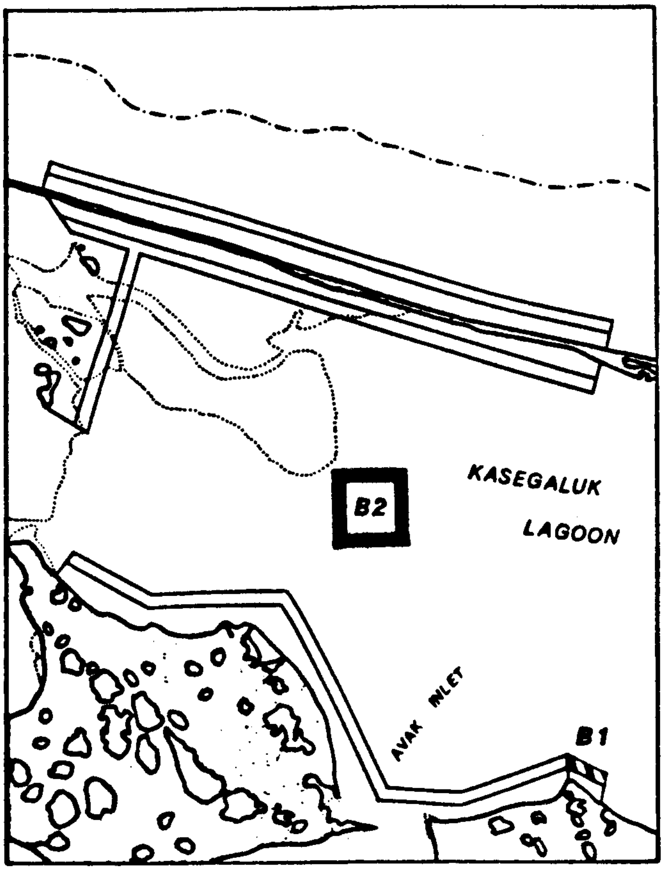
37


A
A
C'
D'
B'
S
KASEGALUK
LAGOON
G'
E'
AVAK INLET
E'
F'
(Adjoins map #40)
38

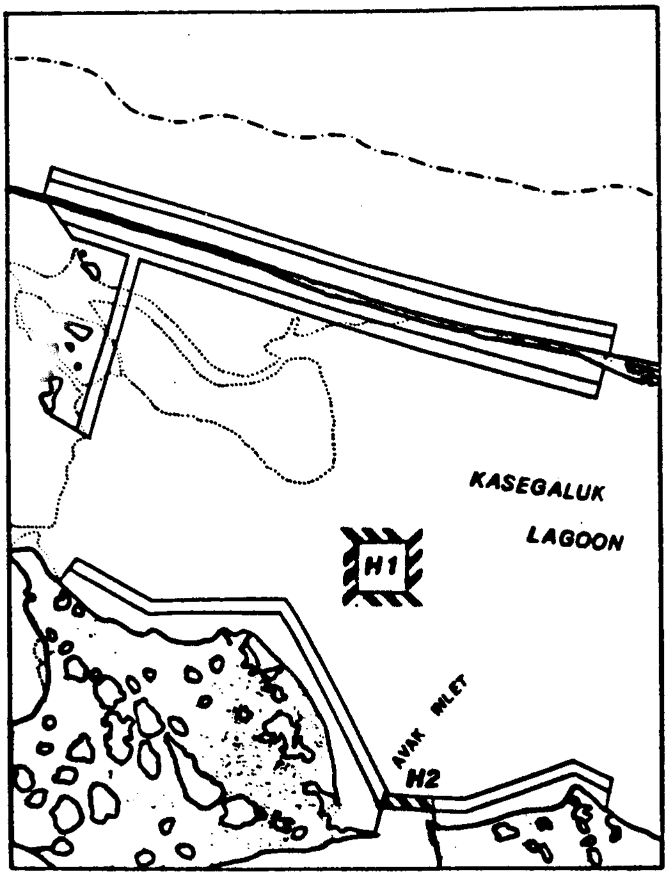
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



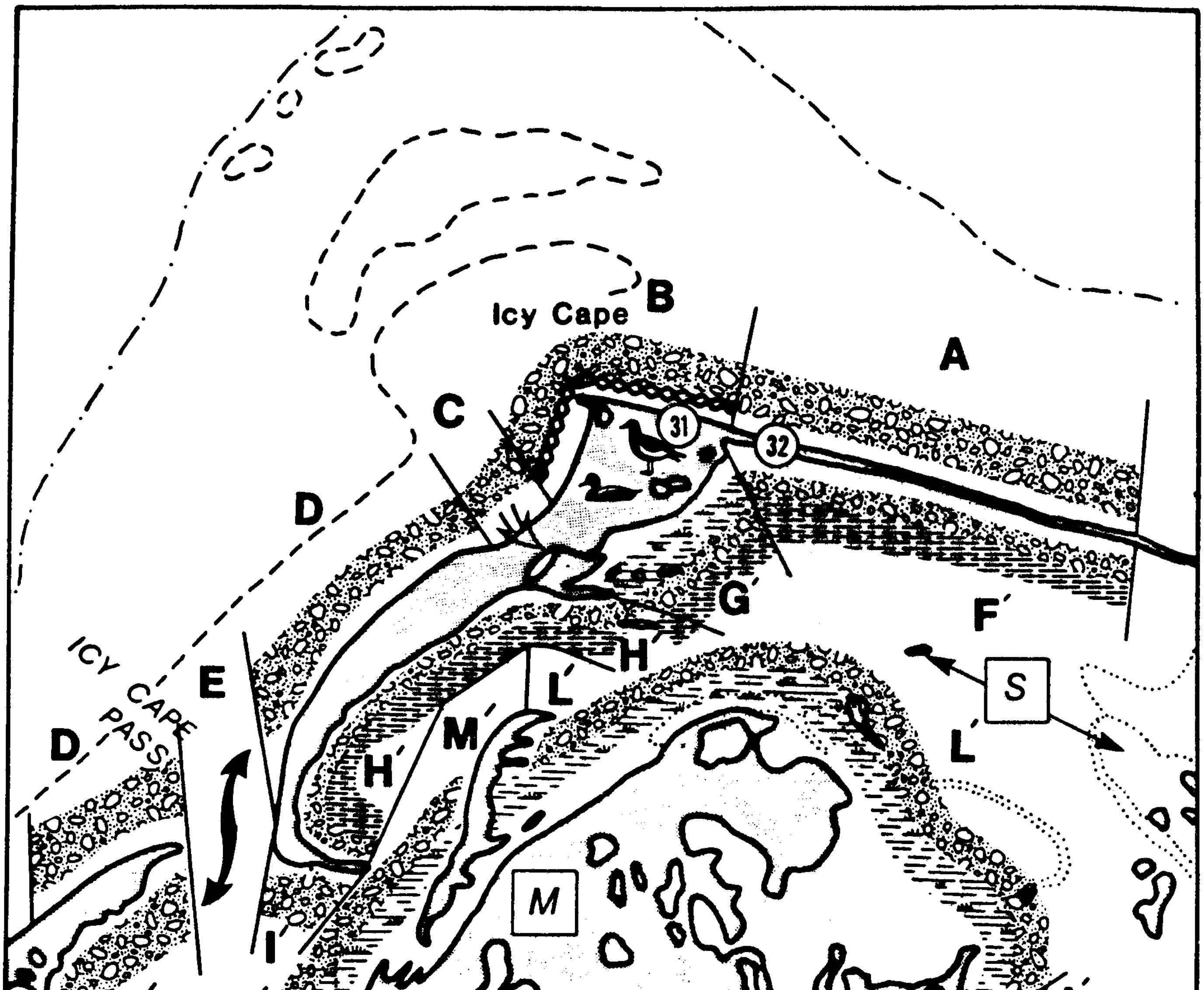
HUMAN USE INDEX



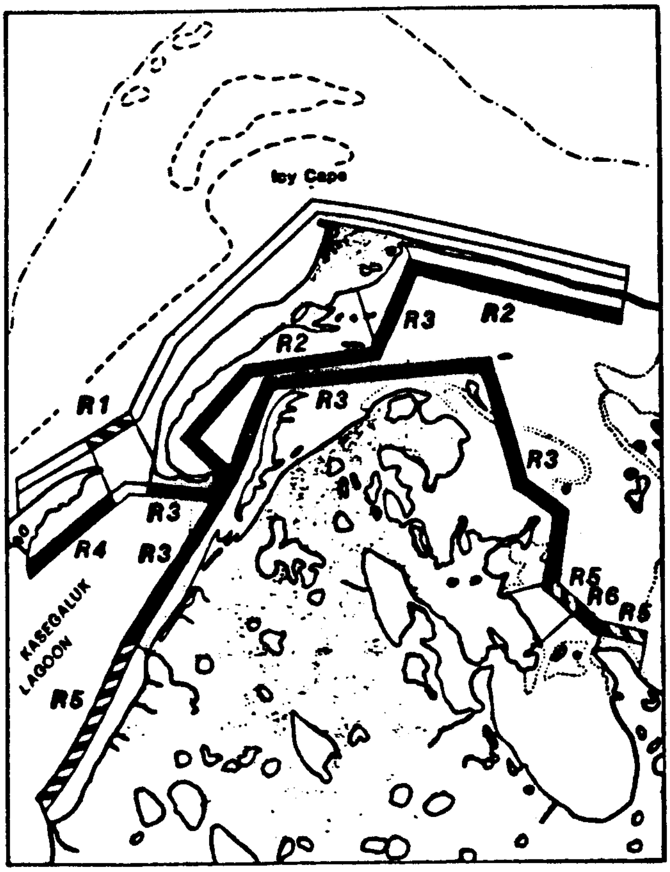
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach				█	█	█		
R2	Low energy beach; Mudflats				█	█	█		
R3	Protected tundra cliff				▨	▨	▨		
R4	Stable inlet and estuary				█	█	█		
R5	Low energy beach; Wetland				█	█	█		
B1	Wetland and mudflats			▨	▨	▨	▨	▨	
B2	Kasegaluk Lagoon; (Icy Cape area)			█	█	█	█		
	Extensive mudflats and wetland			█	█	█	█		
H1	Beluga whale hunting				▨	▨			
	Spotted seal hunting				▨	▨			
H2	Fishing			▨	▨	▨	▨		

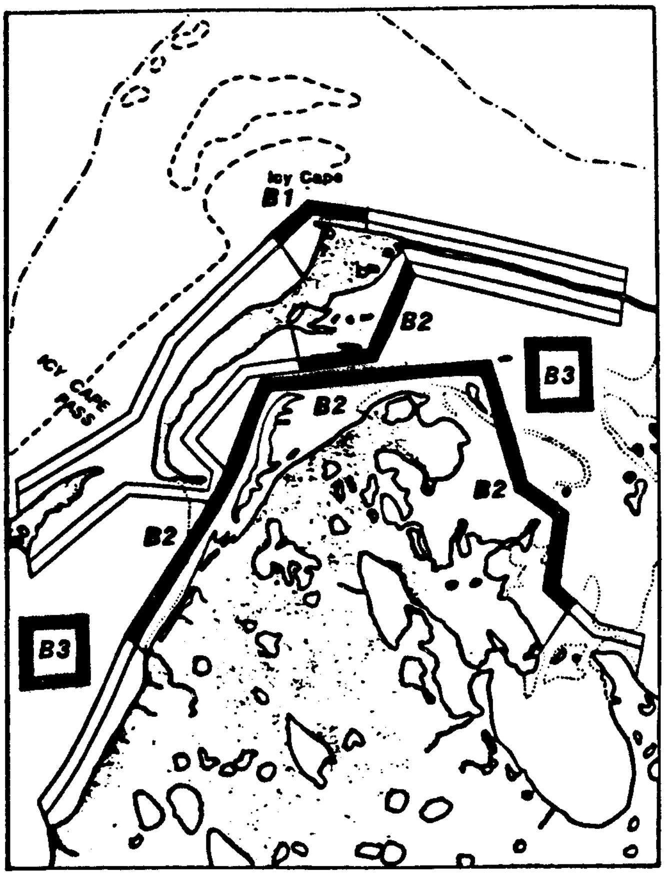
38


Icy Cape
B
A
C
31
32
D
G
F
H
ICY CAPE PASS
E
L
S
D
M
H
L
M
I
I
M
J
K
J
S
N
(Adjoins map #42)
*
39

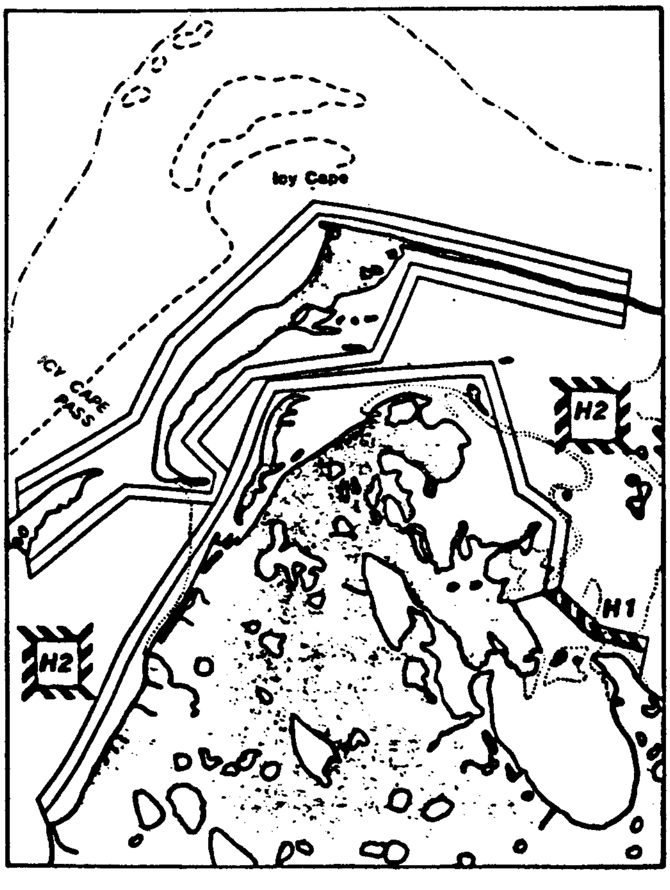
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



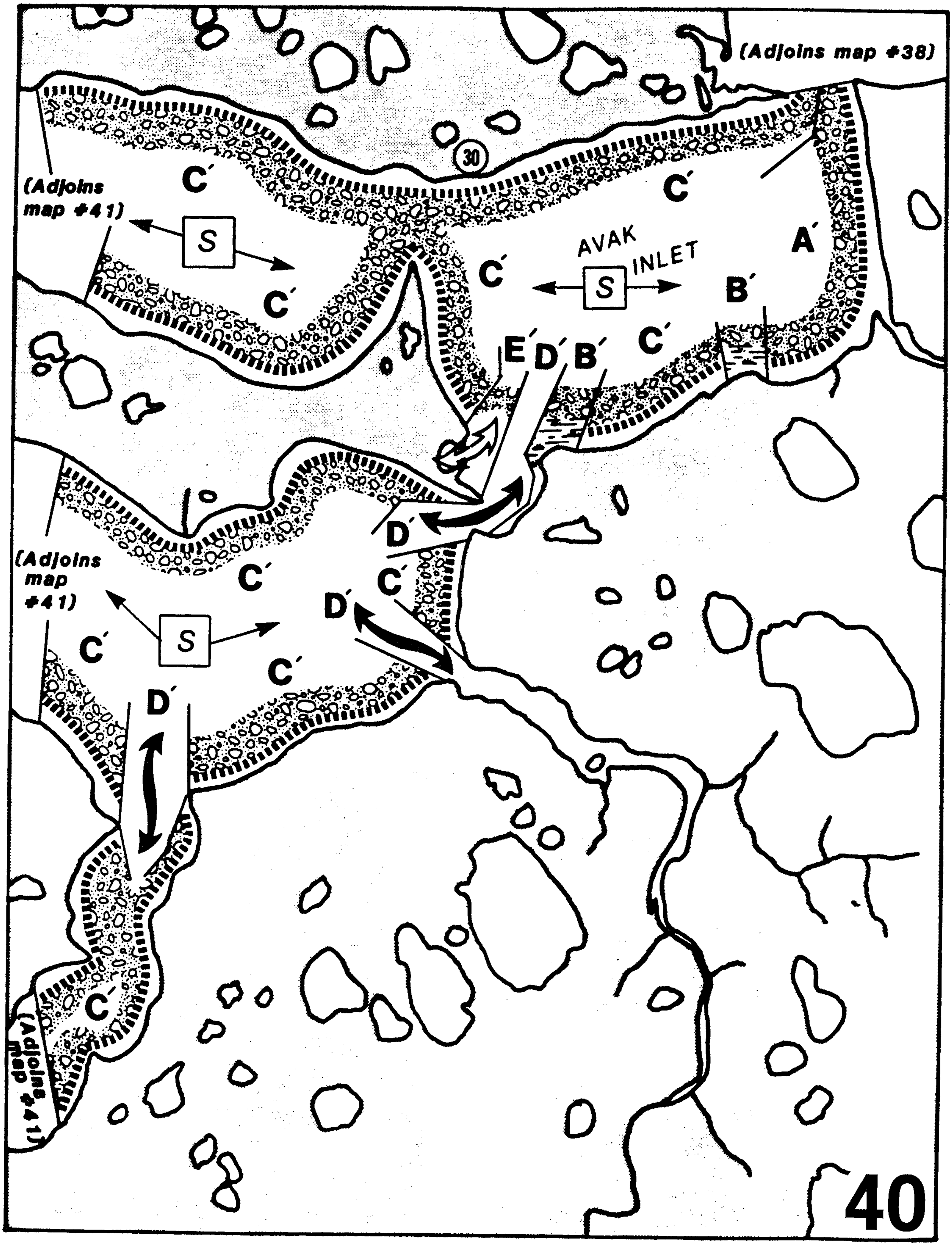
HUMAN USE INDEX



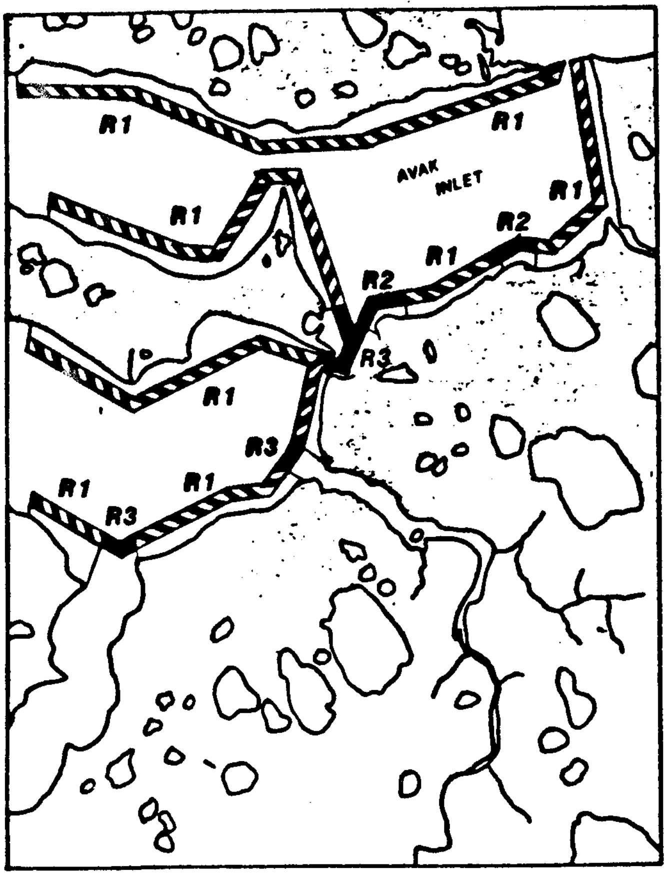
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Stable inlet; recurve spits				▨	▨	▨	▨	
R2	Low energy beach; mudflat				▬	▬	▬		
R3	Low energy beach; mudflat; wetland				▬	▬	▬		
R4	Low energy beach				▬	▬	▬		
R5	Protected tundra cliff				▨	▨	▨		
R6	Stable inlet; lagoon				▬	▬	▬		
R7	Low energy beach; Wetland				▬	▬	▬		
B1	Eider (62 pr), gull (2 pr) and arctic tern (6 pr) nesting			▬	▬				
B2	Extensive mudflats and wetlands			▬	▬	▬	▬	▬	
B3	Kasegaluk Lagoon (Icy Cape area)			▬	▬	▬	▬		
	Extensive mudflats and wetland			▬	▬	▬	▬		
H1	Fishing			▨	▨	▨	▨		
H2	Beluga whale hunting				▨	▨			
	Spotted seal hunting				▨	▨			
	Fishing			▨	▨	▨	▨		

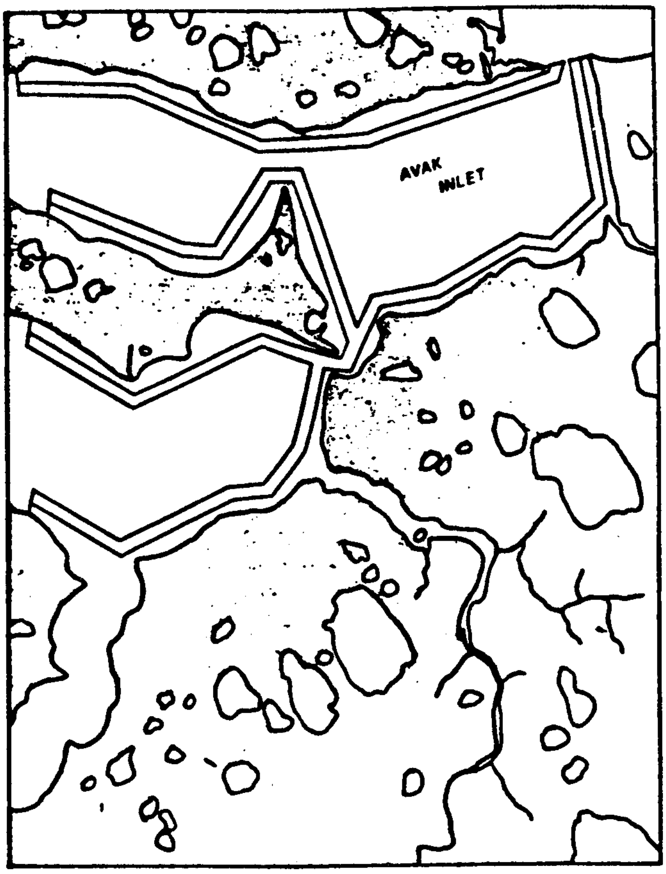
39


(Adjoins map #38)
30
(Adjoins map #41)
C´
S
C´
C´
AVAK
INLET
S
C´
A´
B´
E´
D´
B´
C´
D´
(Adjoins map #41)
C´
D´
C´
S
C´
C´
D´
C´
(Adjoins map #41)
40

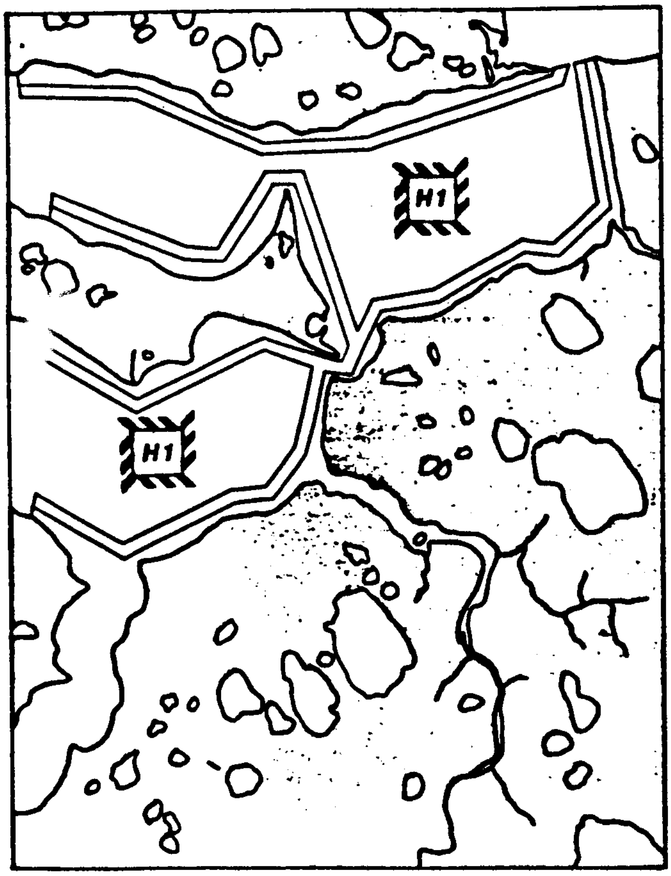
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



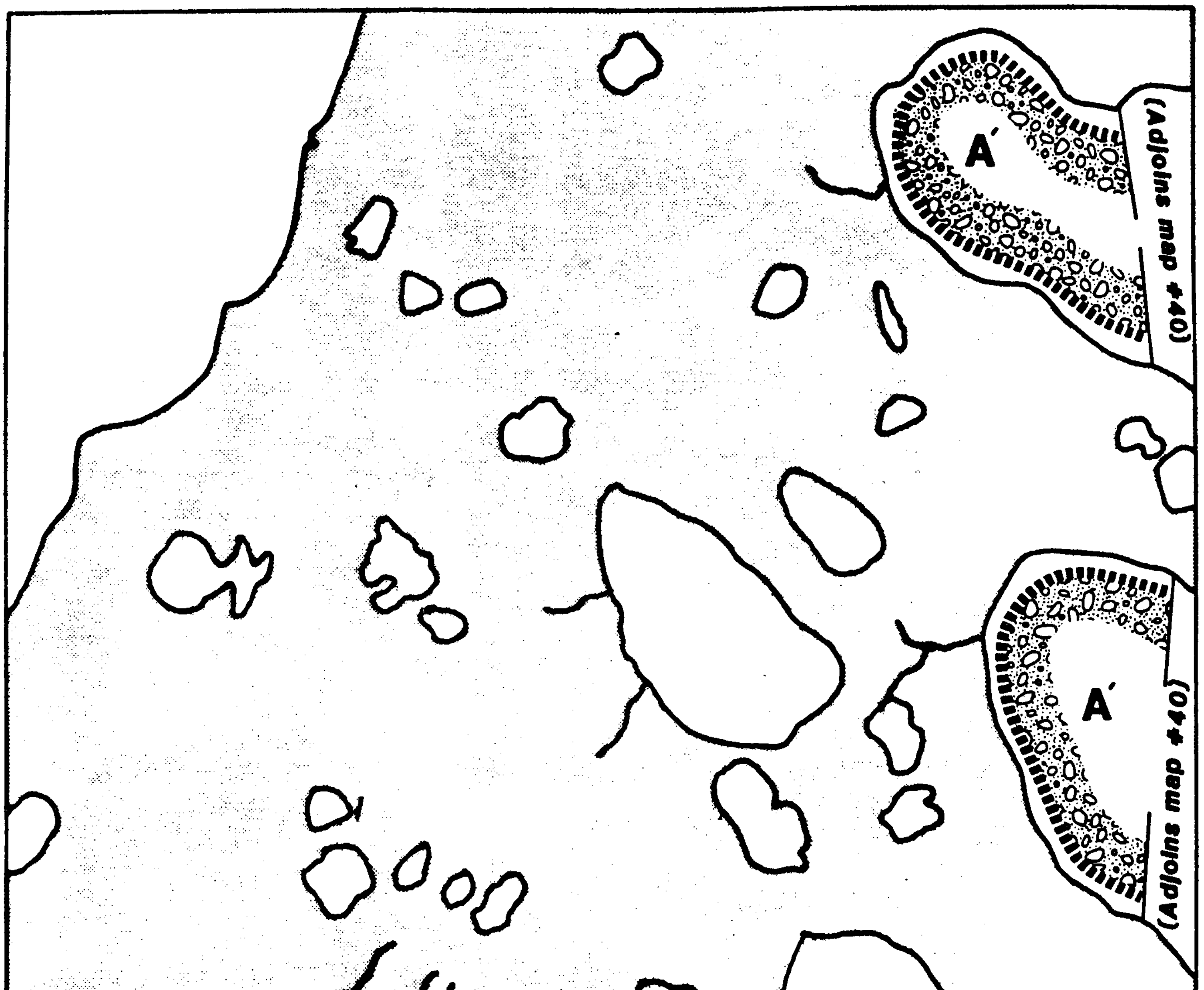
HUMAN USE INDEX



Seasonal Variability of Indices

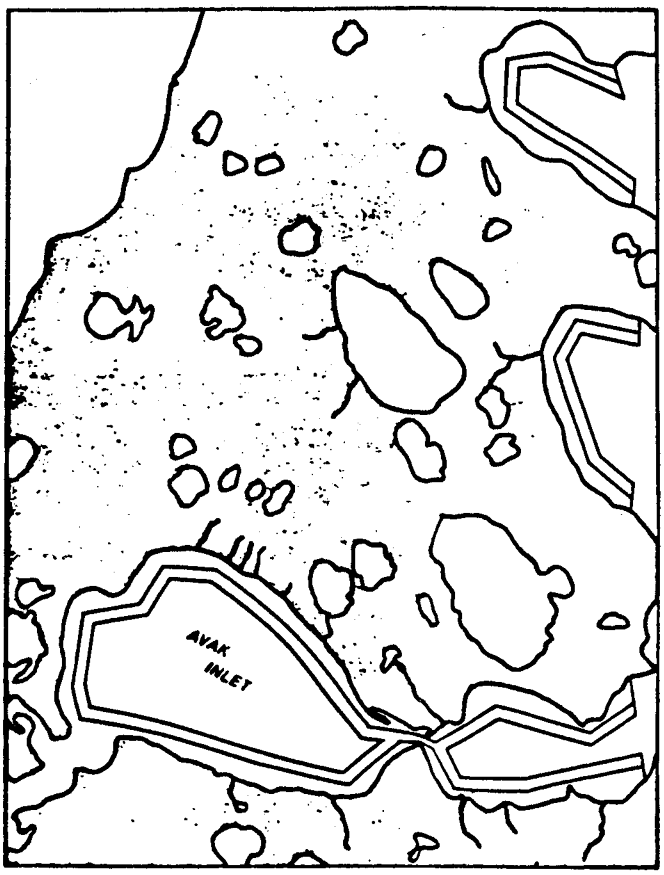
Identi-fier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff				▨	▨	▨		
R2	Low energy beach; Wetland				■	■	■		
R3	Inlet; lagoon/ estuary				■	■	■		
H1	Spotted seal hunting				▨	▨			
	Fishing			▨	▨	▨	▨		

40

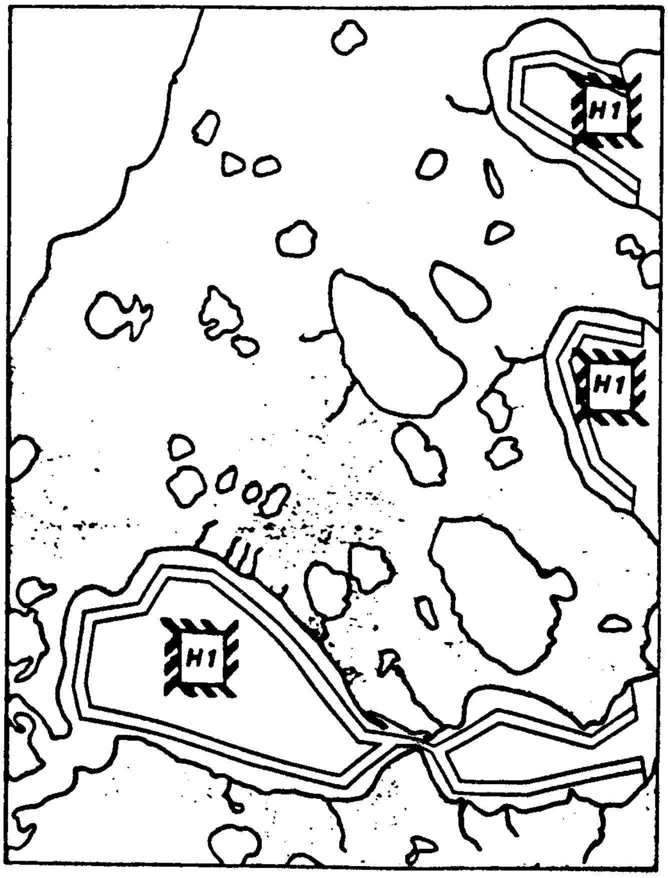

A′
(Adjoins map #40)
A′
(Adjoins map #40)
A′
AVAK
S
INLET
C′
A′
B′
B′
A′
41

OIL RESIDENCE INDEX

BIOLOGICAL SENSITIVITY INDEX



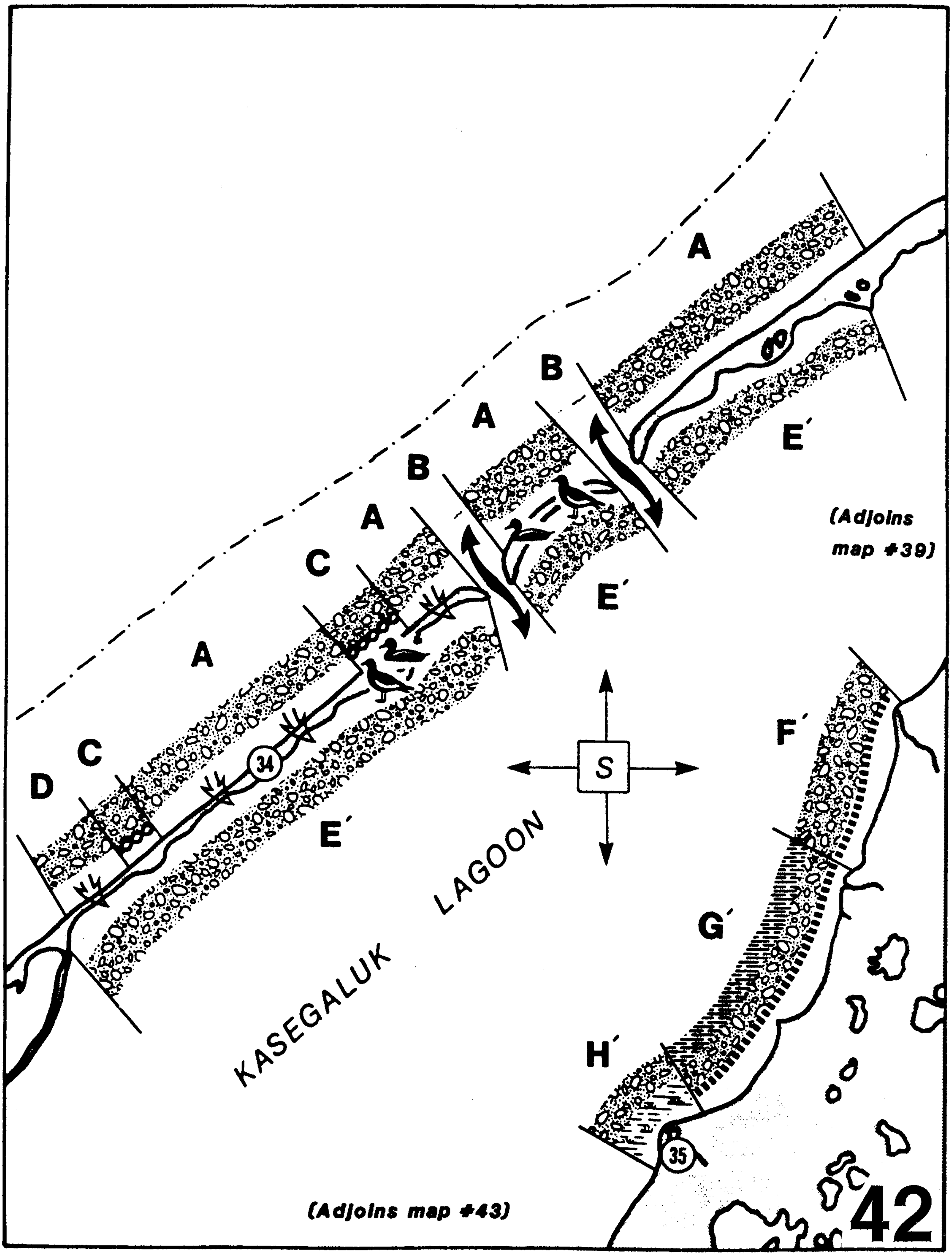
HUMAN USE INDEX



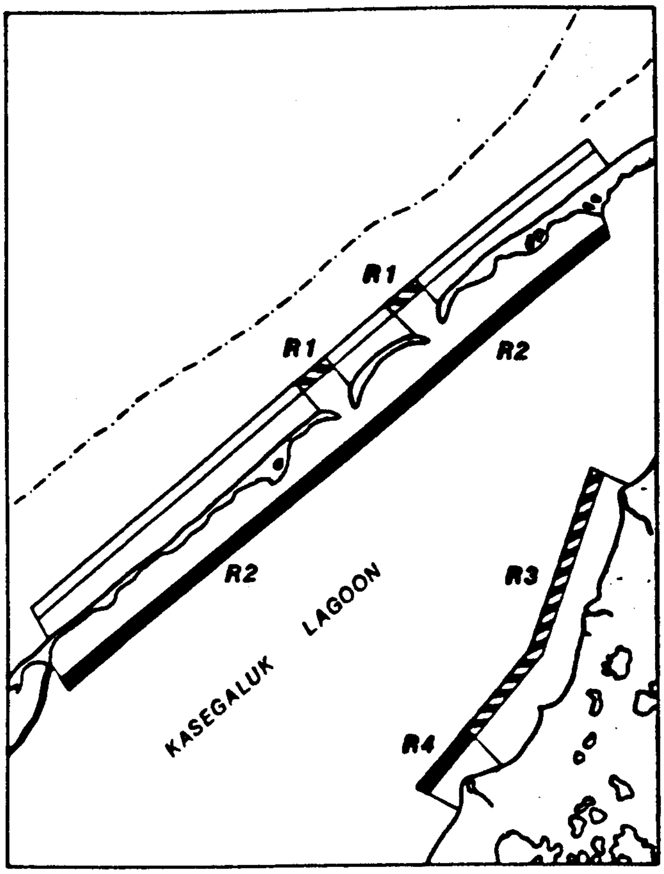
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff				▨	▨	▨		
R2	Inlet; estuary				■	■	■		
H1	Spotted seal hunting				▨	▨			
	Fishing			▨	▨	▨	▨		

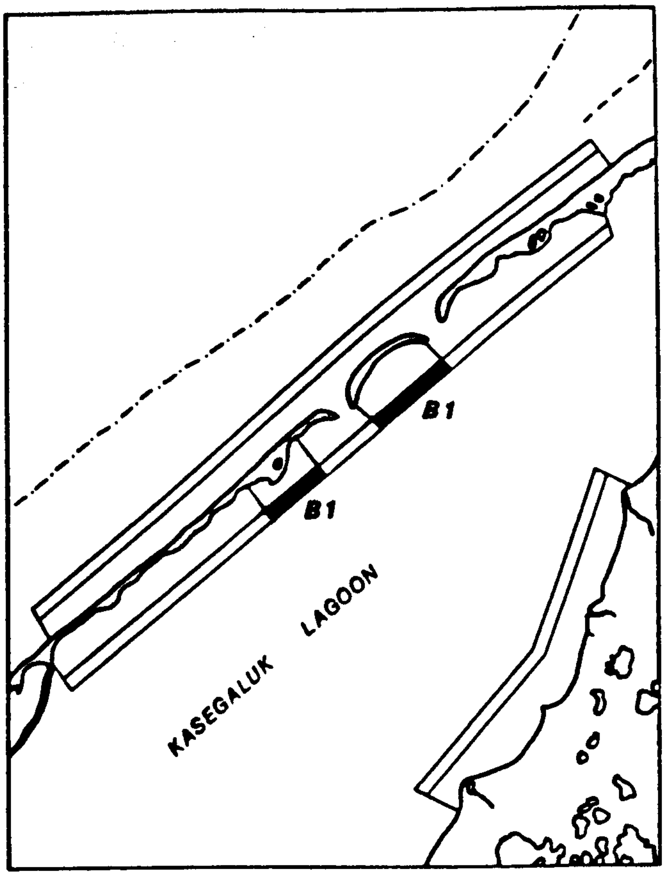
41


A
B
A
B
A
C
A
D
C
E´
E´
E´
34
S
KASEGALUK LAGOON
(Adjoins map #39)
F´
G´
H´
35
(Adjoins map #43)
42

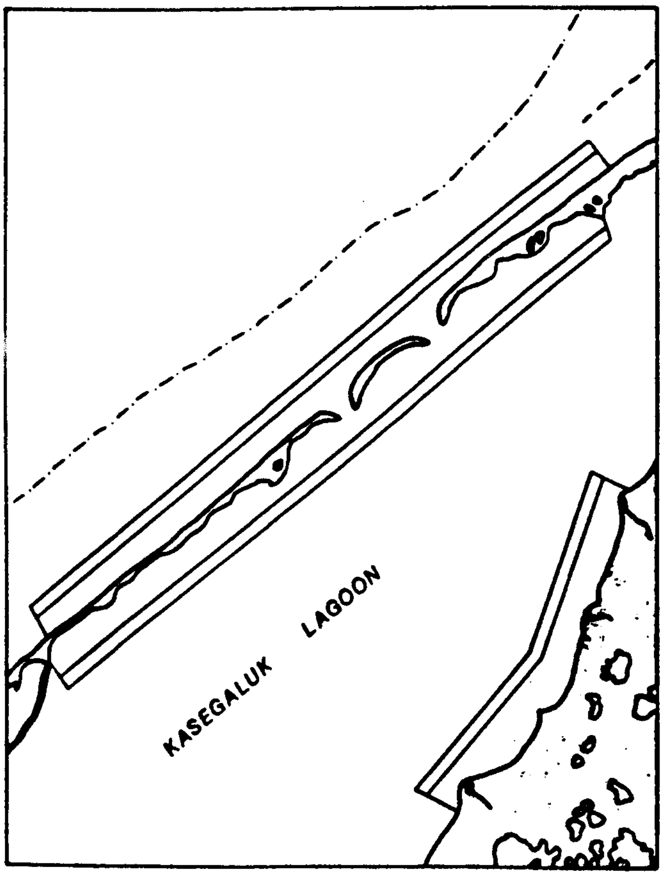
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



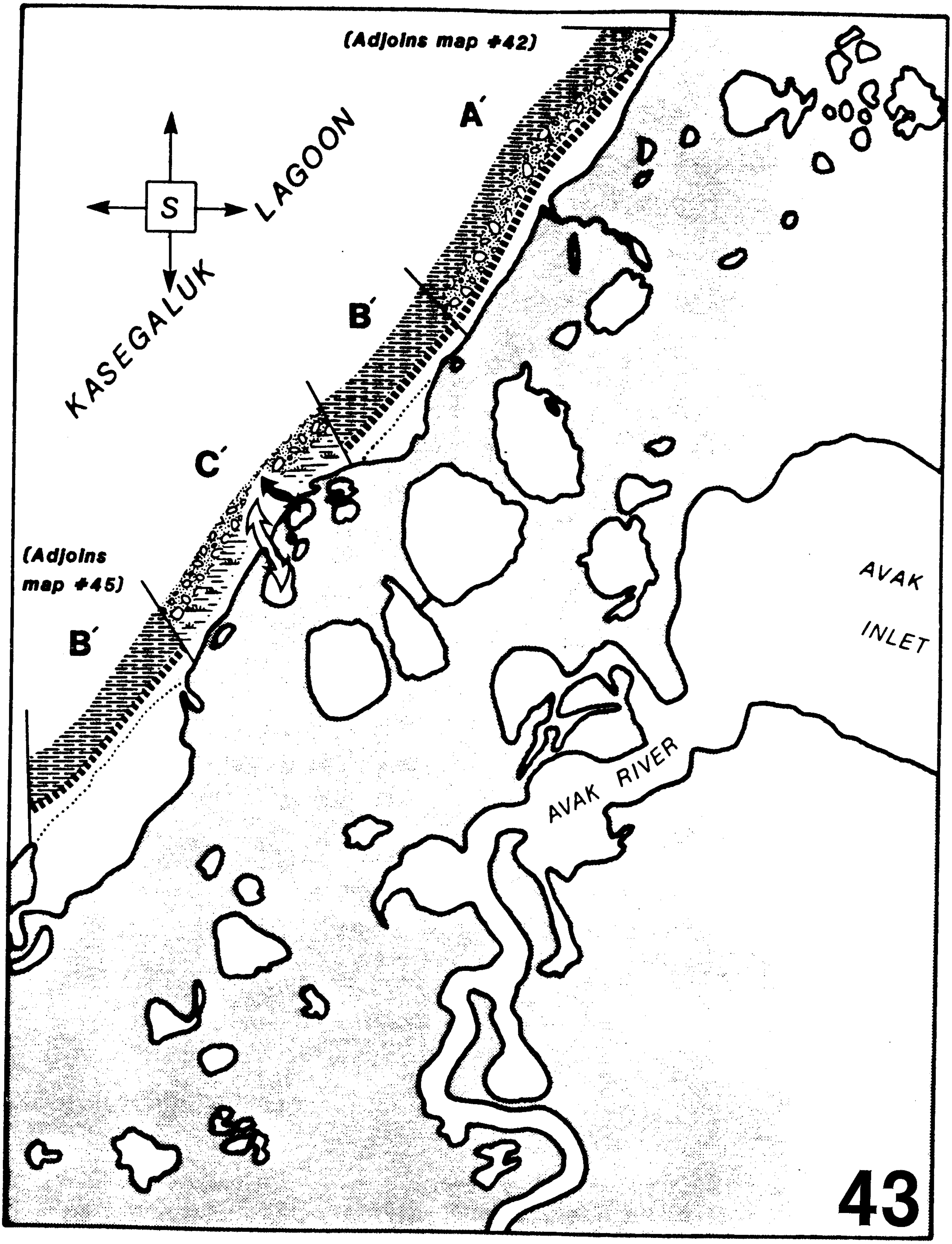
HUMAN USE INDEX



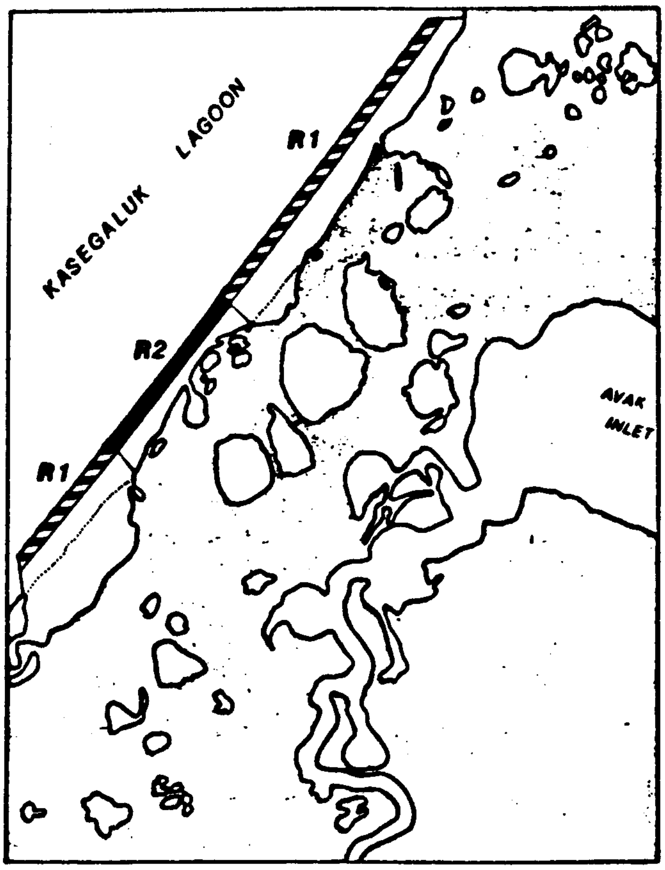
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Stable inlet; Recurve spits				▨	▨	▨	▨	
R2	Low energy beach				■	■	■		
R3	Protected tundra cliff				▨	▨	▨		
R4	Wetland				■	■	■		
B1	Eider (350 pr), gull (15 pr) and arctic tern (20 pr) nesting			■	■				

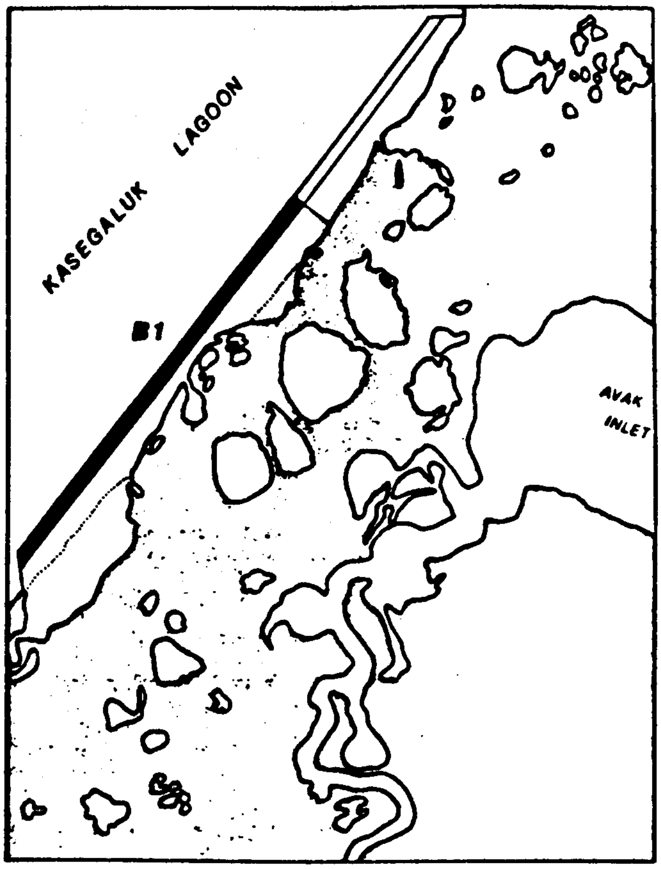
42


(Adjoins map #42)
A´
S
KASEGALUK LAGOON
B´
C´
D
(Adjoins map #45)
B´
AVAK INLET
AVAK RIVER
43

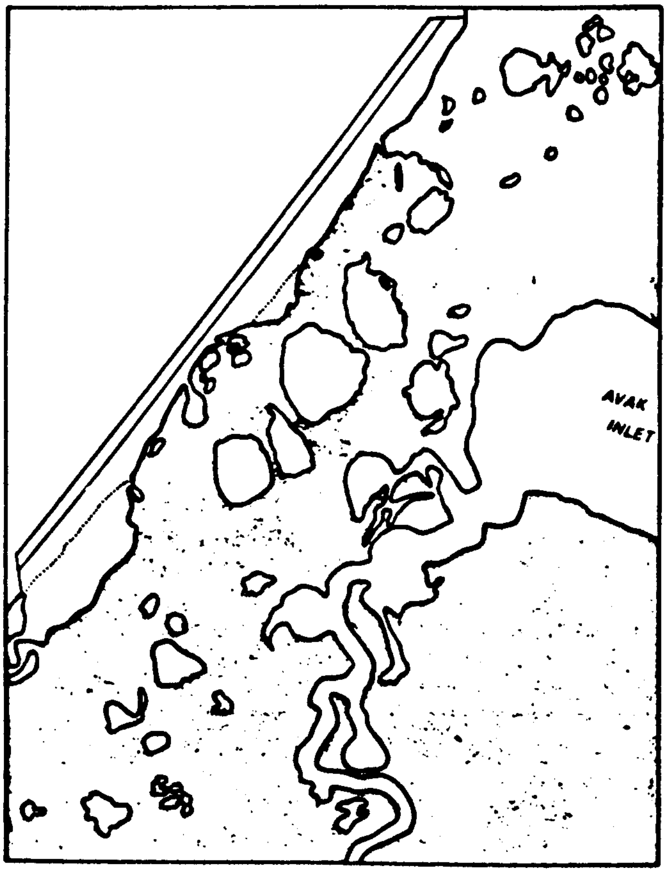
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



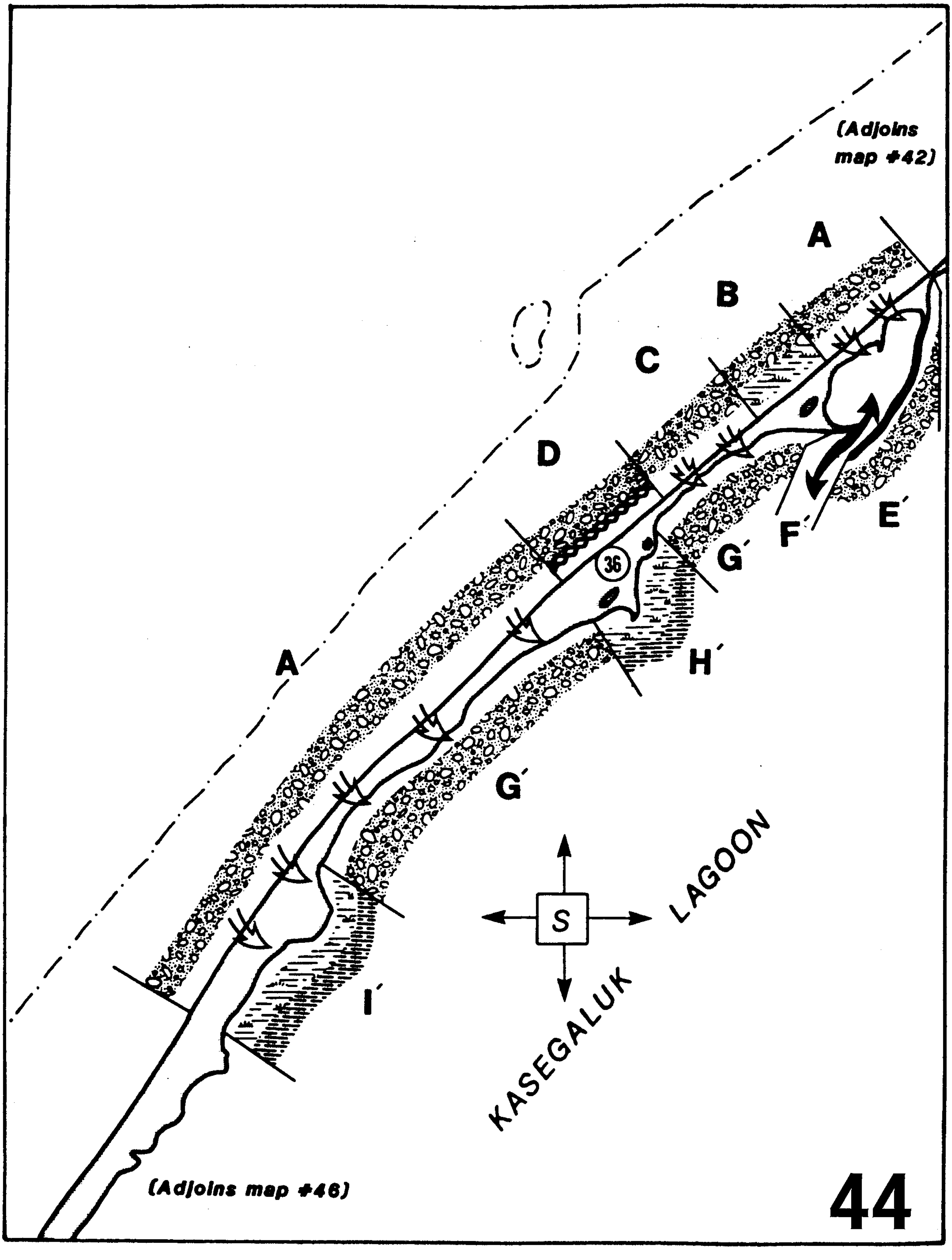
HUMAN USE INDEX

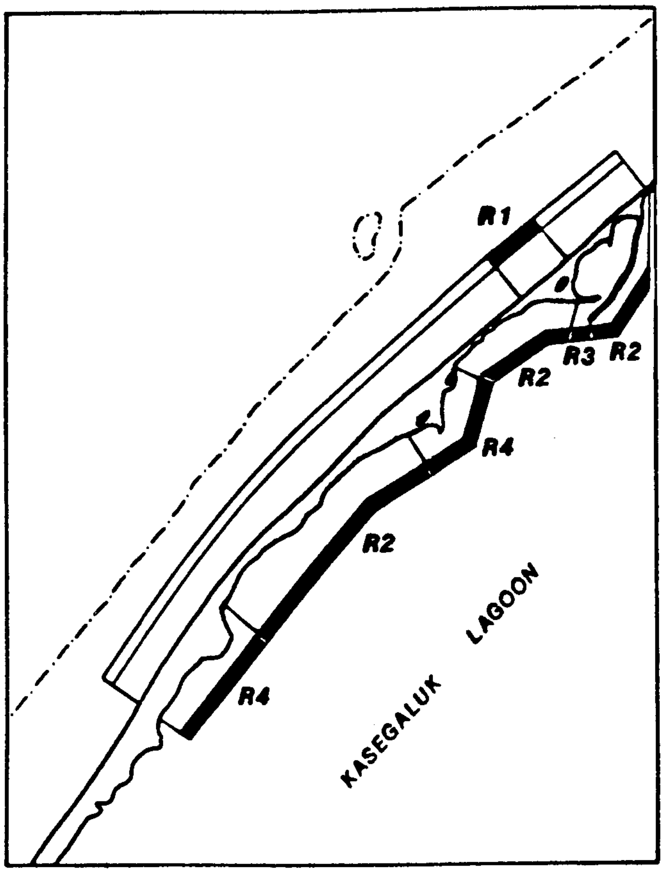


Seasonal Variability of Indices

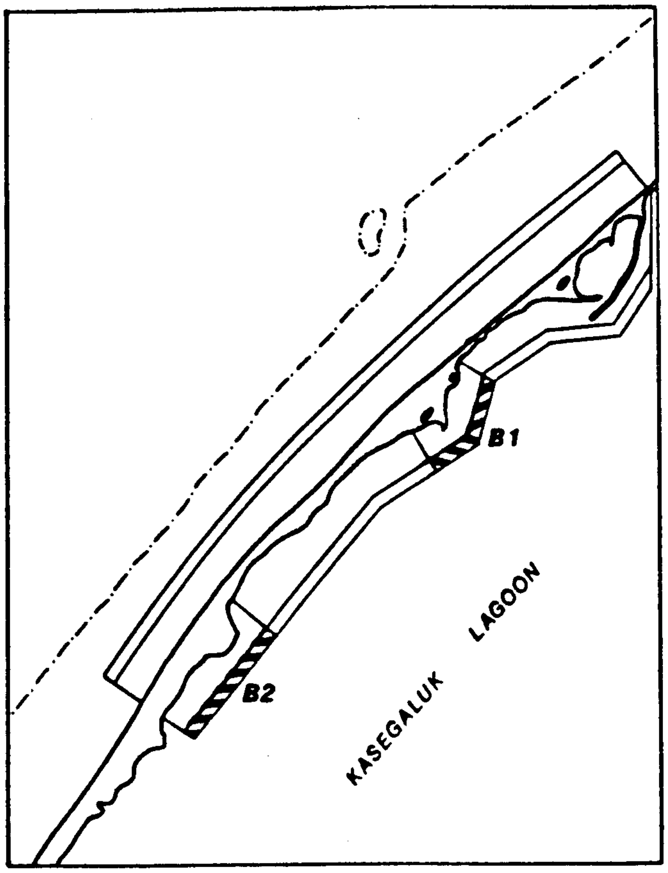
		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff				▨	▨	▨		
R2	Low energy beach; Inlets; wetland				■	■	■		
B1	Wetland and mudflats			■	■	■	■	■	

43

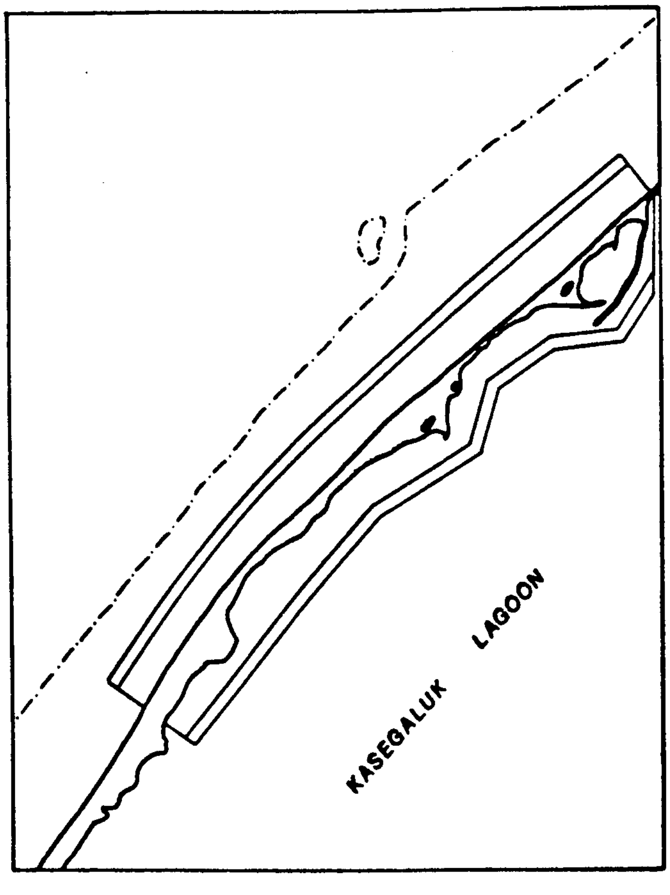

(Adjoins map #42)
A
B
C
D
A
36
E´
F´
G´
H´
G´
I´
S
KASEGALUK LAGOON
(Adjoins map #46)
44



OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX

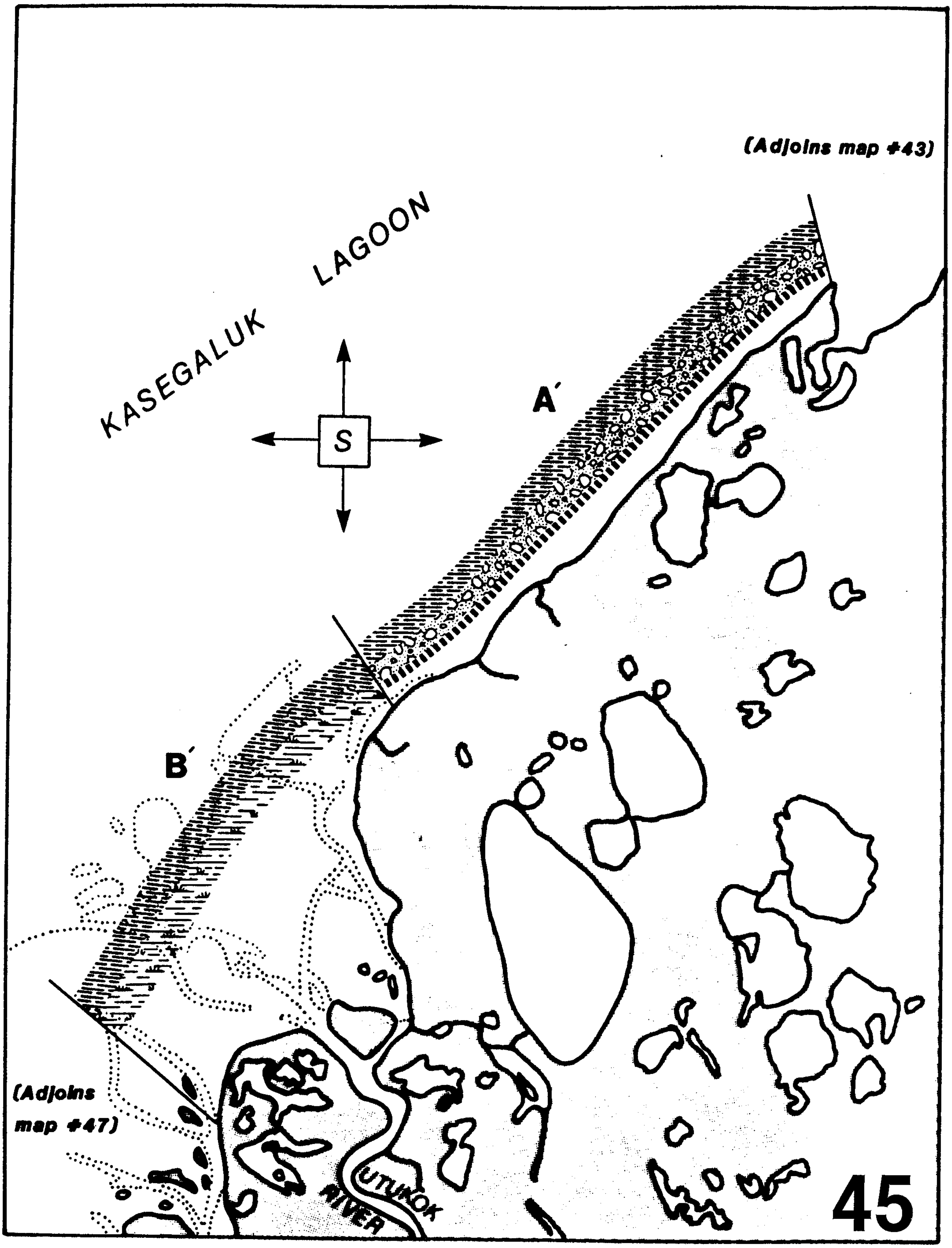


HUMAN USE INDEX

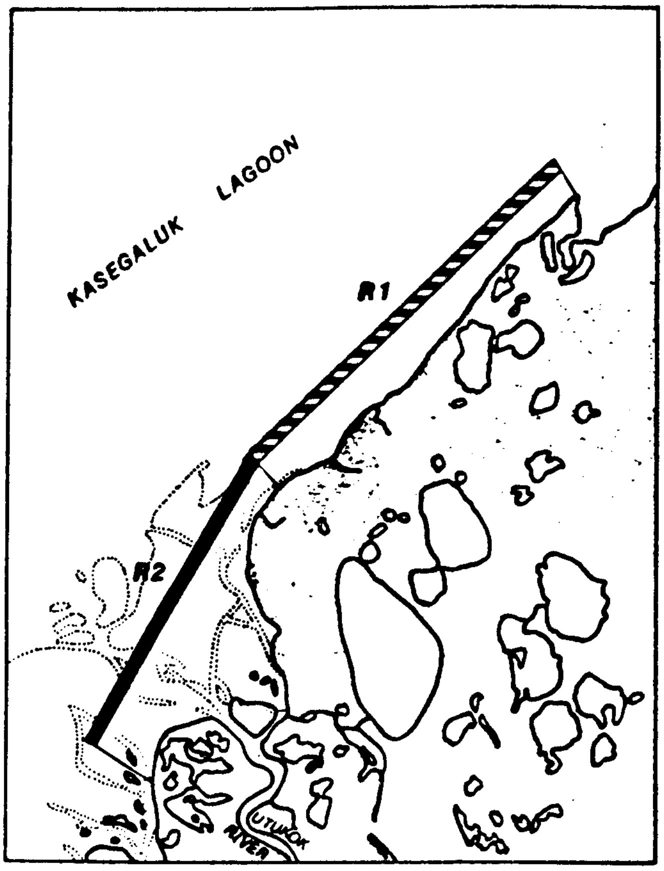
Seasonal Variability of Indices

Identi-fier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Wetland			■	■	■	■		
R2	Low energy beach			■	■	■	■		
R3	Inlet; lagoon			■	■	■	■		
R4	Mudflat; wetland			■	■	■	■		
B1	Wetland			▨	▨	▨	▨	▨	
B2	Wetland			▨	▨	▨	▨	▨	

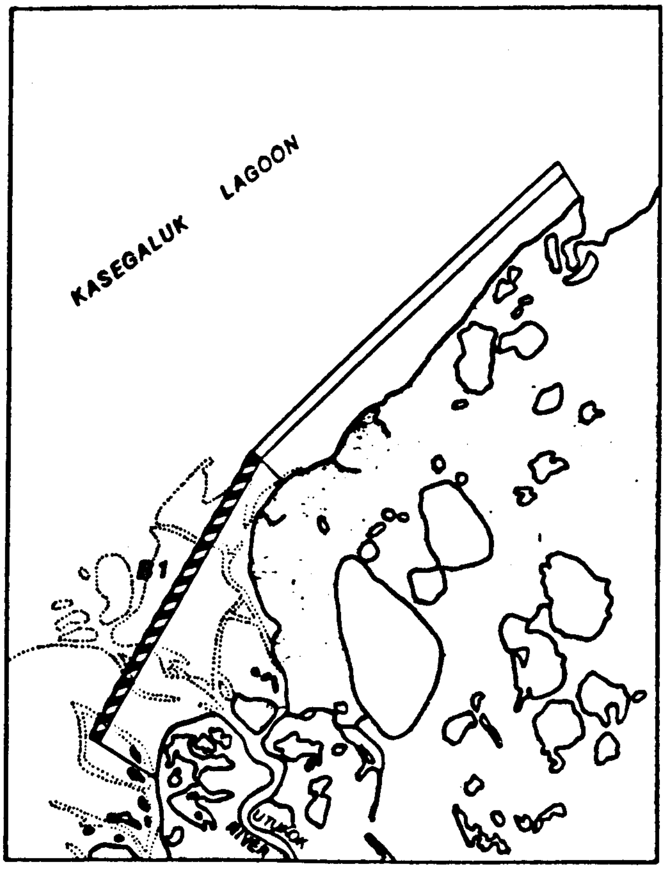
44


(Adjoins map #43)
KASEGALUK LAGOON
S
A´
B´
(Adjoins map #47)
UTUKOK RIVER
45

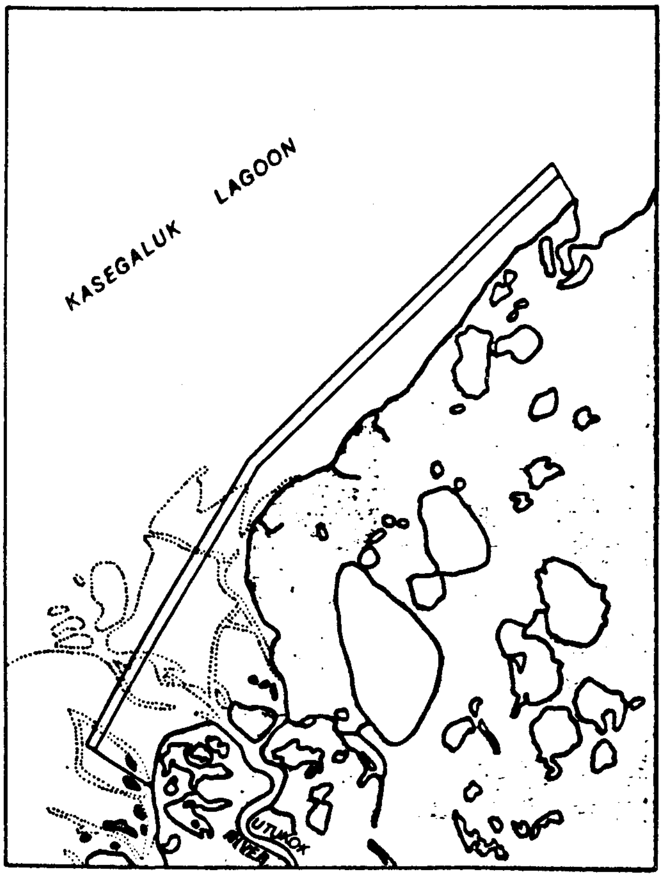
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



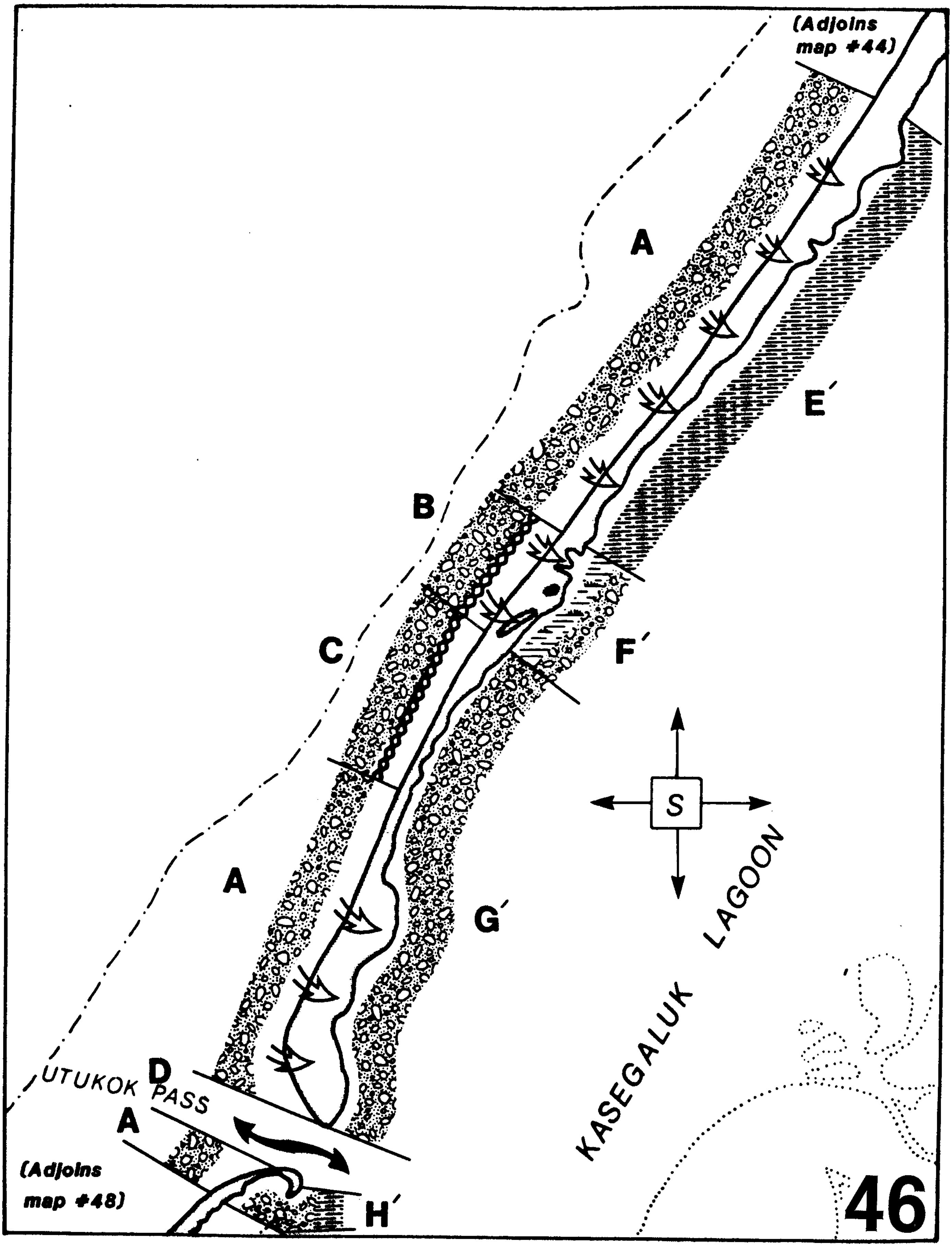
HUMAN USE INDEX



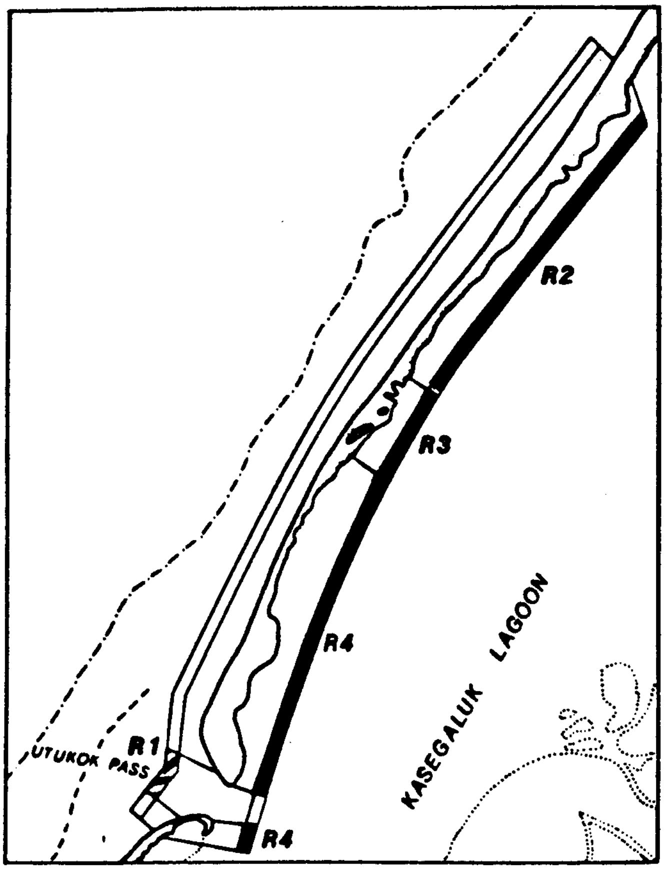
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff			▨	▨	▨	▨		
R2	Delta flats; Wetland			■	■	■	■		
B1	Wetland and mudflats			▨	▨	▨	▨	▨	

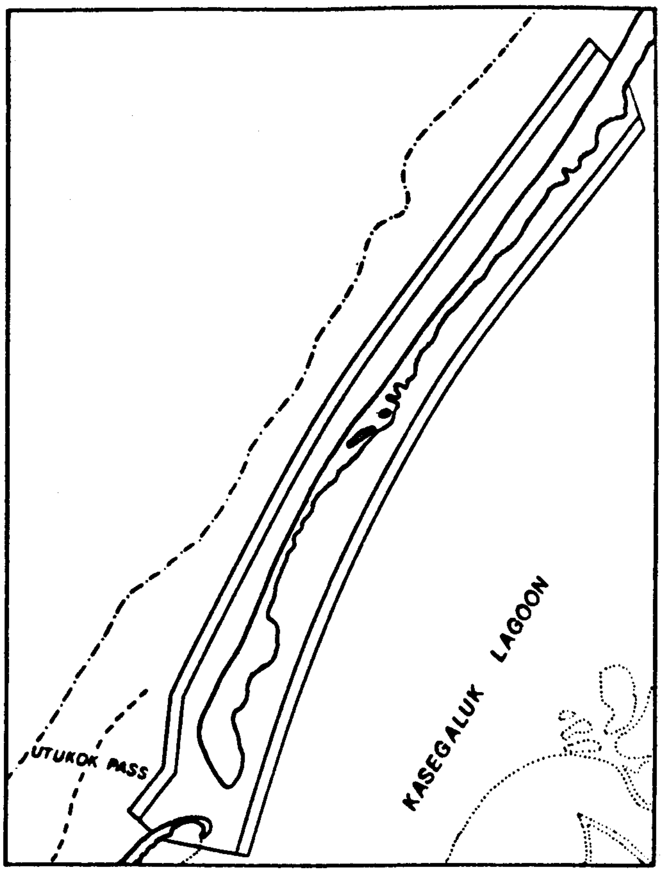
45


(Adjoins map #44)
A
E′
B
C
F′
S
LAGOON
A
G′
KASEGALUK
D
UTUKOK PASS
A
(Adjoins map #48)
H′
46

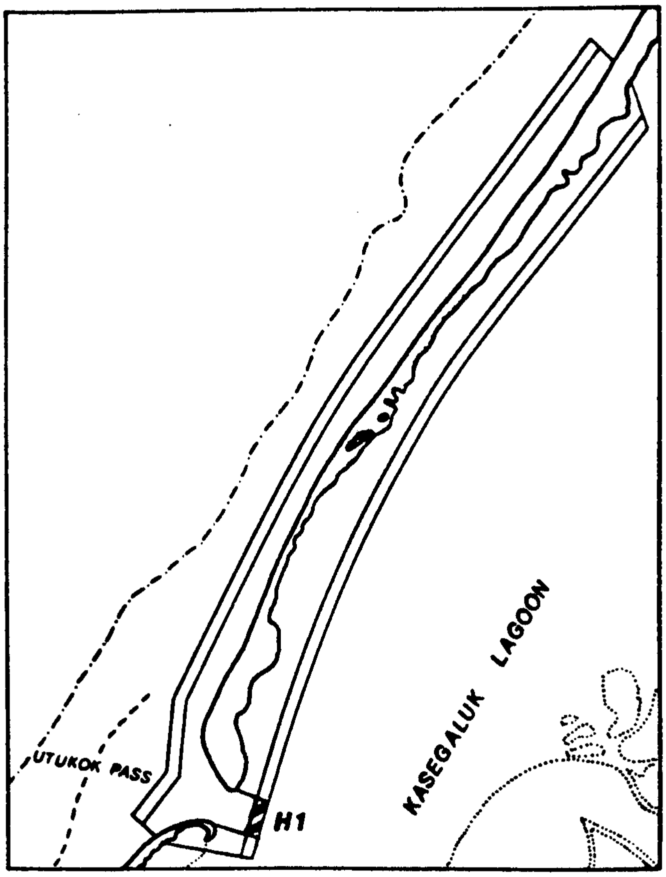
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



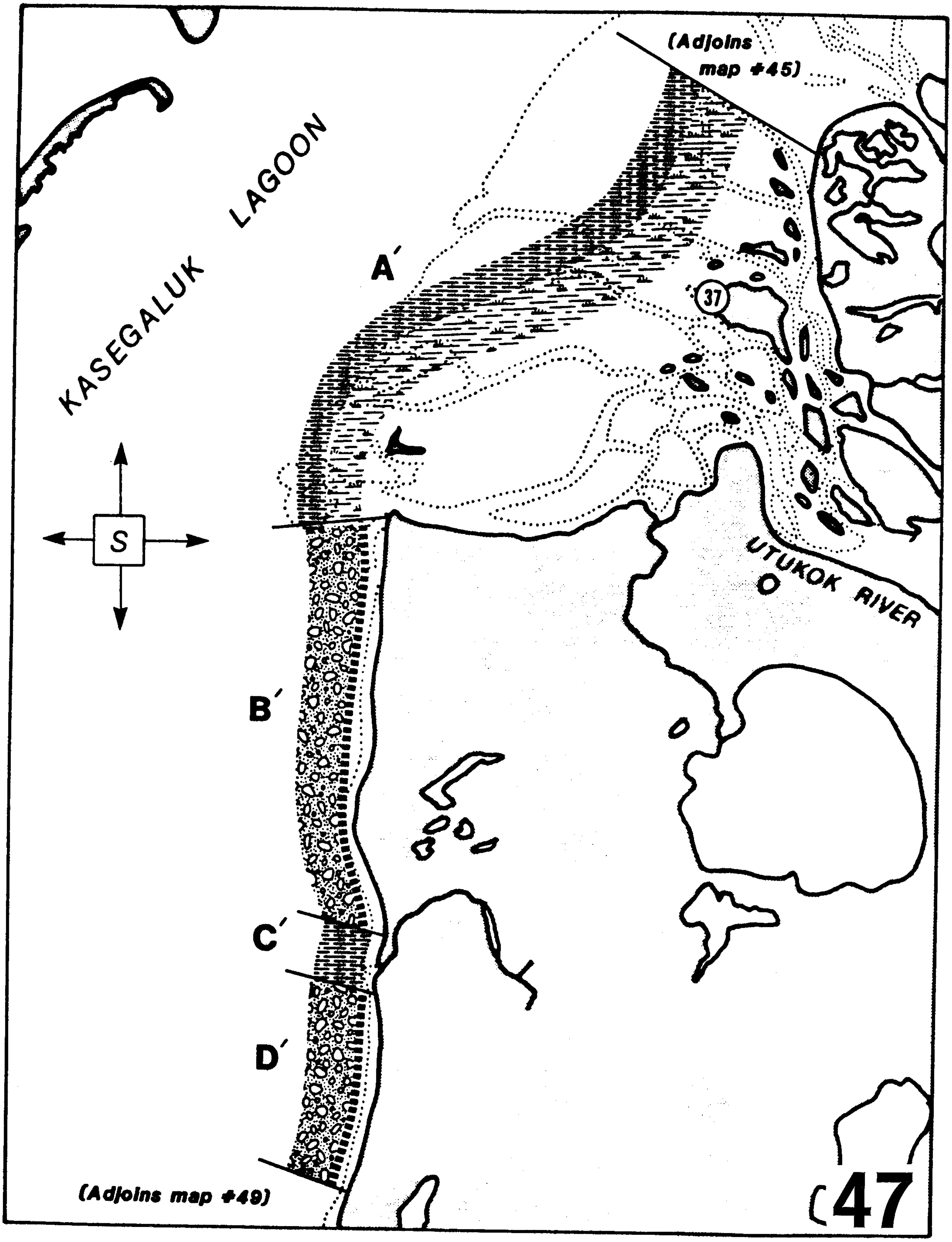
HUMAN USE INDEX



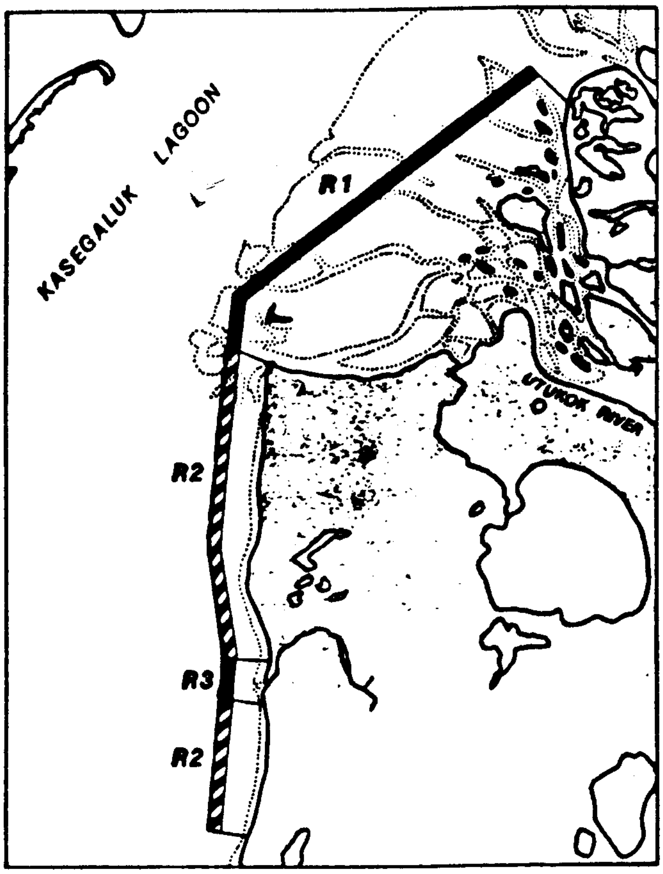
Seasonal Variability of Indices

		SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
Identifier	RESOURCE		May	Jun	Jul	Aug	Sep	Oct	
R1	Stable inlet; Recurve spits			▨	▨	▨	▨		
R2	Low energy beach and mudflats			■	■	■	■		
R3	Low energy beach; Wetland			■	■	■	■		
R4	Low energy beach			■	■	■	■		
H1	Spotted seal hunting				▨	▨			
	Beluga whale hunting				■	■			

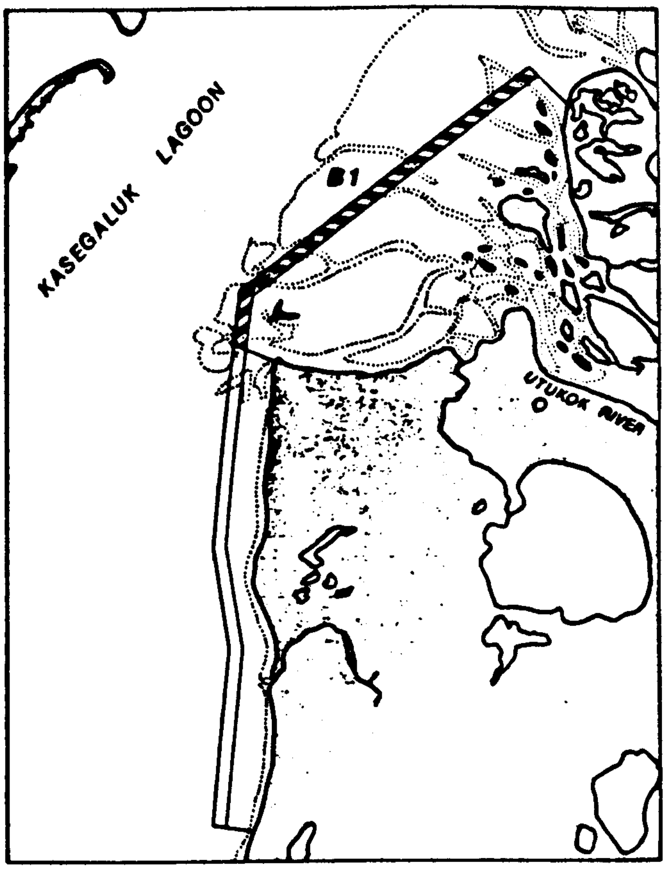
46


(Adjoins map #45)
KASEGALUK LAGOON
A´
37
S
UTUKOK RIVER
B´
C´
D´
(Adjoins map #49)
47

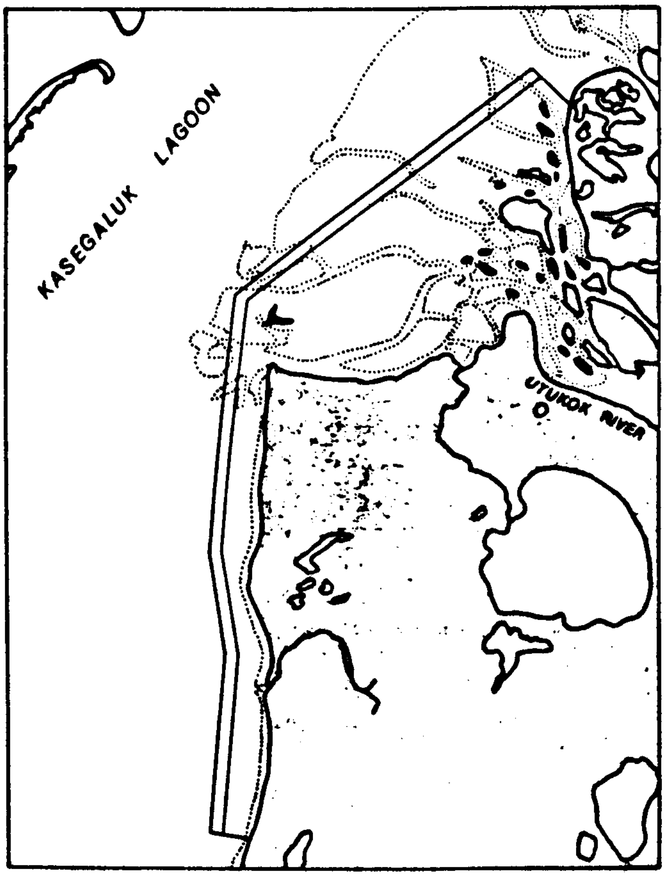
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



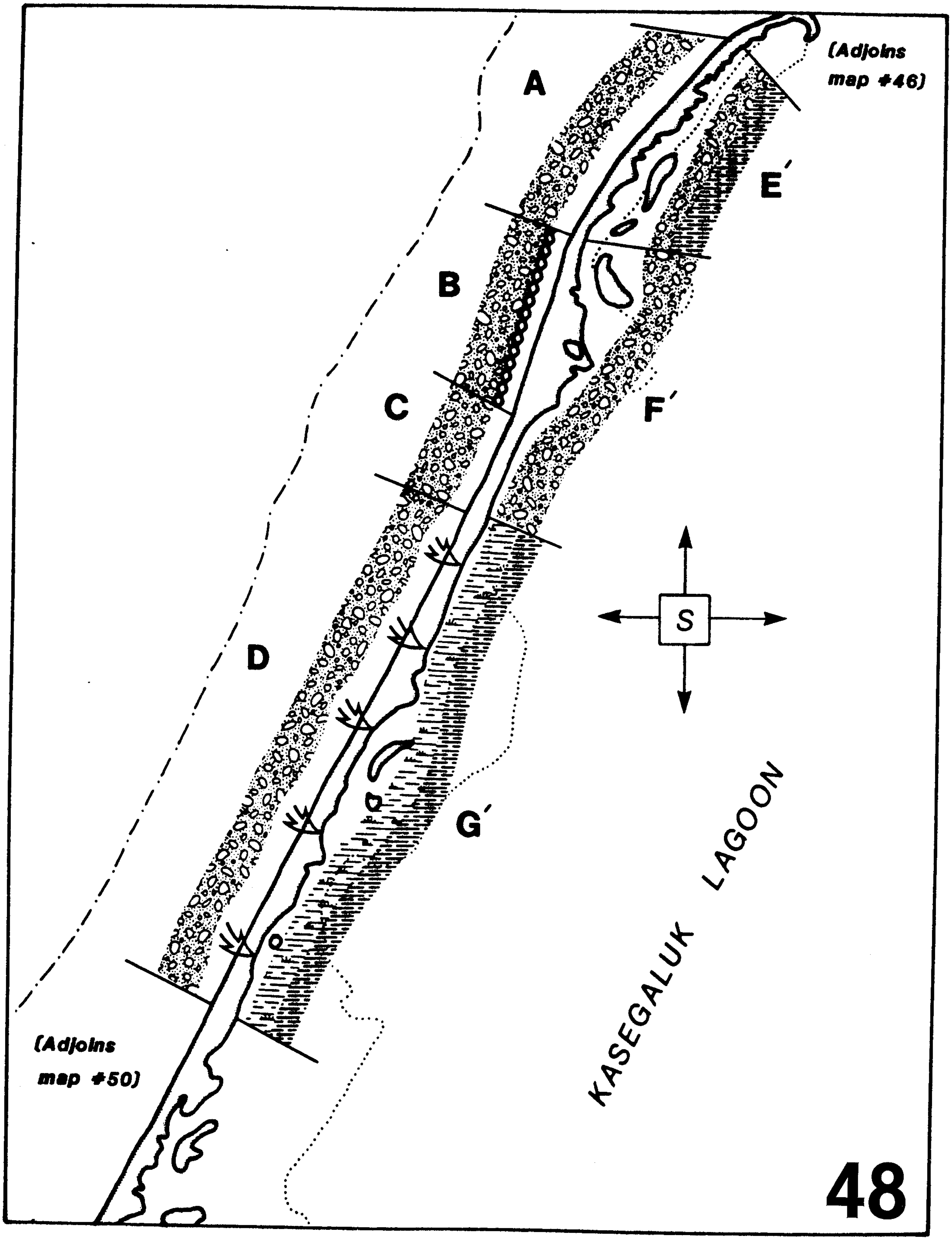
HUMAN USE INDEX



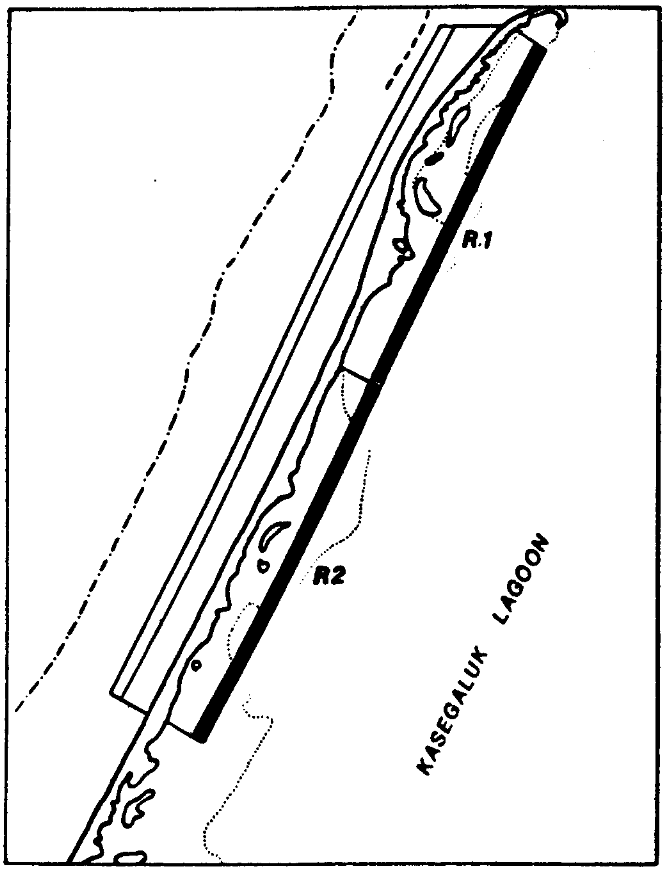
Seasonal Variability of Indices

		SEASON							
			Break-Up/Summer/Freeze-Up						
Identifier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Delta flats; Wetland			■	■	■	■		
R2	Protected tundra cliff			▨	▨	▨	▨		
R3	Mudflat; Estuary			■	■	■	■		
B1	Wetland and mudflats			▨	▨	▨	▨	▨	

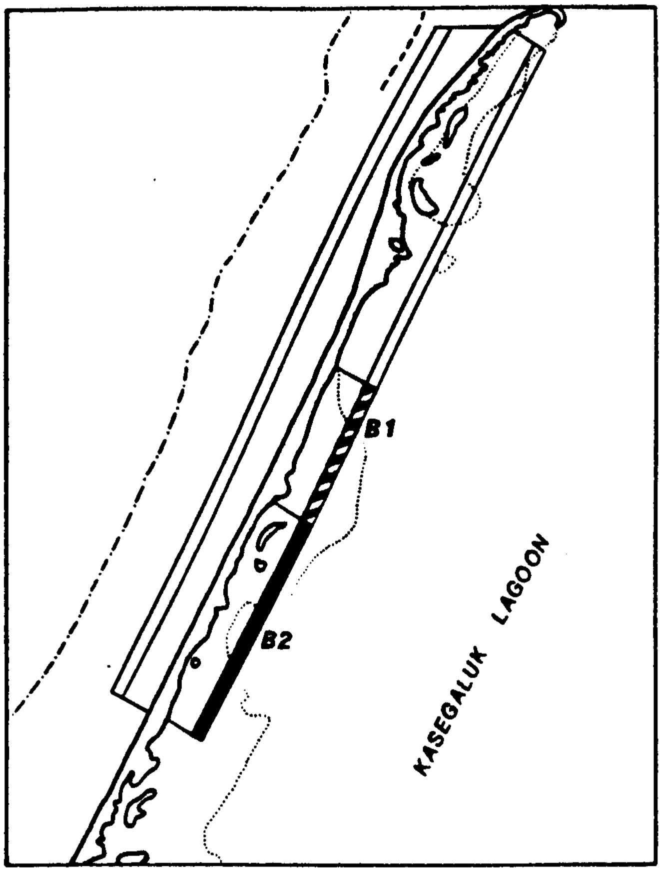
47


(Adjoins map #46)
A
E'
B
C
F'
S
D
G'
KASEGALUK LAGOON
(Adjoins map #50)
48

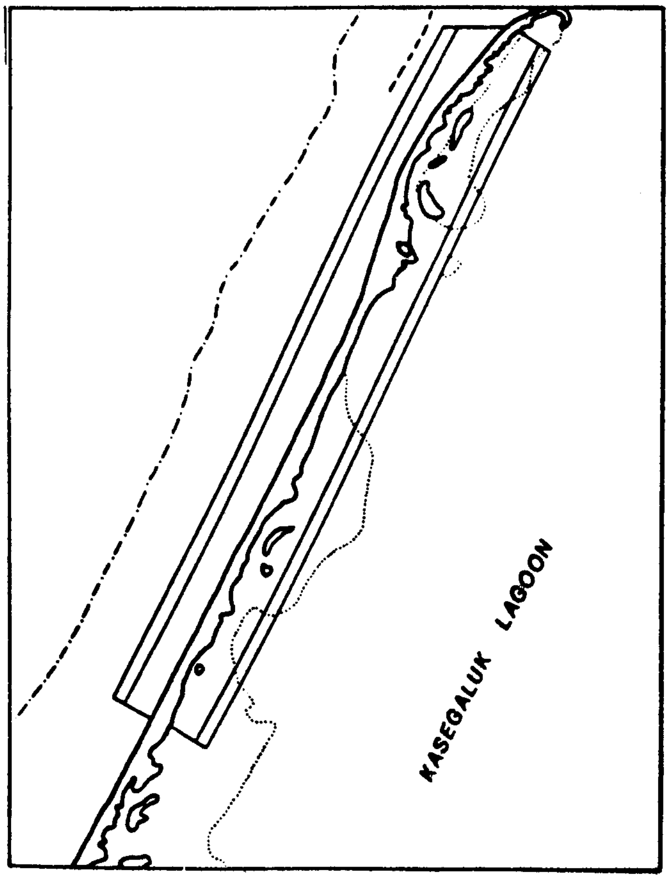
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



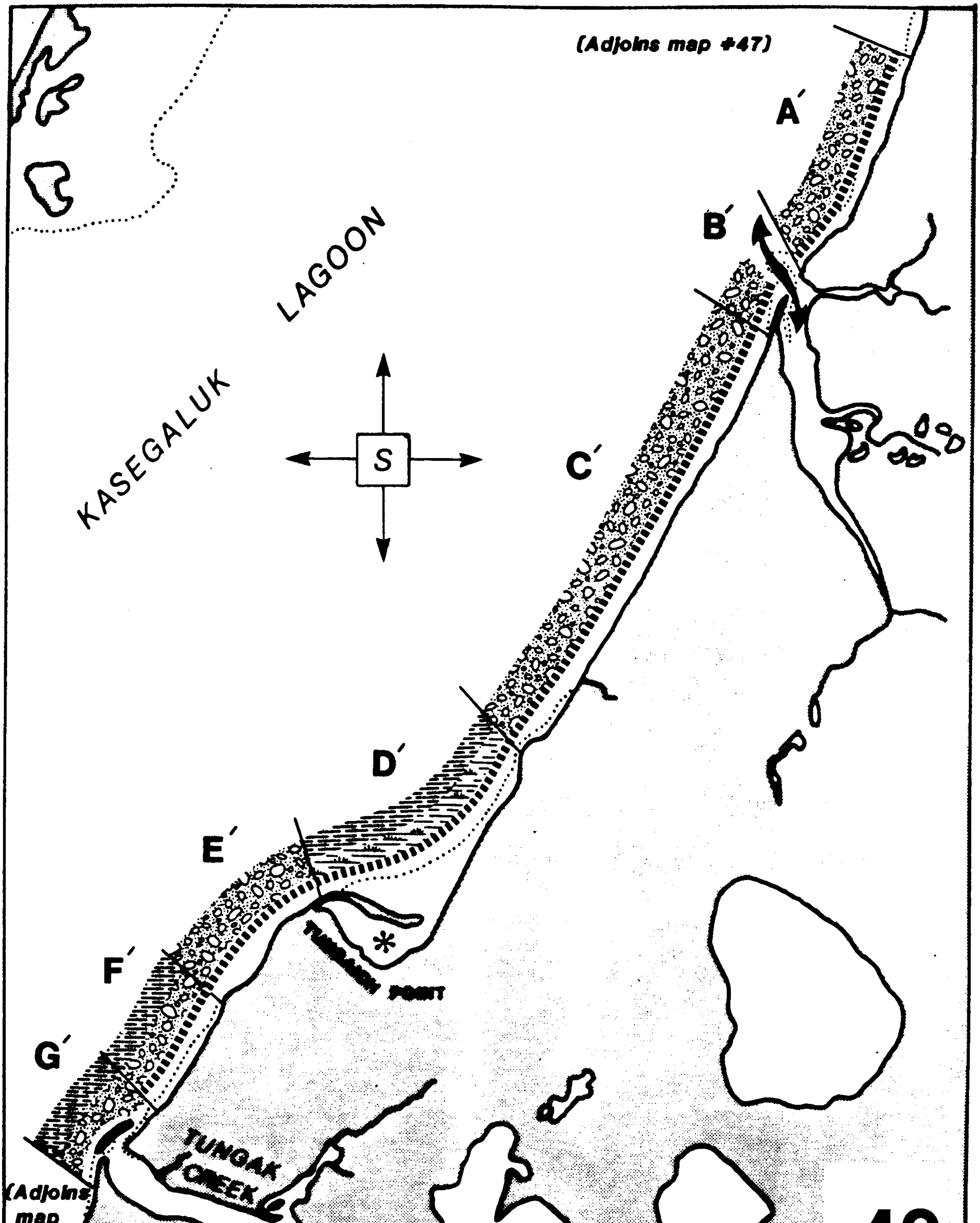
HUMAN USE INDEX



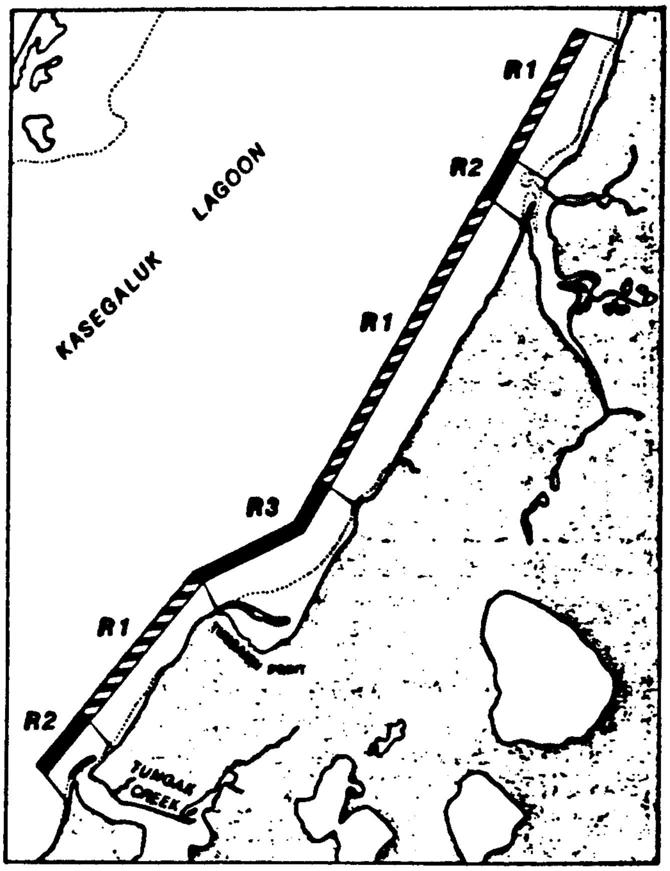
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach			■	■	■	■		
R2	Low energy beach; Wetland			■	■	■	■		
B1	Wetland			▨	▨	▨	▨	▨	
B2	Wetland; Brant and shorebird staging			■	■	■	■	■	

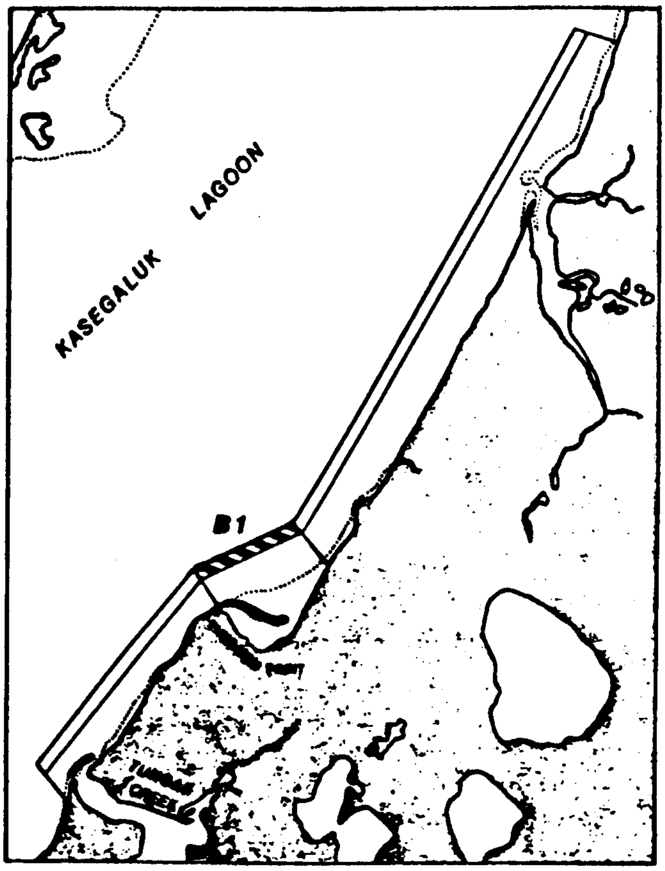
48


(Adjoins map #47)
A´
B´
KASEGALUK LAGOON
S
C´
D´
E´
F´
G´
POINT
TUNGAK CREEK
(Adjoins map #51)
49

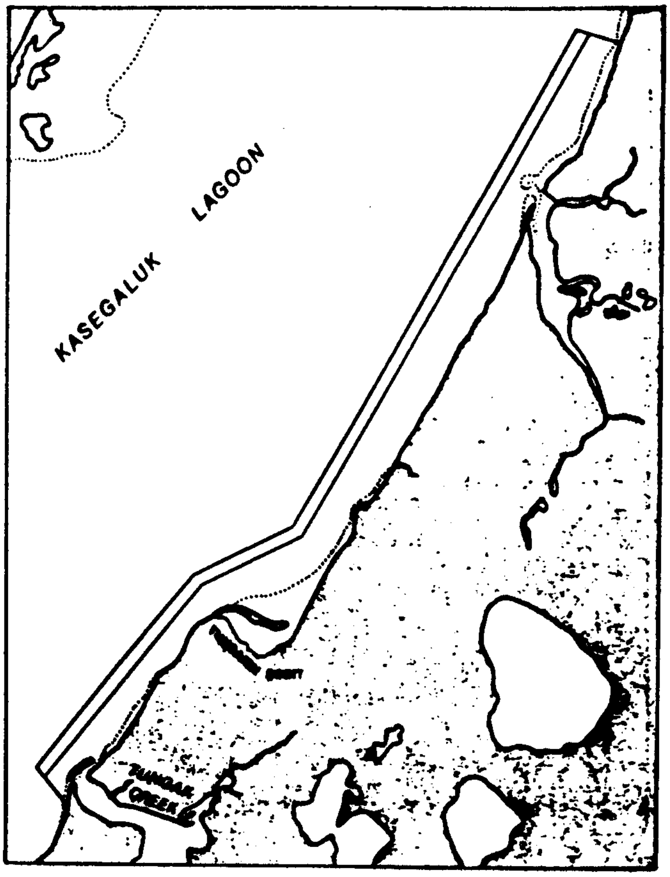
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



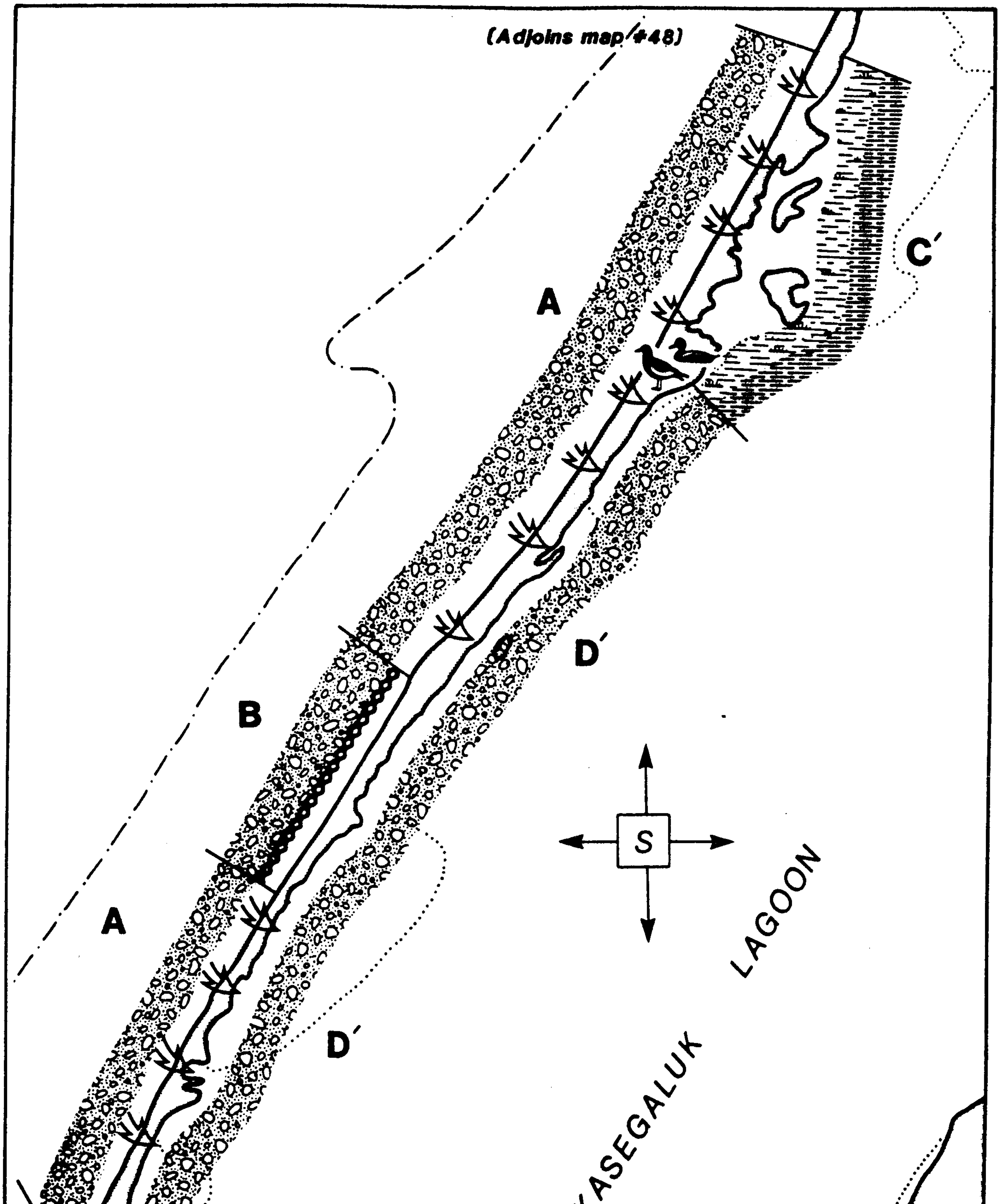
HUMAN USE INDEX



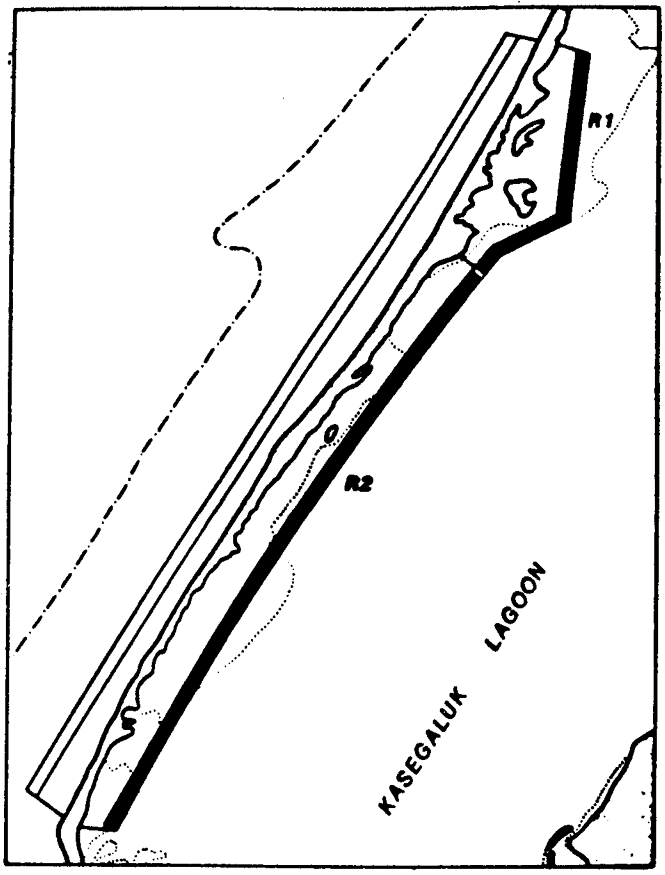
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Protected tundra cliff			▨	▨	▨	▨		
R2	Stable inlet; Estuary			■	■	■	■		
R3	Lagoon			■	■	■	■		
B1	Wetland, mudflats and ponds			▨	▨	▨	▨	▨	

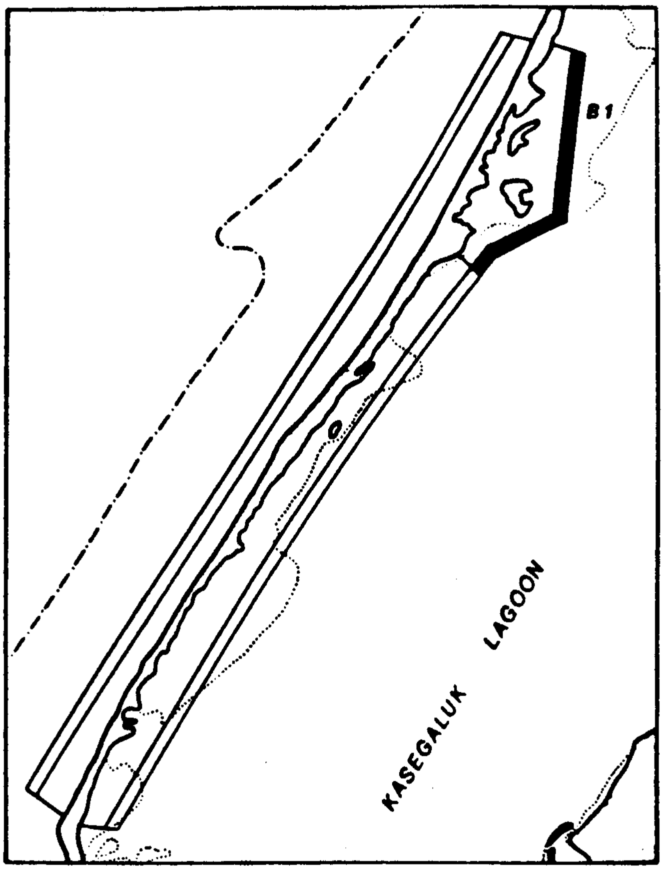
49


(Adjoins map #48)
A
C´
B
D´
S
A
LAGOON
D´
KASEGALUK
(Adjoins map #52)
50

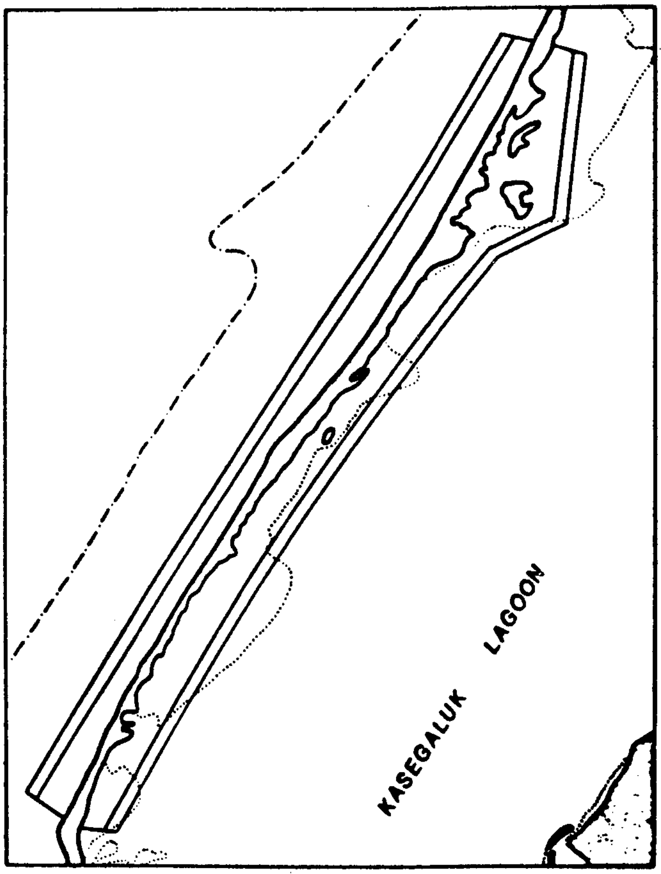
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX

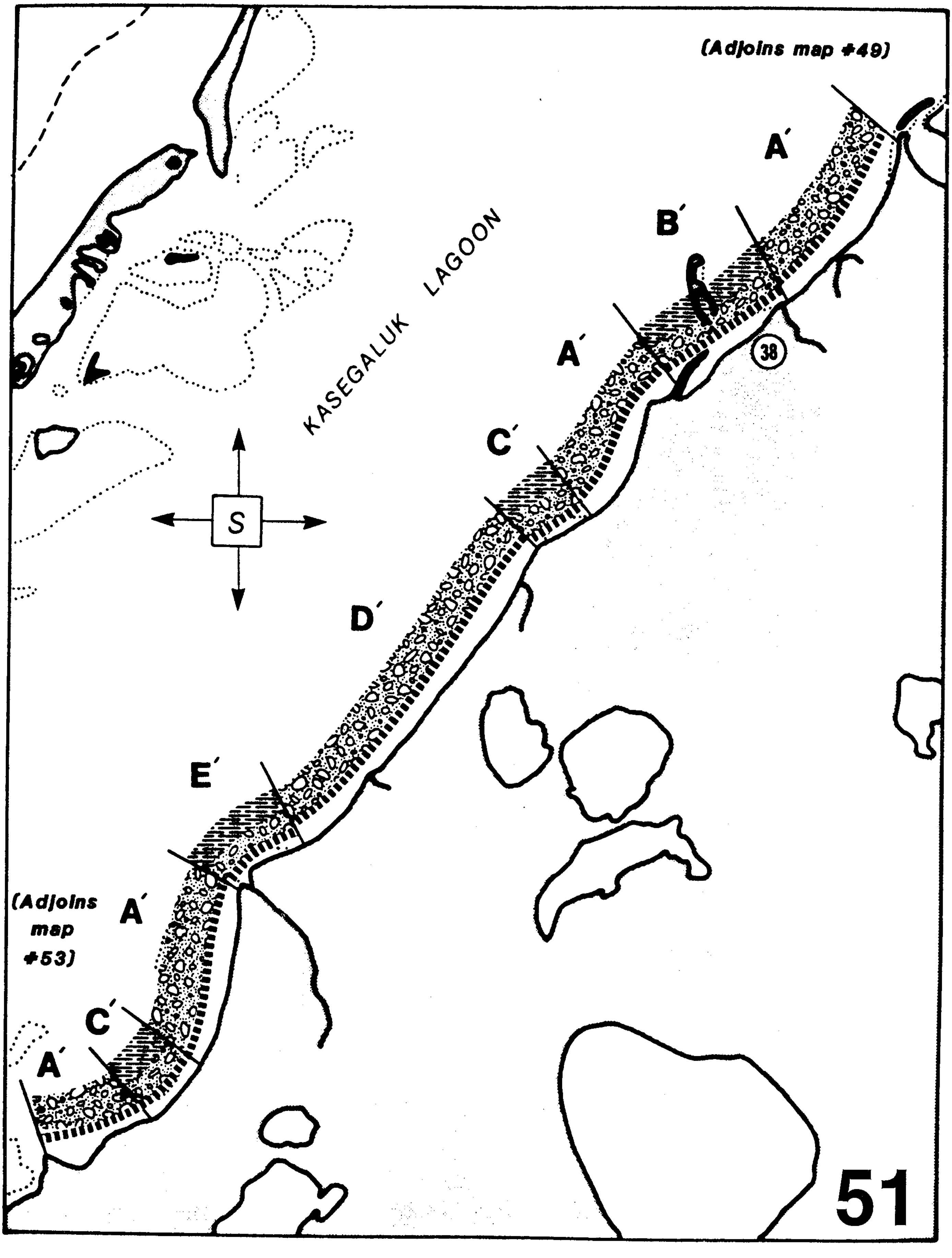


HUMAN USE INDEX

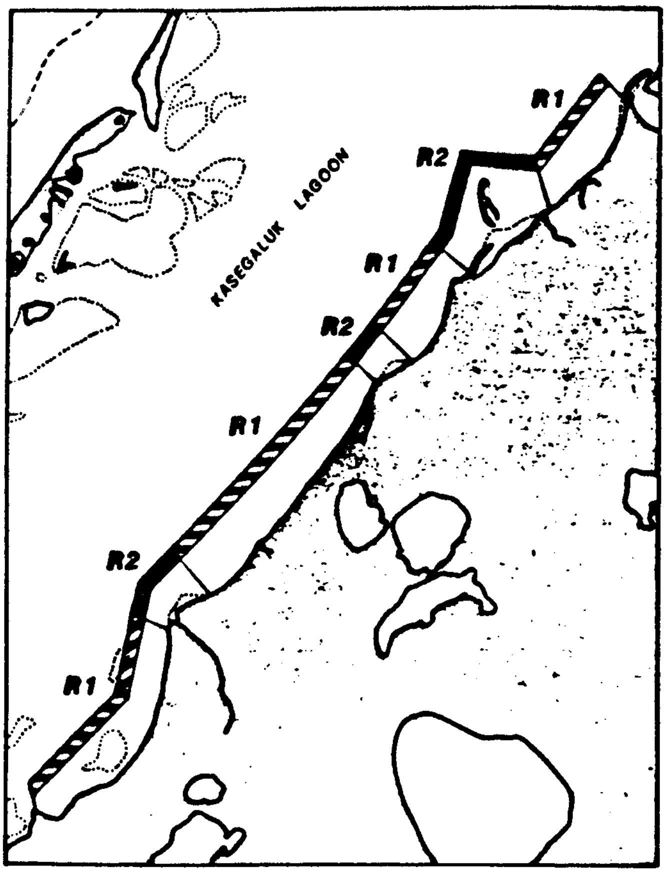


Seasonal Variability of Indices

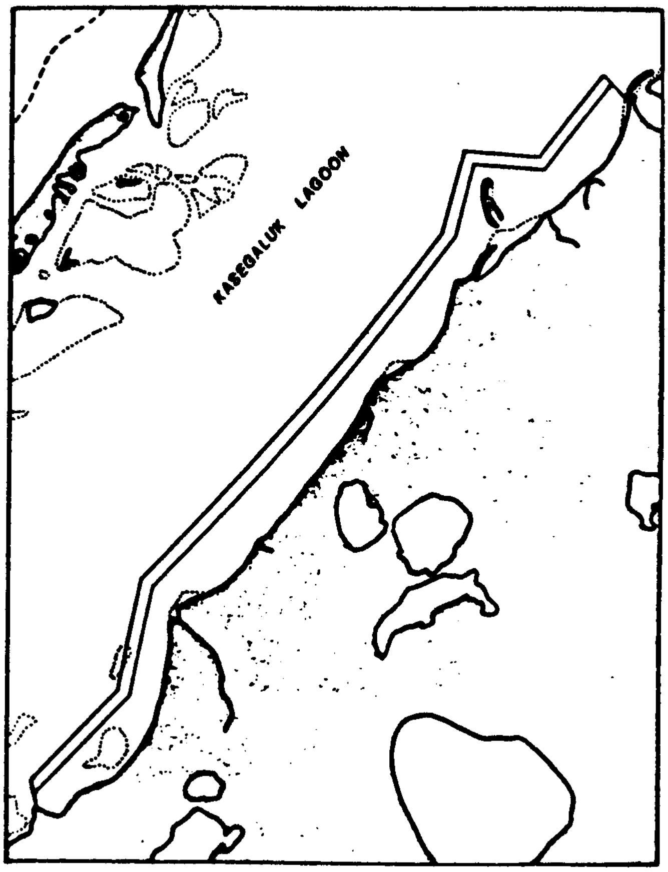
		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Mudflat; Wetland			■	■	■	■		
R2	Mudflat; Low energy beach			■	■	■	■		
B1	Wetland			■	■	■	■		
	Eider (22 pr), arctic tern (16 pr) and brant (4 pr) nesting			▨	▨				


(Adjoins map #49)
A´
B´
A´
38
KASEGALUK LAGOON
C´
S
D´
E´
(Adjoins map #53)
A´
C´
A´
51

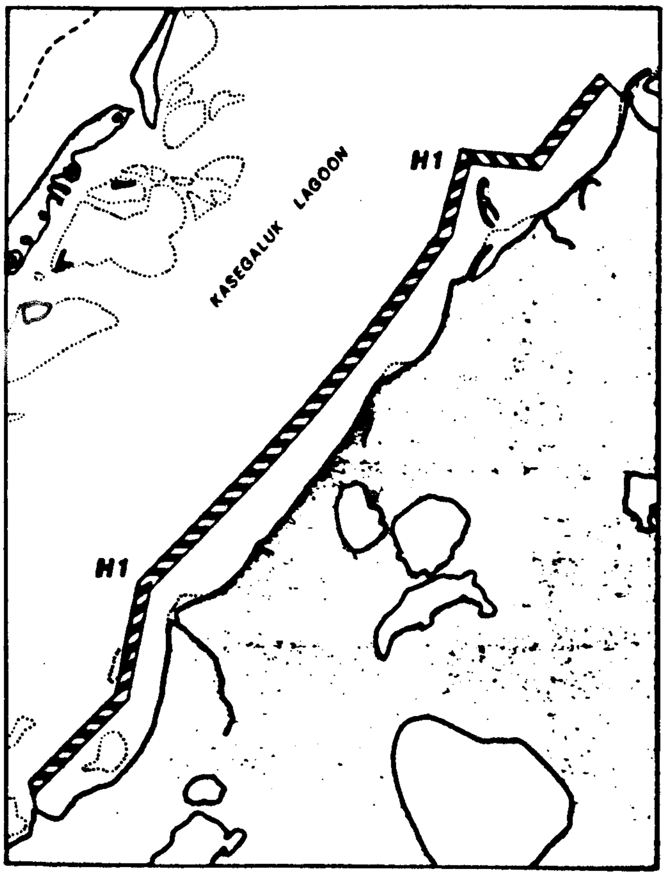
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



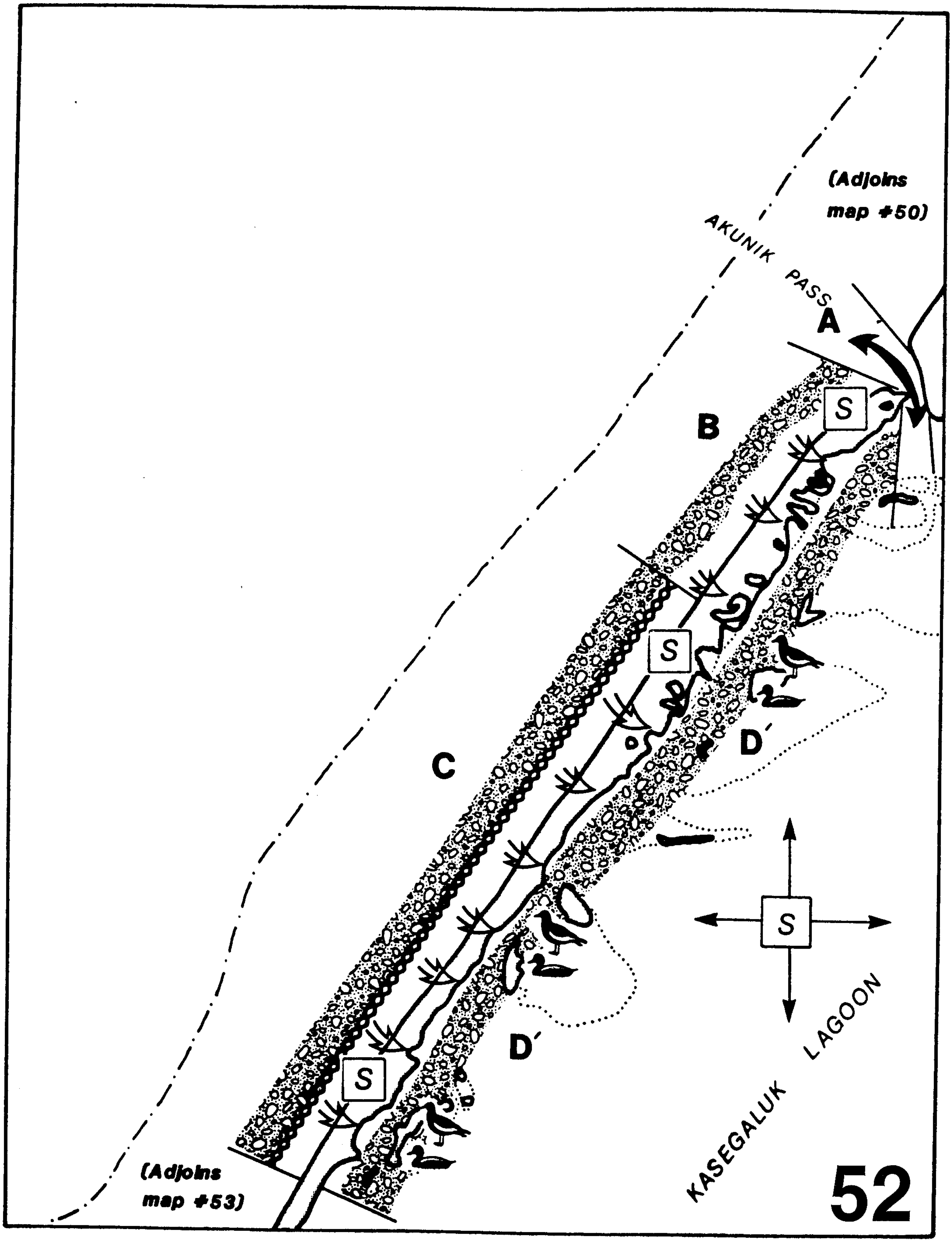
HUMAN USE INDEX



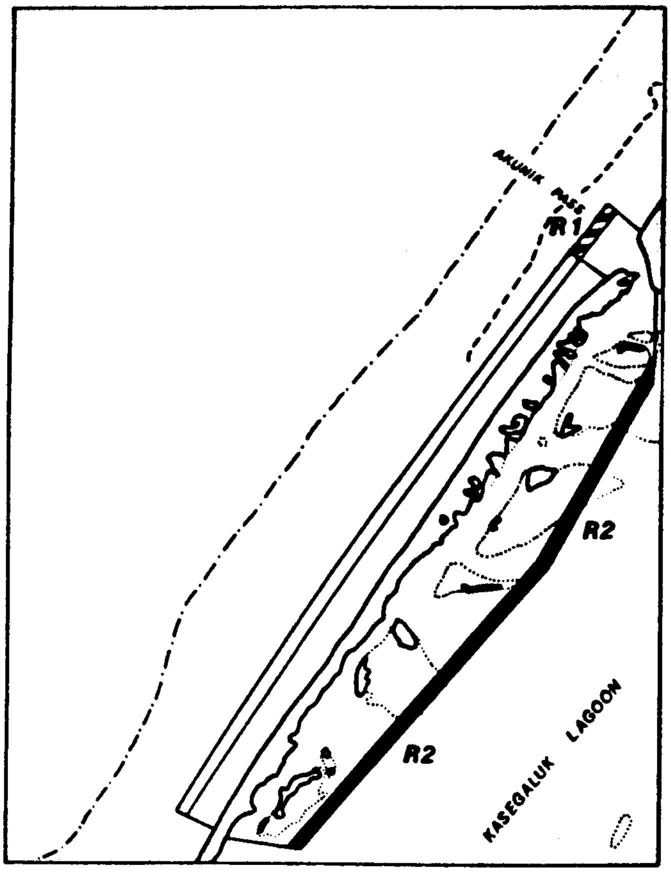
Seasonal Variability of Indices

		SEASON							
			Break-Up/Summer/Freeze-Up						
Identifier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Protected tundra cliff			▨	▨	▨	▨		
R2	Mudflat; lagoon/ estuary			■	■	■	■		
H1	Waterfowl hunting			▨	▨				

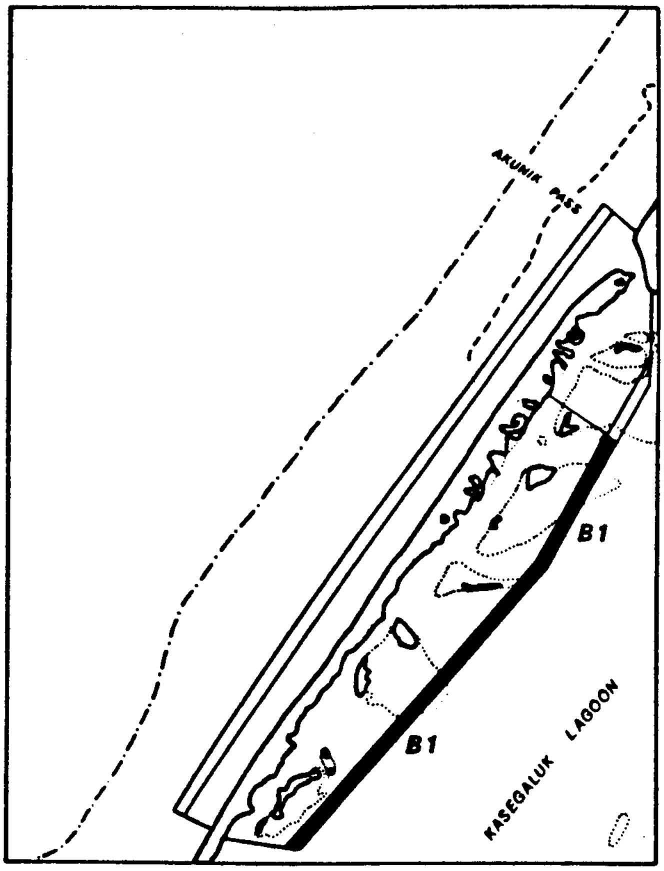
51


(Adjoins map #50)
AKUNIK PASS
A
S
B
S
C
D´
S
D´
S
KASEGALUK LAGOON
(Adjoins map #53)
52

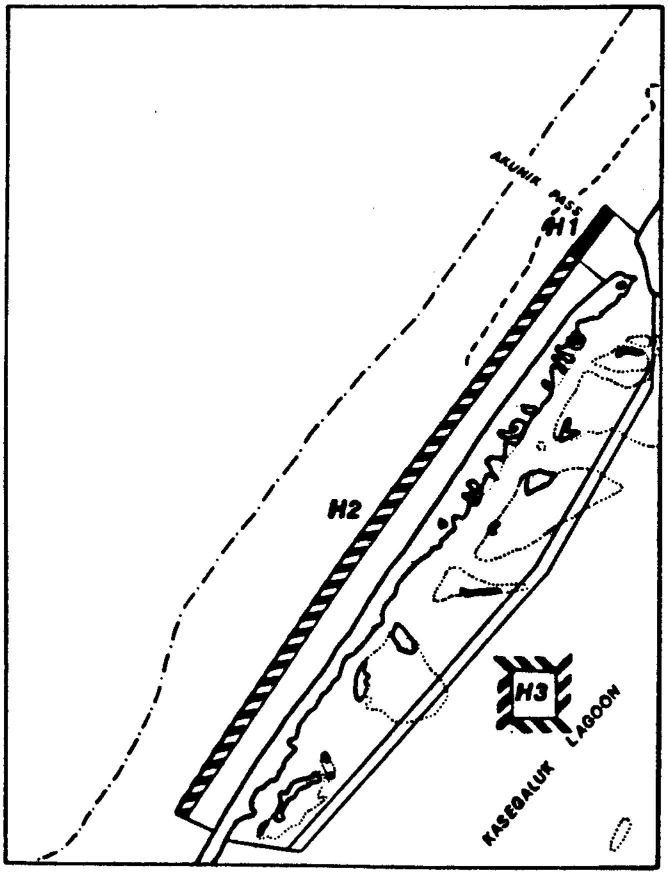
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



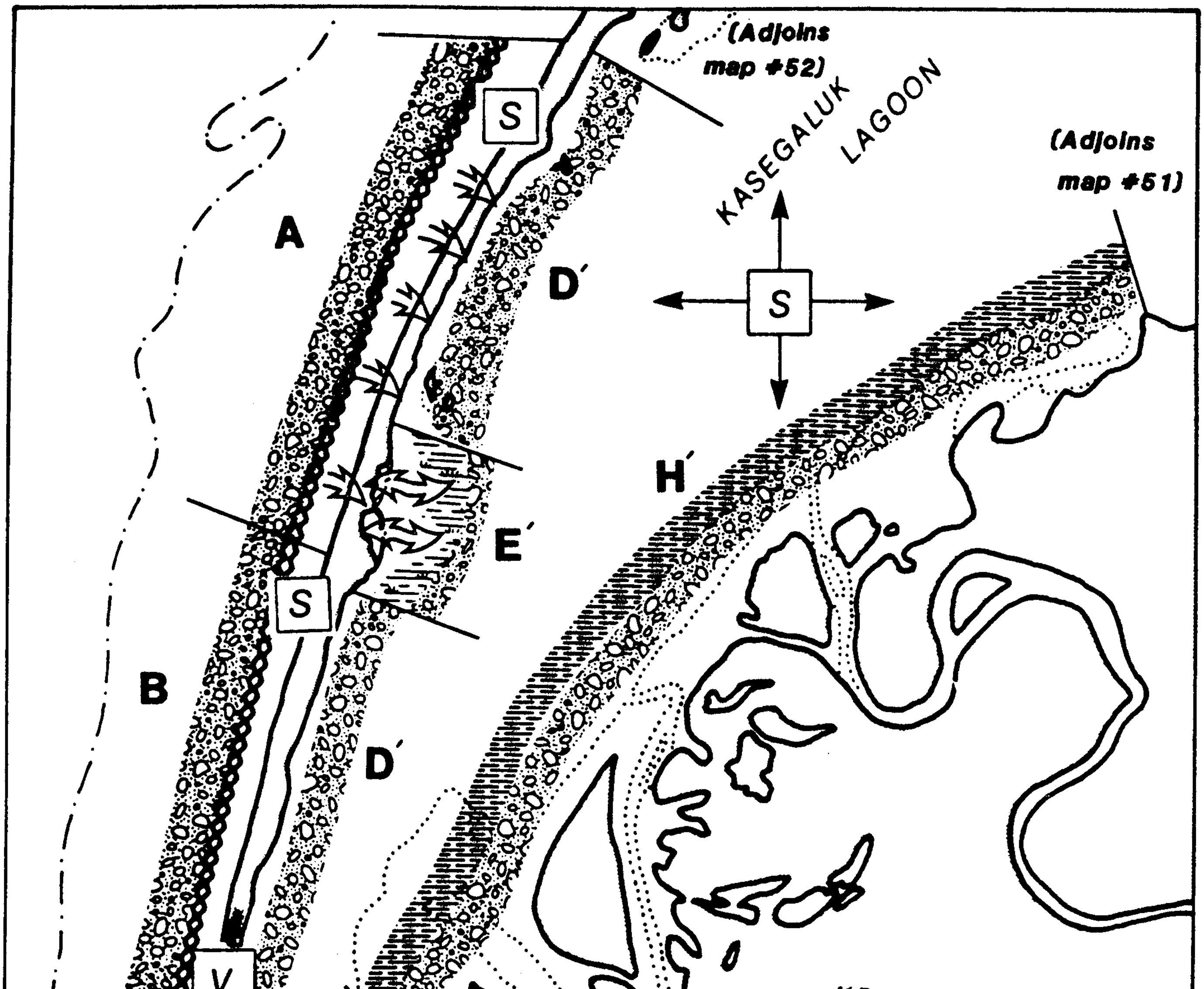
HUMAN USE INDEX



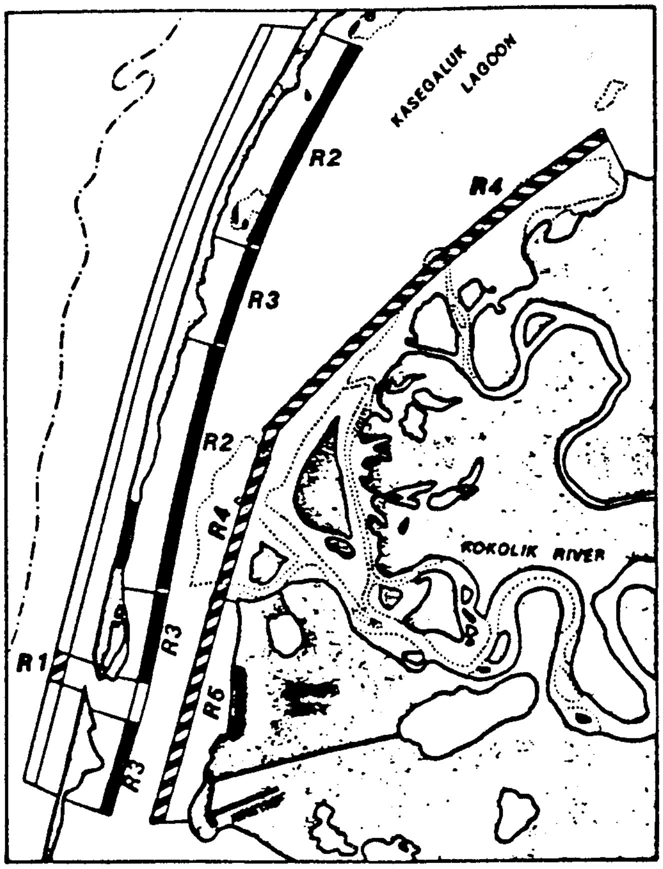
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Permanent inlet; Recurve spits			▨	▨	▨	▨	▨	
R2	Low energy beach; Some wetlands			■	■	■	■		
B1	Wetland			▨	▨	▨	▨	▨	
	Eider (28 pr), arctic tern (54 pr), gull (4 pr), brant (4 pr), oldsquaw (6 pr) nesting on islands			■	■				
H1	Spotted seal hunting				■	■			
	Beluga whale hunting				■	■			
H2	Waterfowl hunting			▨	▨				
	Egg gathering			▨	▨				
H3	Spotted seal hunting				▨	▨			
	Beluga whale hunting				▨	▨			

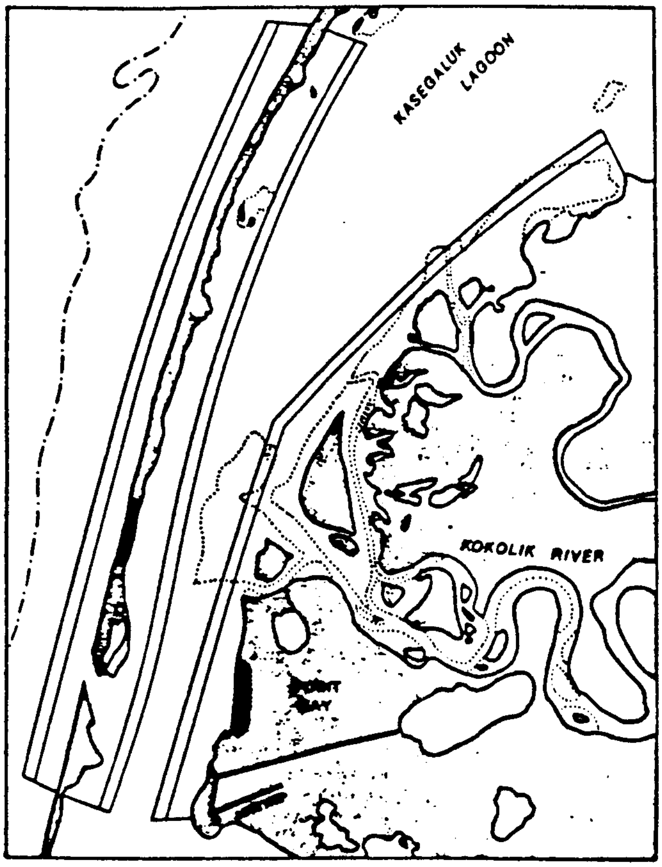
52


(Adjoins map #52)
KASEGALUK LAGOON
(Adjoins map #51)
S
A
D´
S
H´
E´
S
B
D´
V
KOKOLIK RIVER
A
F´
C
I´
A
POINT LAY
V
S
M
AIRSTRIP
G´
53

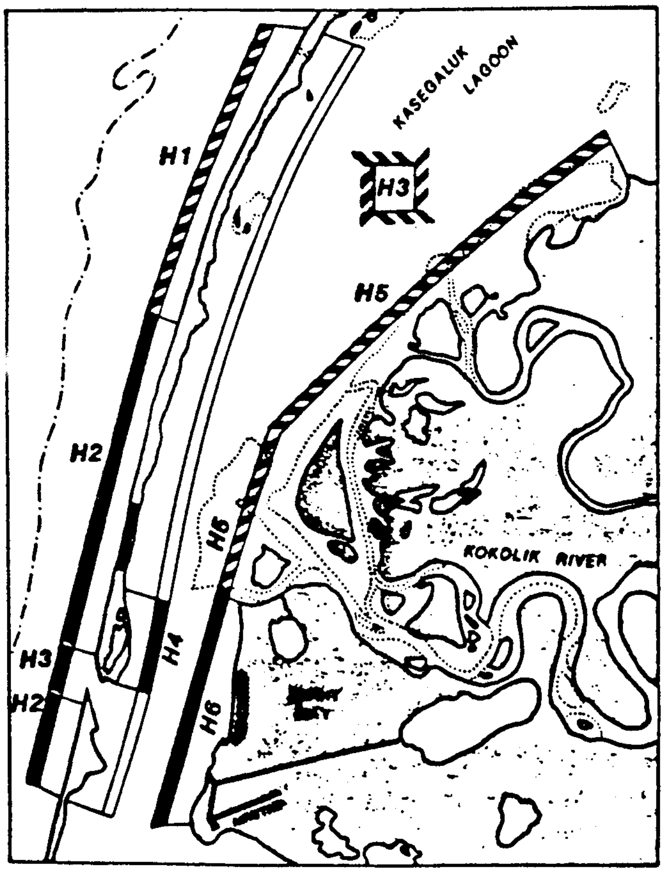
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



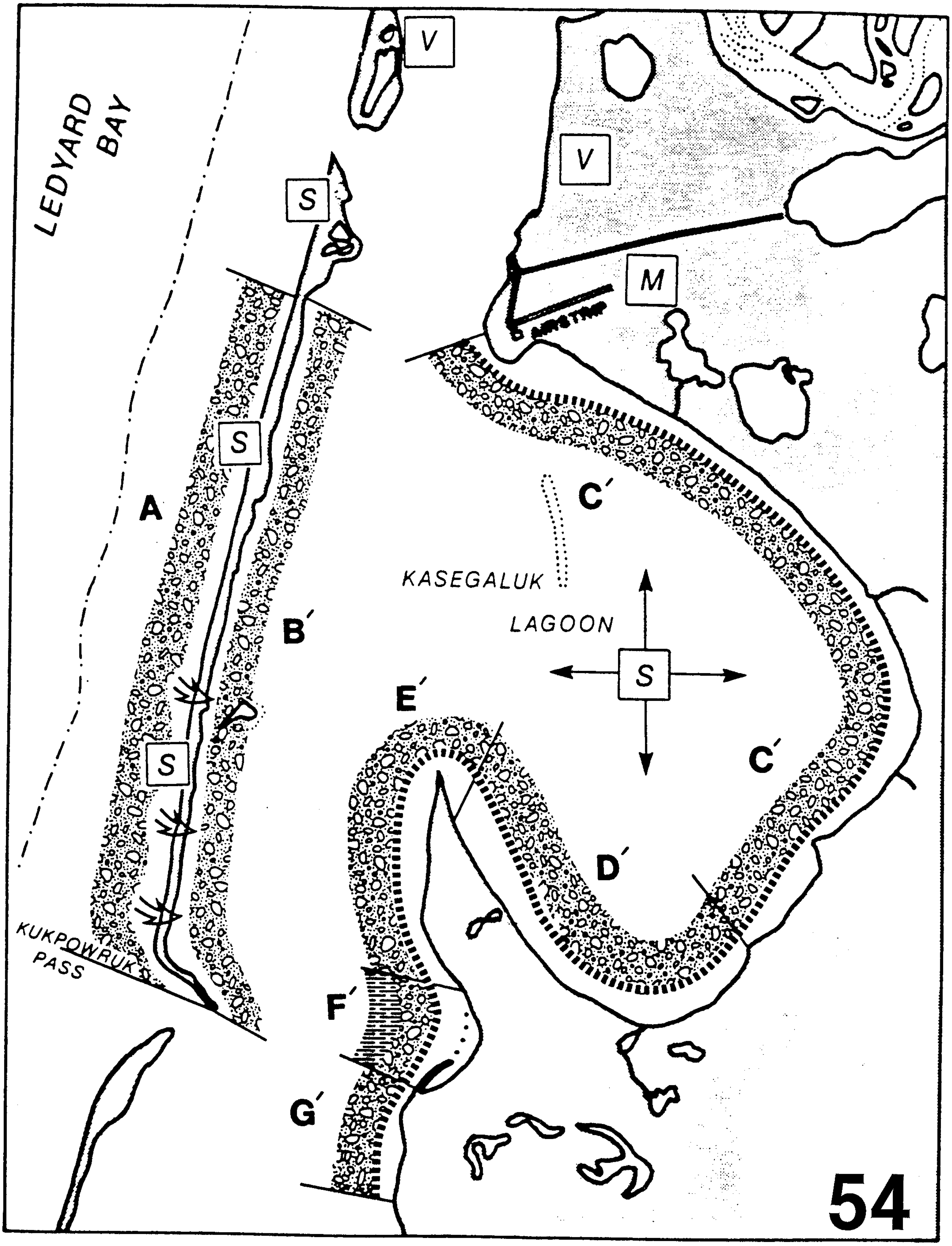
HUMAN USE INDEX



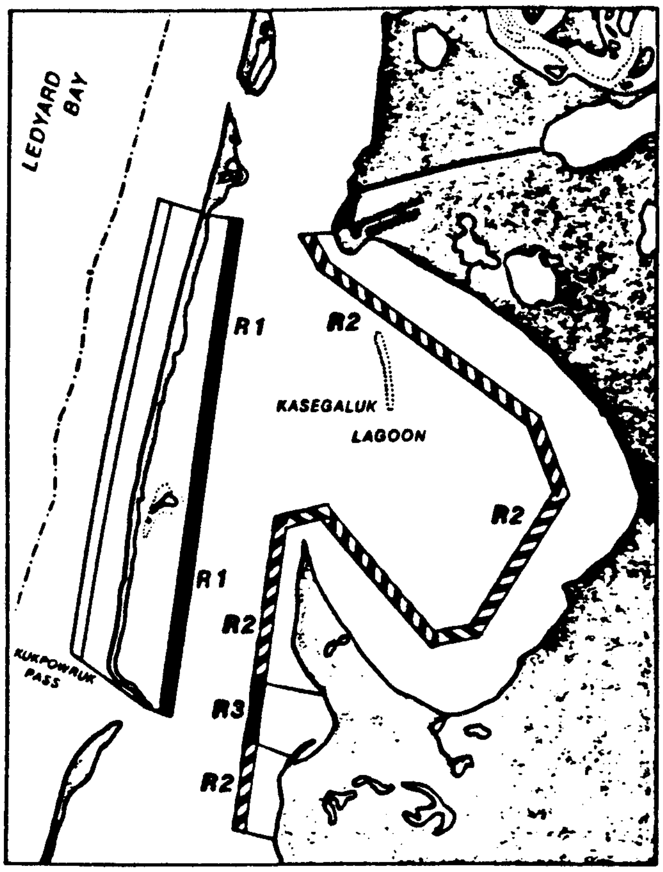
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Permanent inlet; Recurve spits			▨	▨	▨	▨	▨	
R2	Low energy beach			▬	▬	▬	▬		
R3	Low energy beach; Wetland			▬	▬	▬	▬		
R4	Delta front; Wetland			▨	▨	▨	▨		
R5	Protected tundra cliff			▨	▨	▨	▨		
H1	Waterfowl hunting			▨	▨				
	Egg gathering			▨	▨				
H2	Seasonal village Subsistence access			▬	▬	▬	▬	▬	
	Waterfowl hunting			▬	▬				
	Egg gathering			▬	▬				
H3	Beluga whale hunting				▬	▬			
	Spotted seal hunting				▬	▬			
H4	Beluga landing and harvesting area				▬	▬			
H5	Waterfowl hunting			▨	▨				
	Fishing			▨	▨	▨	▨		
H6	Village of Point Lay			▬	▬	▬	▬		
	Subsistence access			▬	▬	▬	▬		

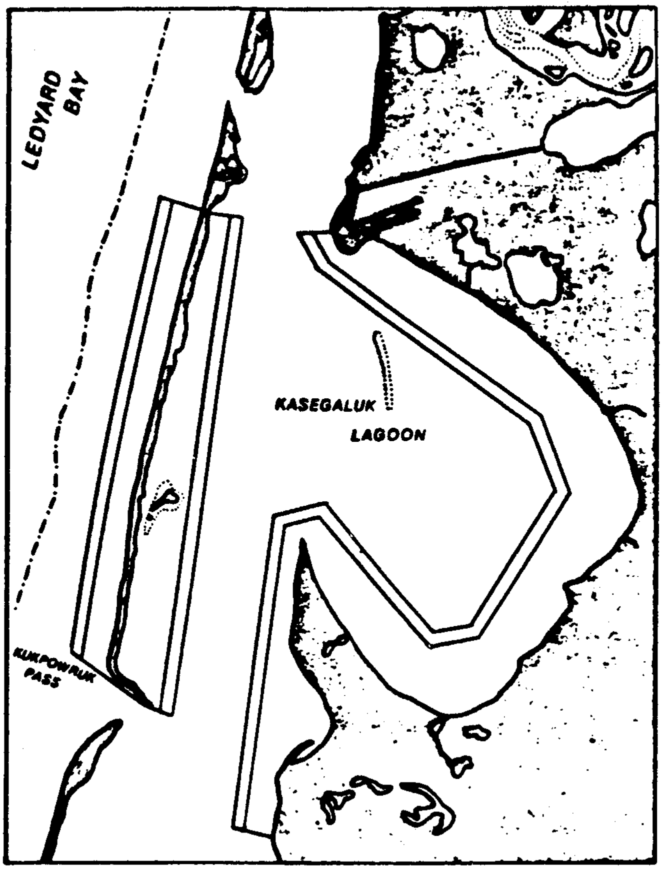
53


LEDYARD BAY
V
V
S
M
AIRSTRIP
S
A
C´
KASEGALUK
LAGOON
B´
S
E´
S
C´
D´
KUKPOWRUK PASS
F´
G´
54

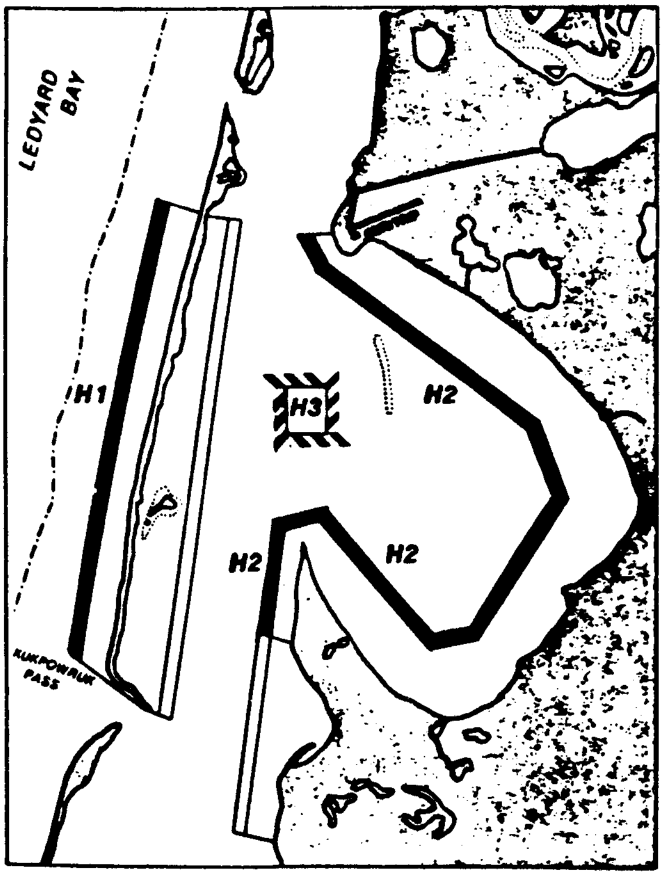
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



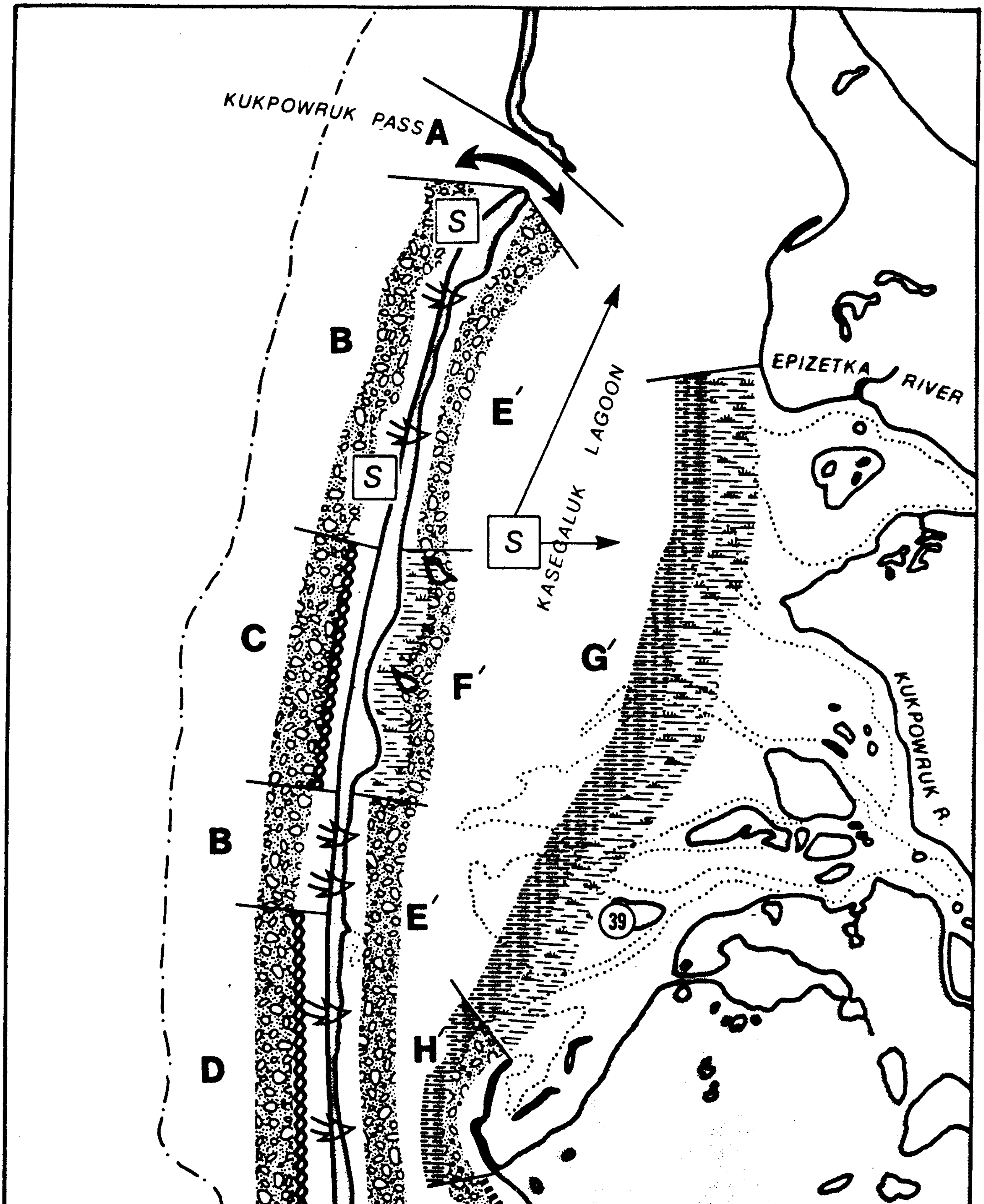
HUMAN USE INDEX



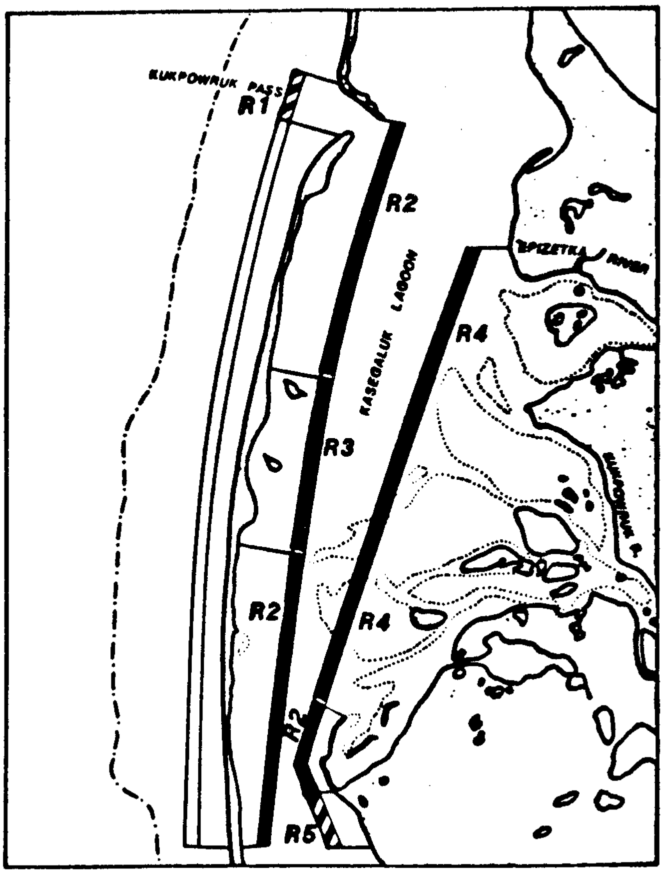
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach			■	■	■	■		
R2	Protected tundra cliff			▨	▨	▨	▨		
R3	Small lagoon			■	■	■	■		
H1	Egg gathering			■	■				
H2	Waterfowl hunting			■	■				
H3	Fishing			▨	▨	▨	▨		

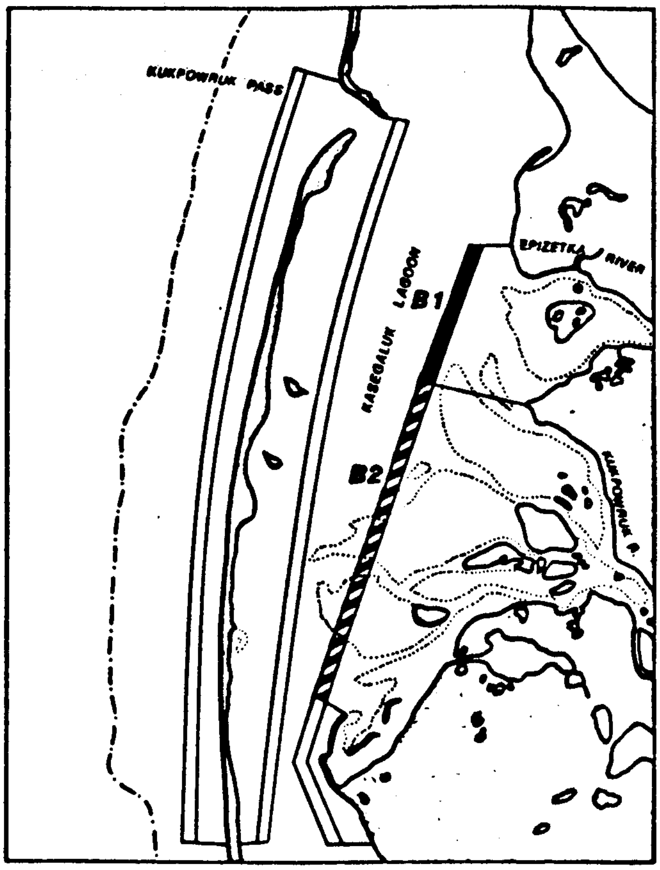
54


KUKPOWRUK PASS
A
S
B
E′
KASEGALUK LAGOON
EPIZETKA RIVER
S
S
C
G′
F′
KUKPOWRUK R.
B
E′
39
H′
D
I′
55

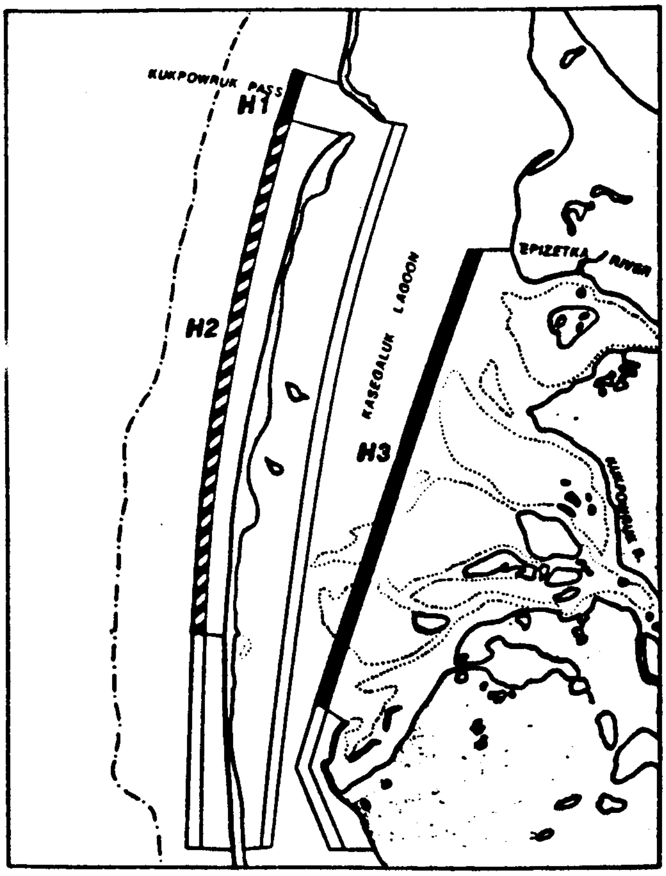
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



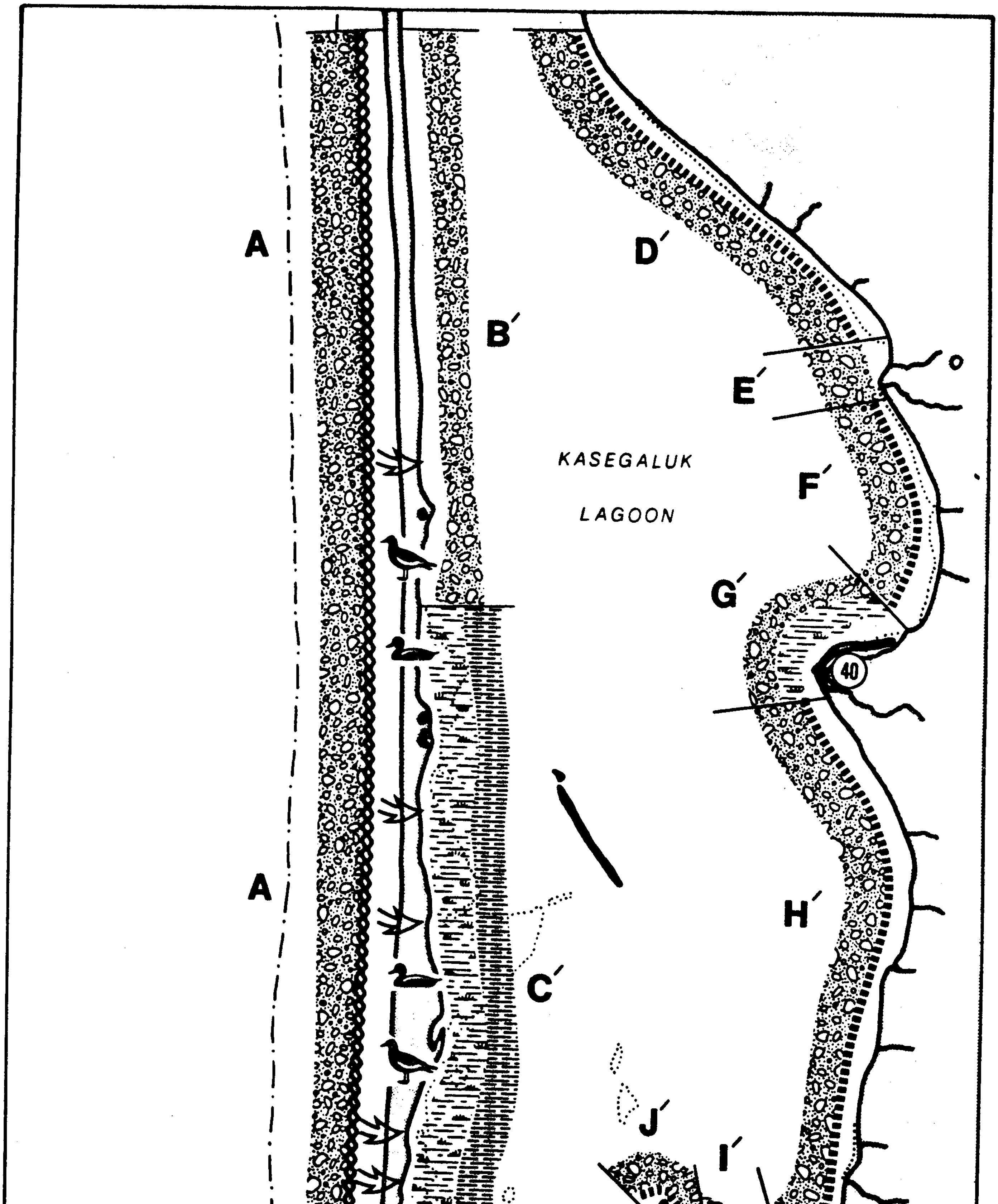
HUMAN USE INDEX



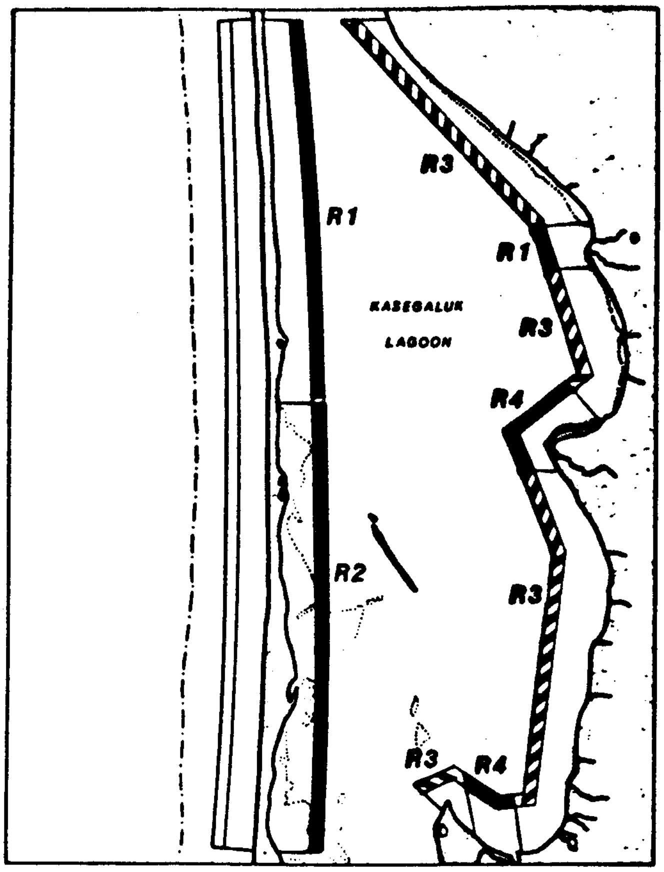
Seasonal Variability of Indices

Identi-fier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Stable inlet; Recurve spits			▨	▨	▨	▨	▨	
R2	Low energy beach			■	■	■	■		
R3	Low energy beach; Wetland			■	■	■	■		
R4	Tidal flats; delta wetlands			■	■	■	■		
R5	Protected tundra cliff			■	■	■	■		
B1	Wetland and mudflats			■	■	■	■	■	
B2	Mudflats with some wetland			▨	▨	▨	▨	▨	
H1	Beluga whale hunting				■	■			
	Spotted seal hunting				■	■			
H2	Egg gathering			▨	▨				
H3	Waterfowl hunting				■	■			

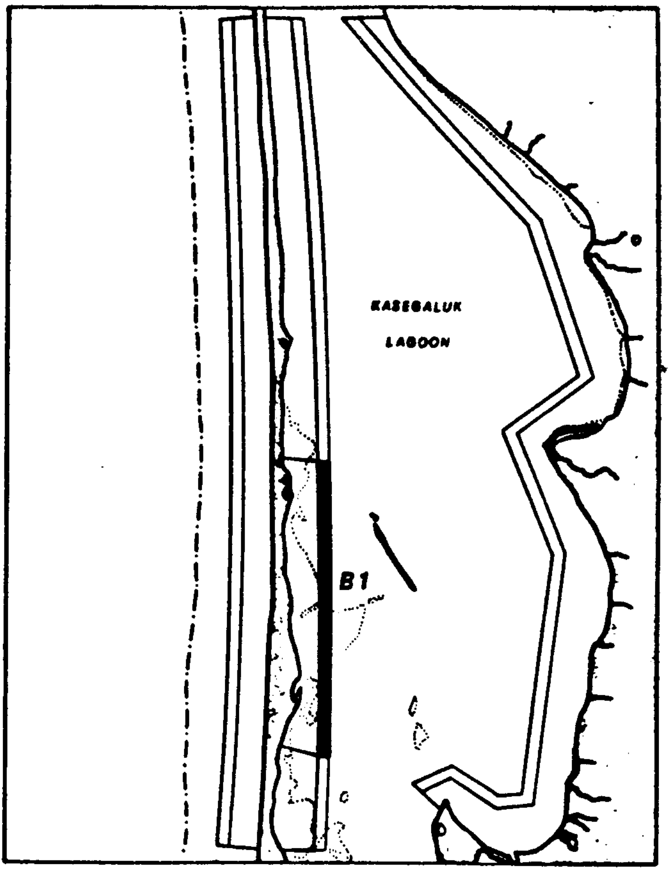
55


A
A
B´
C´
D´
E´
F´
G´
H´
I´
J´
KASEGALUK
LAGOON
40
56

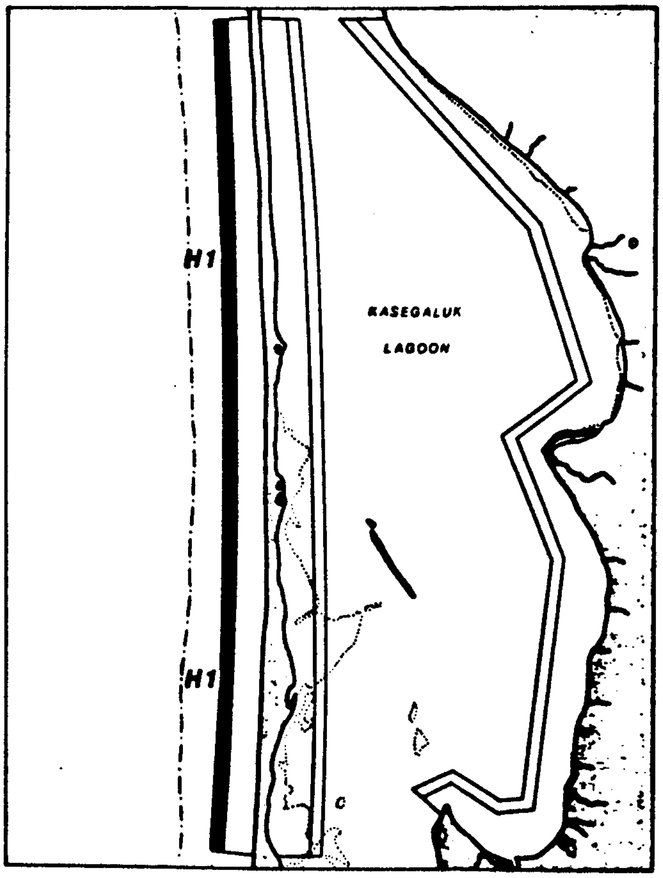
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



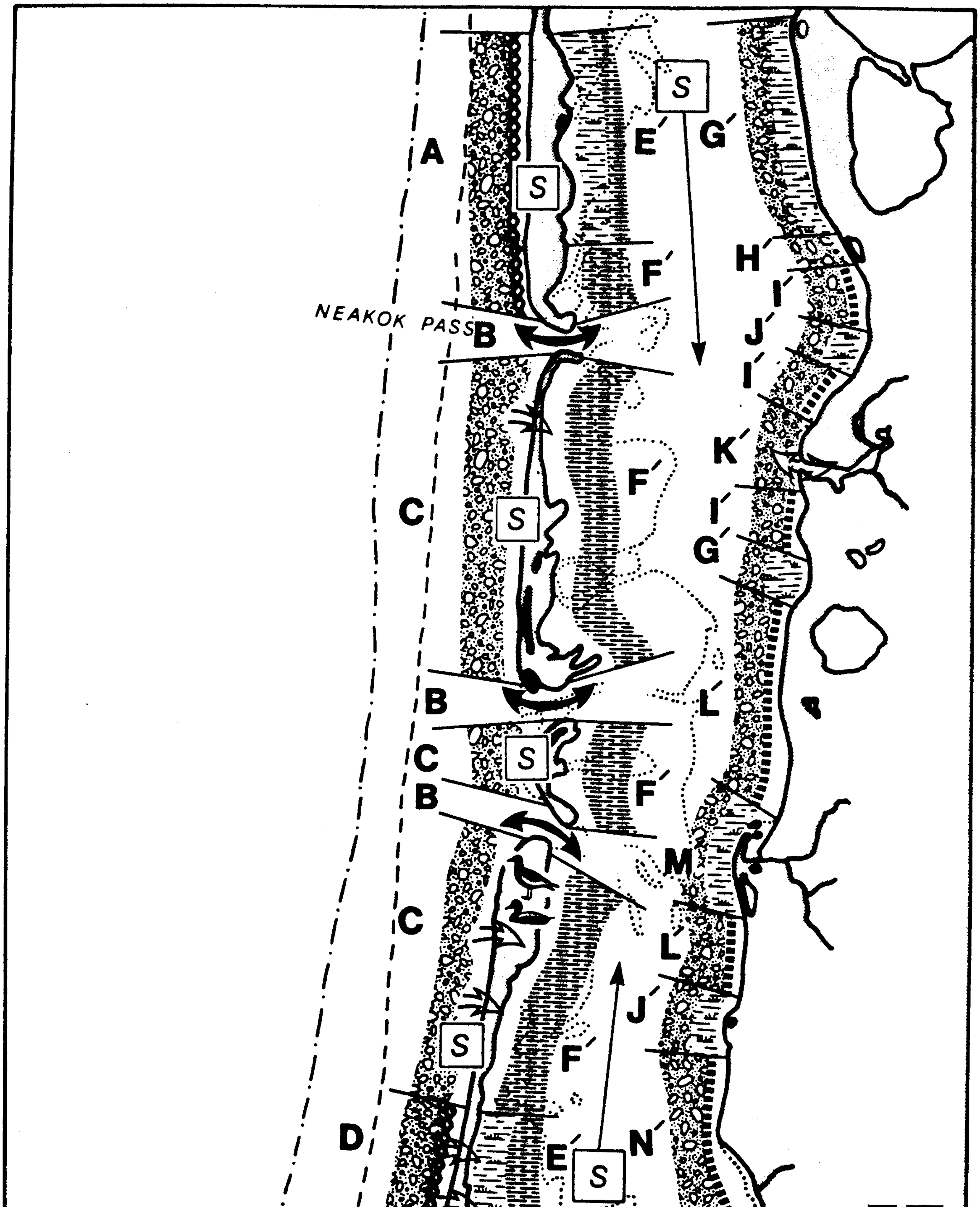
HUMAN USE INDEX



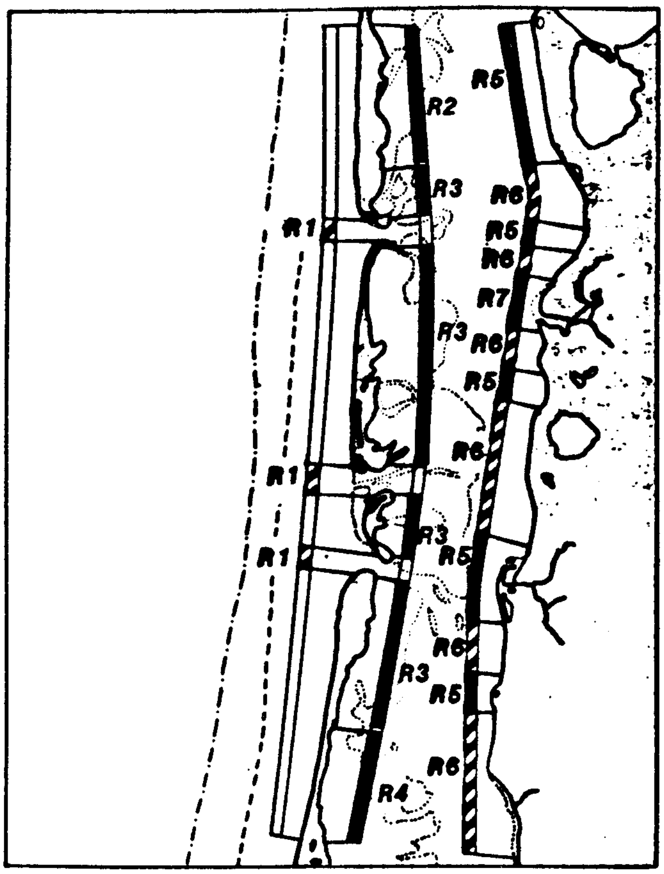
Seasonal Variability of Indices

Identi-fier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach			■	■	■	■		
R2	Tidal flats; Wetland			■	■	■	■		
R3	Protected tundra cliff			▨	▨	▨	▨		
R4	Tidal flats; Ephemeral inlet; Lagoon			■	■	■	■		
B1	Wetland			■	■	■	■	■	
	Eider (8 pr), arctic tern (28 pr), oldsquaw (2 pr) nesting			▨	▨				
H1	Beluga whale hunting				■	■			
	Spotted seal hunting				■	■			
	Fishing			■	■	■	■		

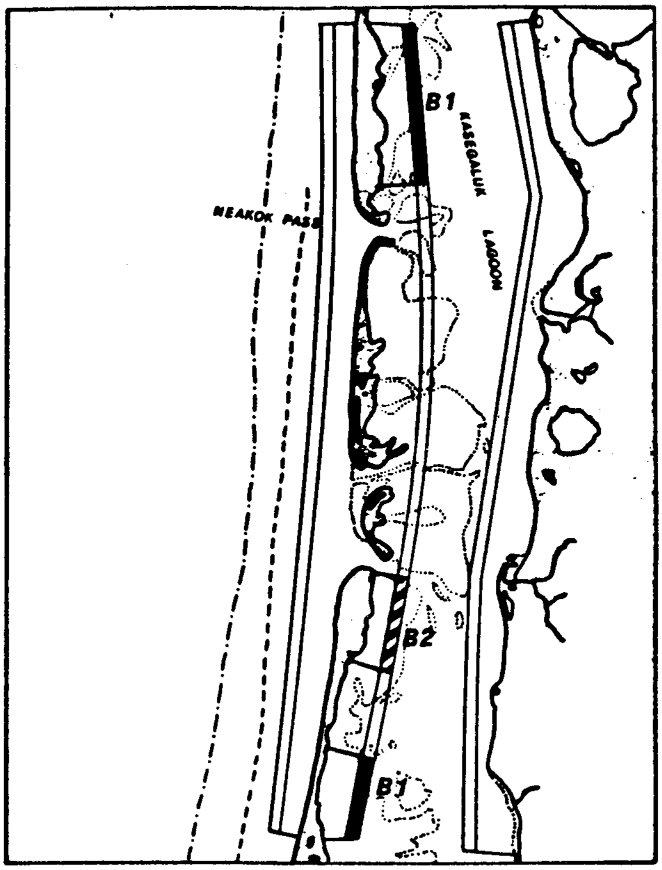
56


A
S
E´
G´
S
H´
F´
I´
NEAKOK PASS
B
J´
I´
K´
F´
C
S
I´
G´
B
L´
C
S
F´
B
M
C
L´
J´
S
F´
D
E´
S
N´
57

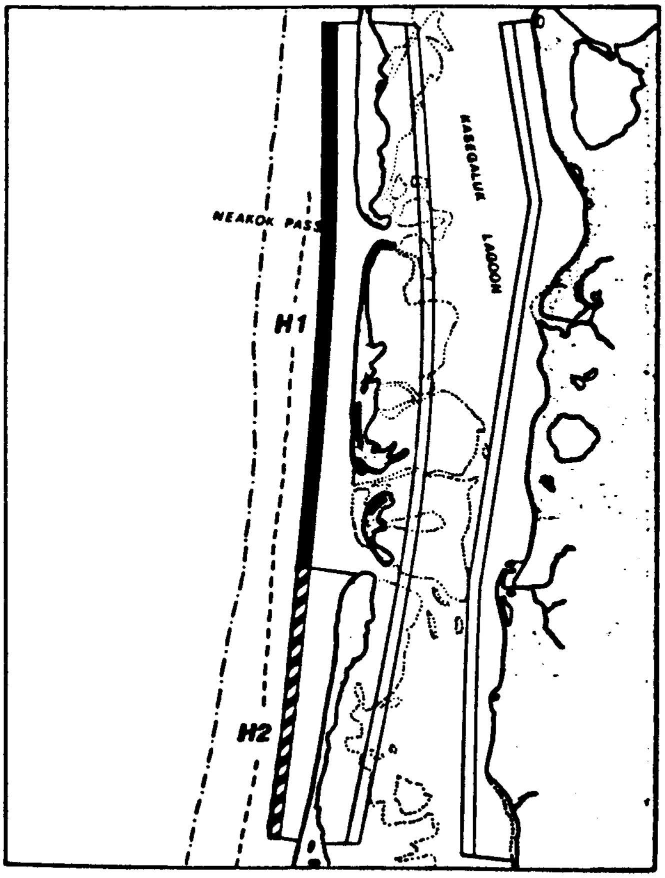
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



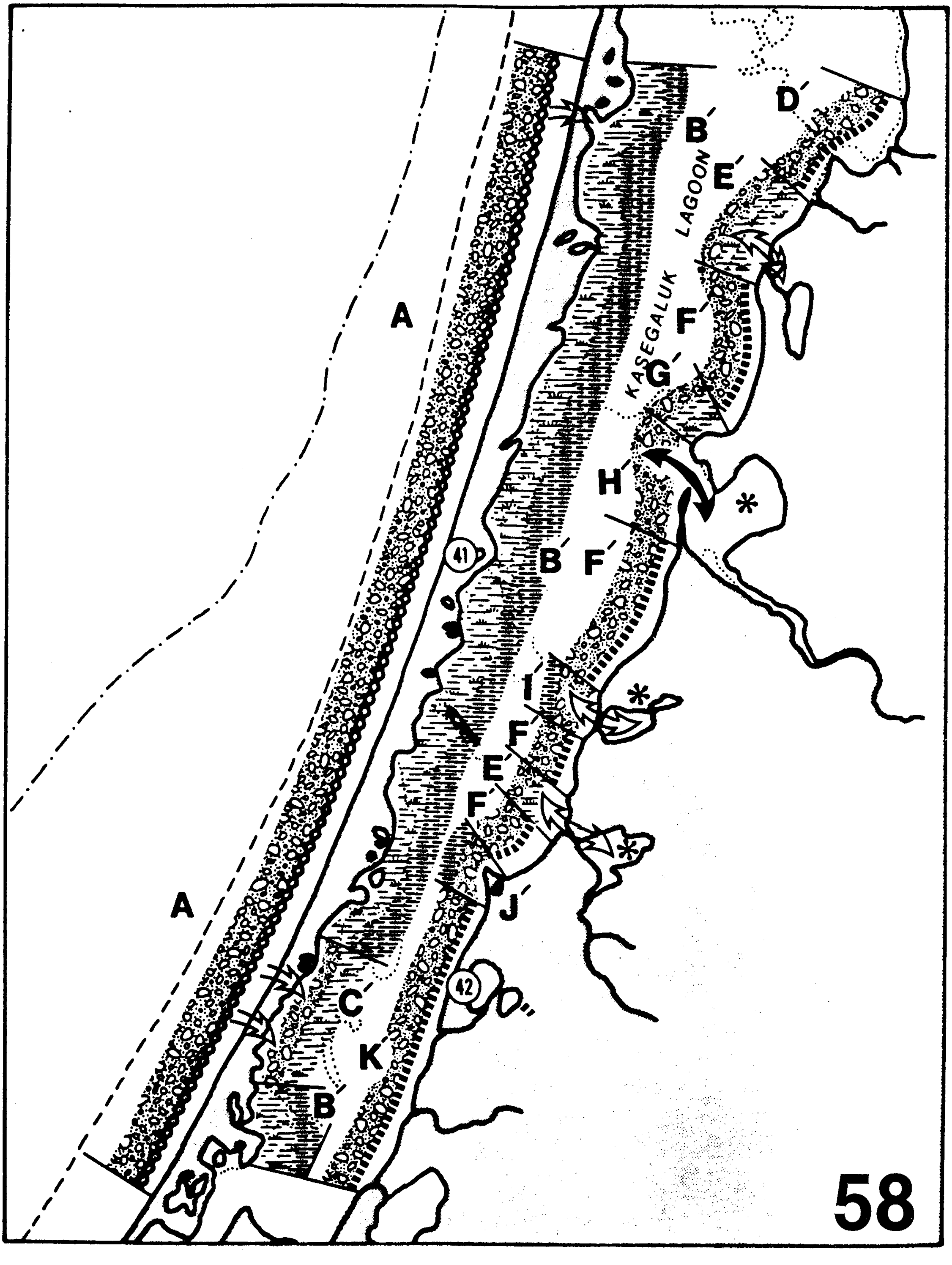
HUMAN USE INDEX



Seasonal Variability of Indices

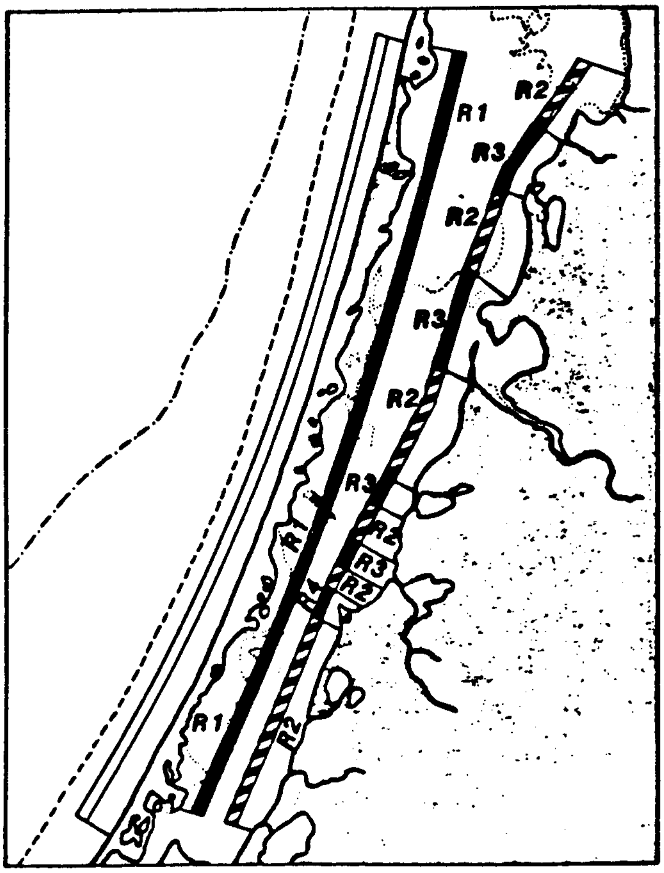
Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Stable inlet; Recurve spits			▨	▨	▨	▨	▨	
R2	Wetland			■	■	■	■		
R3	Tidal flats			■	■	■	■		
R4	Tidal flat; wetland			■	■	■	■		
R5	Low energy beach; Wetland			■	■	■	■		
R6	Protected tundra cliff			▨	▨	▨	▨		
R7	Ephemeral inlet; Estuary			■	■	■	■		
B1	Wetland			■	■	■	■	■	
B2	Eider (6 pr), and arctic tern (2 pr) nesting			▨	▨				
H1	Fishing			■	■	■	■		
	Beluga whale hunting			■	■				
H2	Spotted seal hunting			▨	▨				
	Fishing			▨	▨	▨	▨		

57

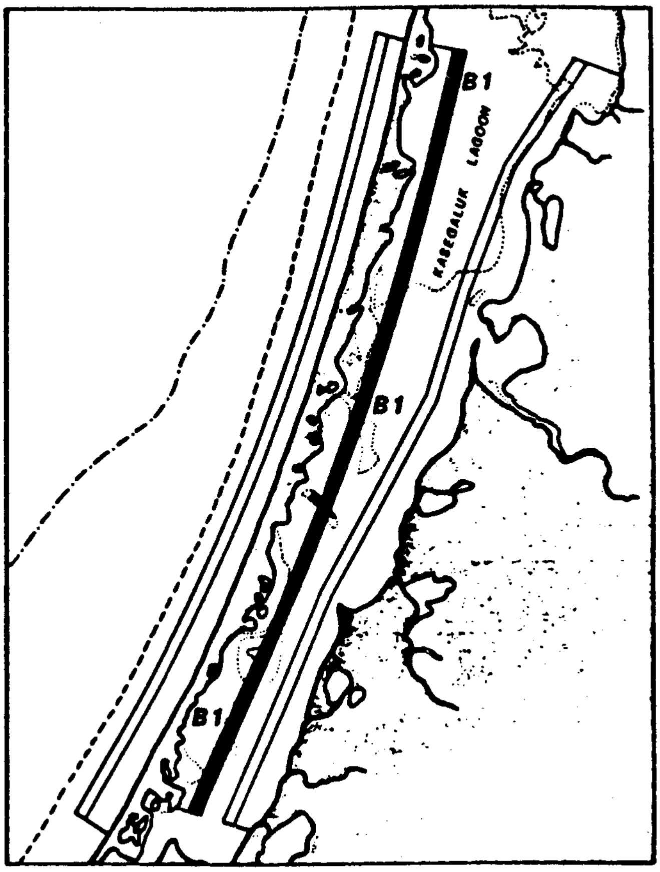


A
A
B
B
B
C
D
E
E
F
F
F
F
G
H
I
J
K
KASEGALUK LAGOON
41
42
*
*
*
58

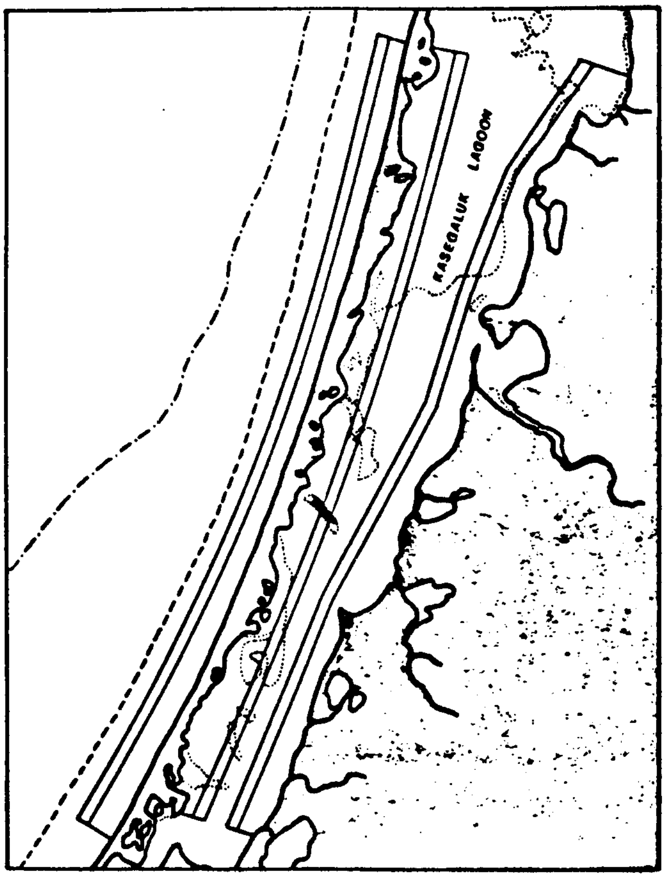
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



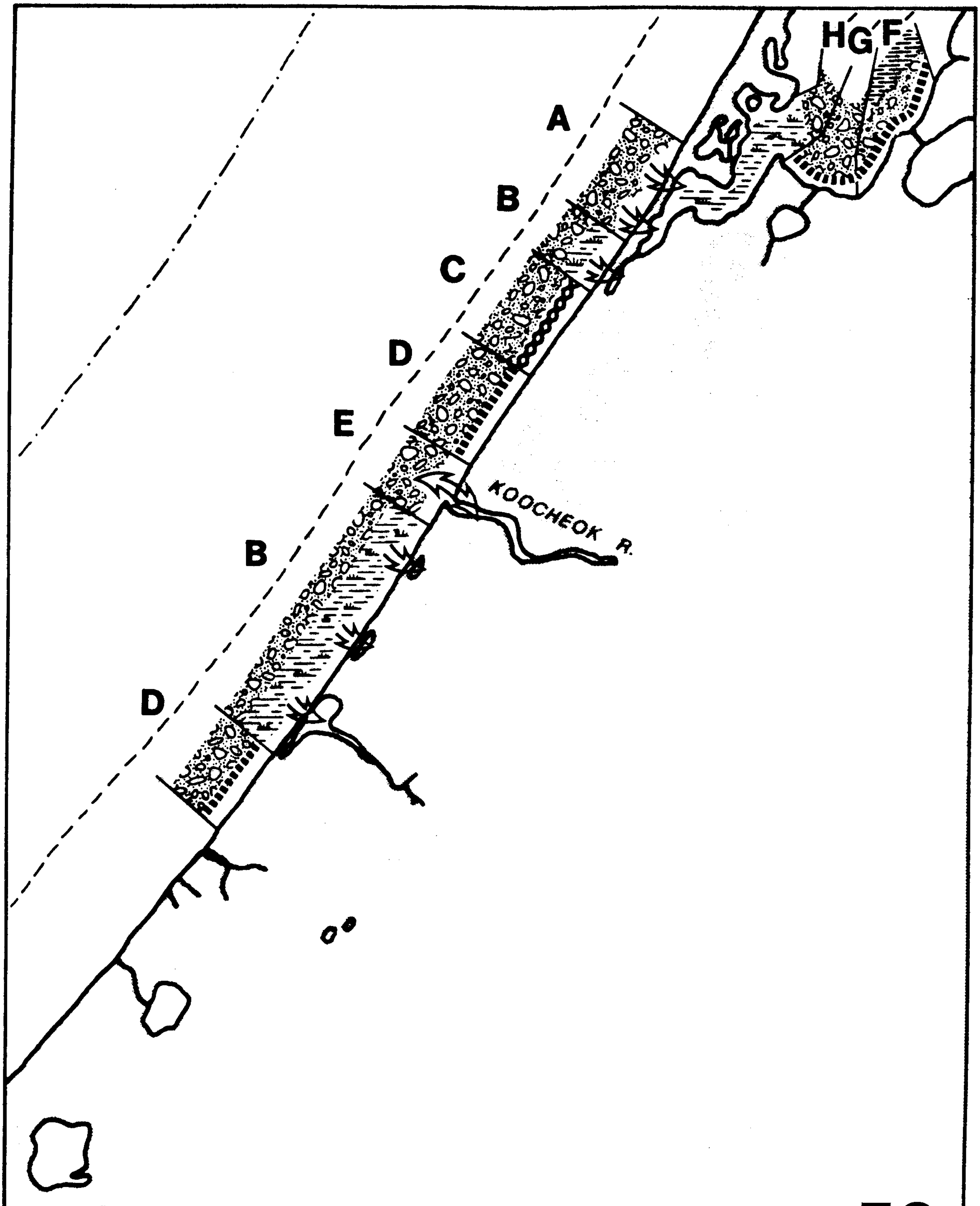
HUMAN USE INDEX



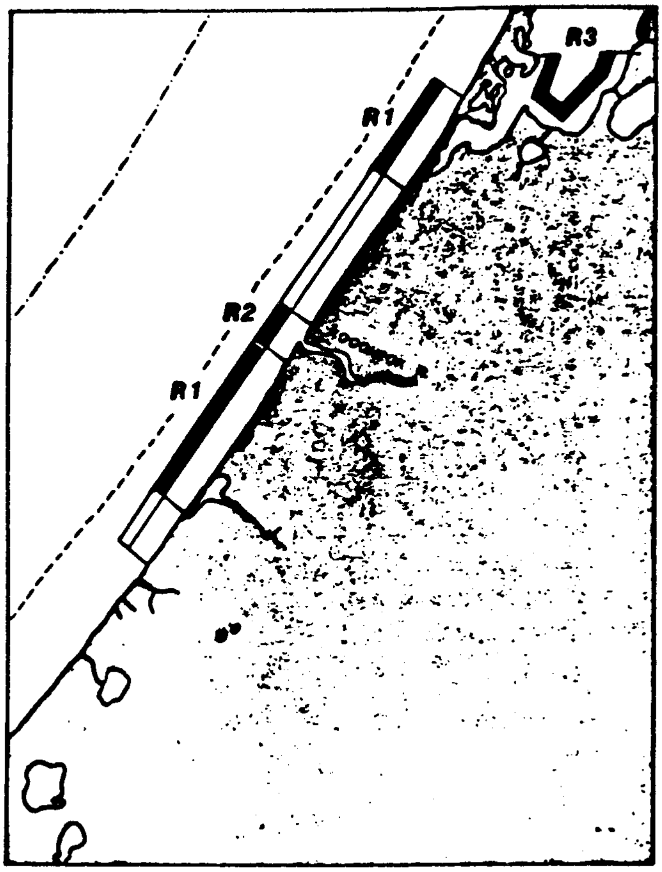
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Tidal flats; Wetland			■	■	■	■		
R2	Protected tundra cliff			▨	▨	▨	▨		
R3	Wetland; inlet; Lagoon			■	■	■	■		
R4	Tidal flat; low energy beach			■	■	■	■		
B1	Wetland			■	■	■	■	■	

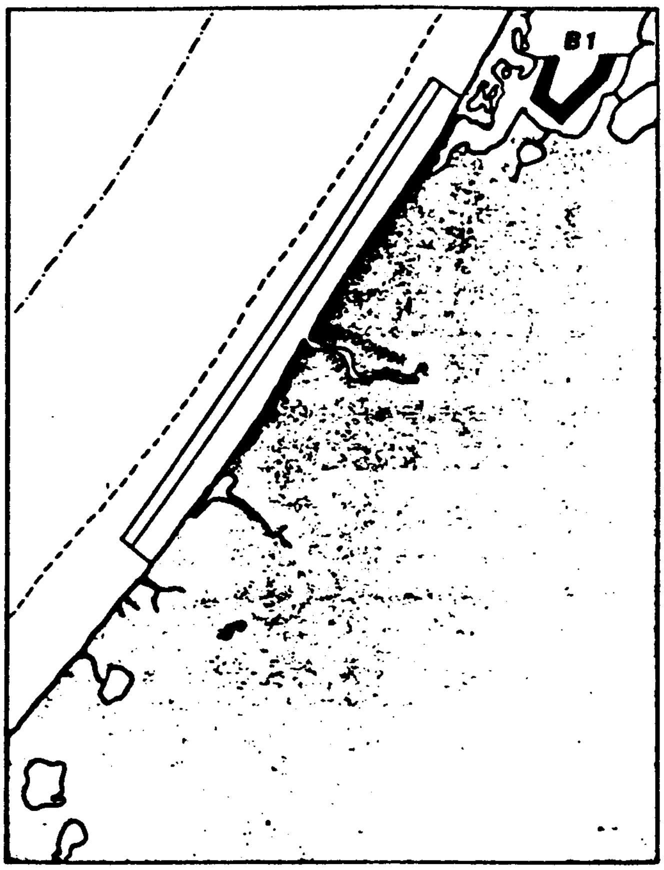
58


HGF
A
B
C
D
E
KOOCHEOK R.
B
D
59

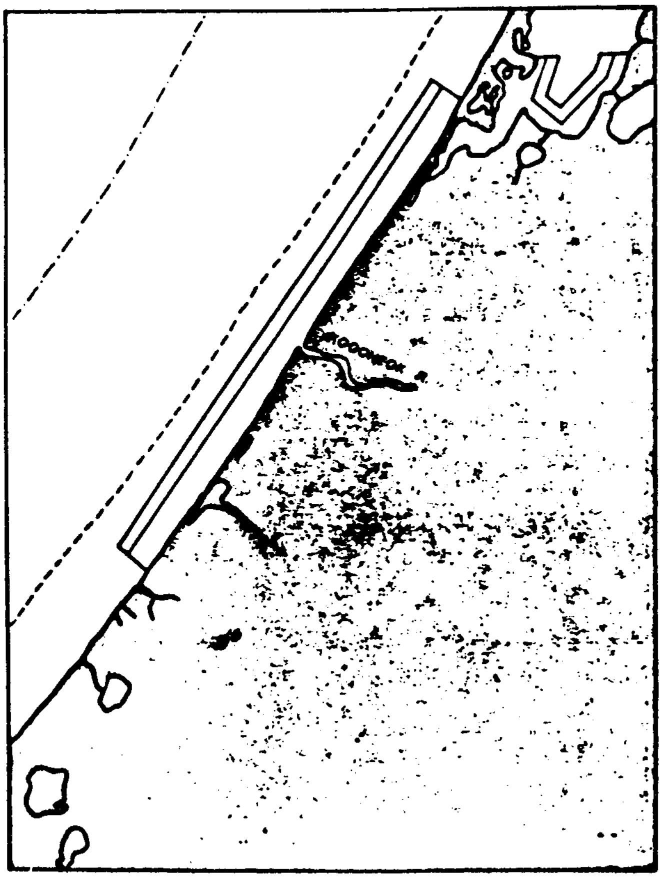
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



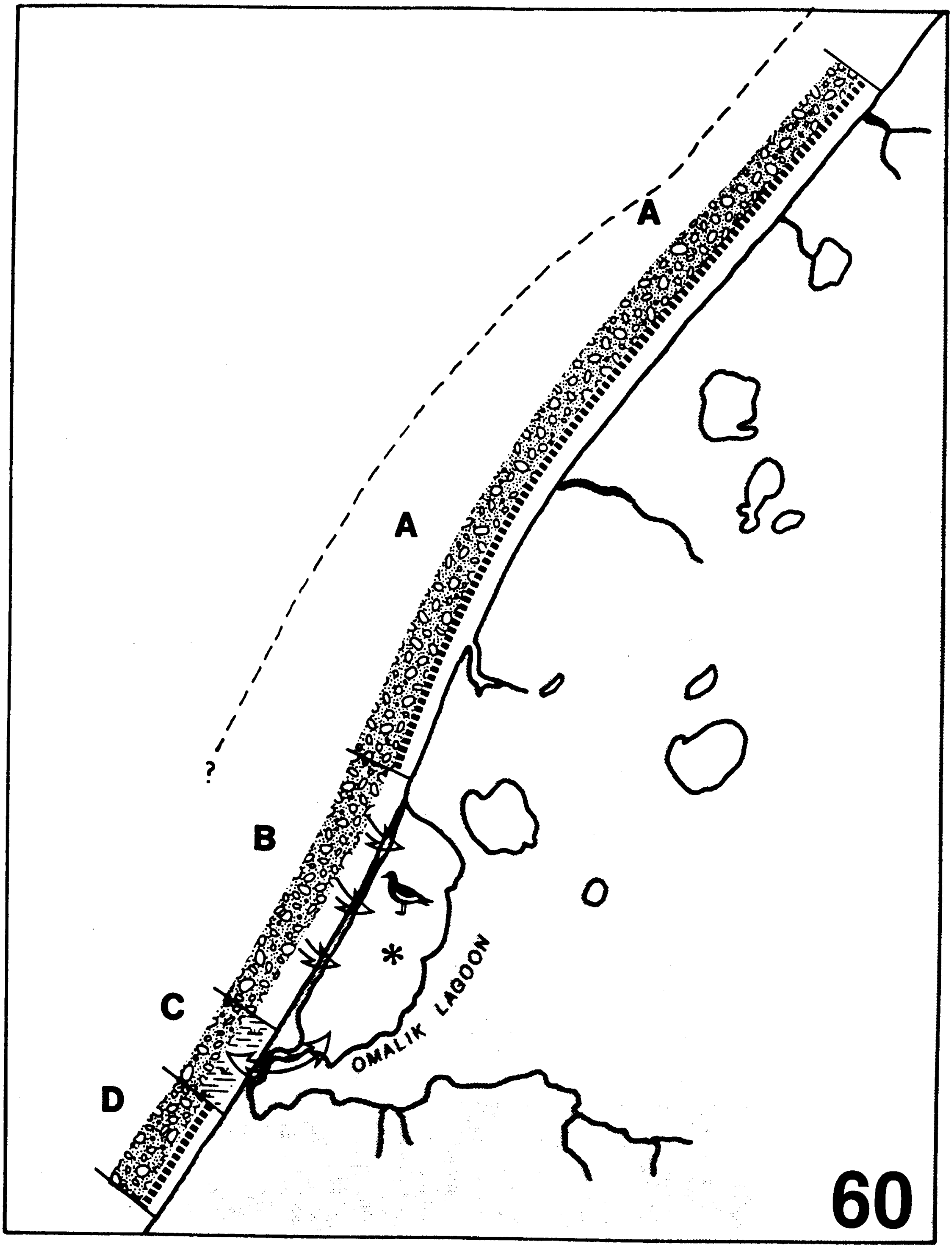
HUMAN USE INDEX

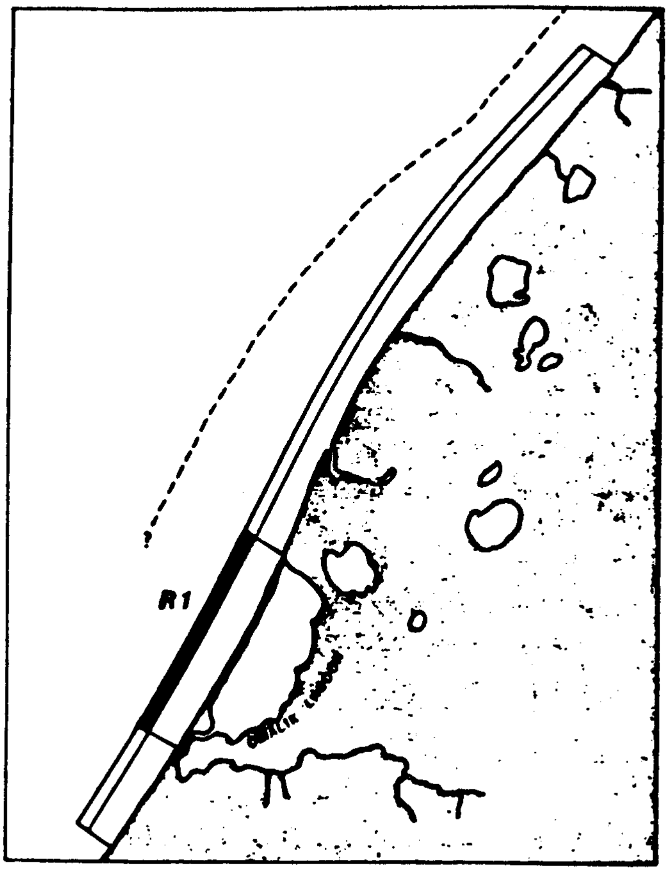


Seasonal Variability of Indices

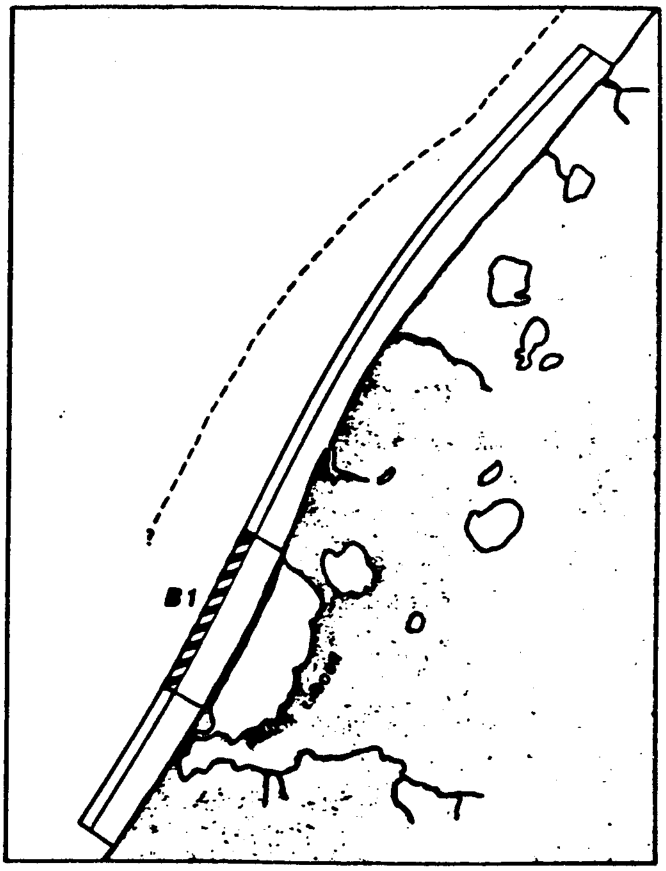
		SEASON							
Identi-fier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Washover channels; Wetland				■	■	■	■	
R2	Ephemeral inlet; Estuary				■	■	■	■	
R3	Low energy beaches; Wetlands			■	■	■	■		
B1	Wetland			■	■	■	■	■	

59

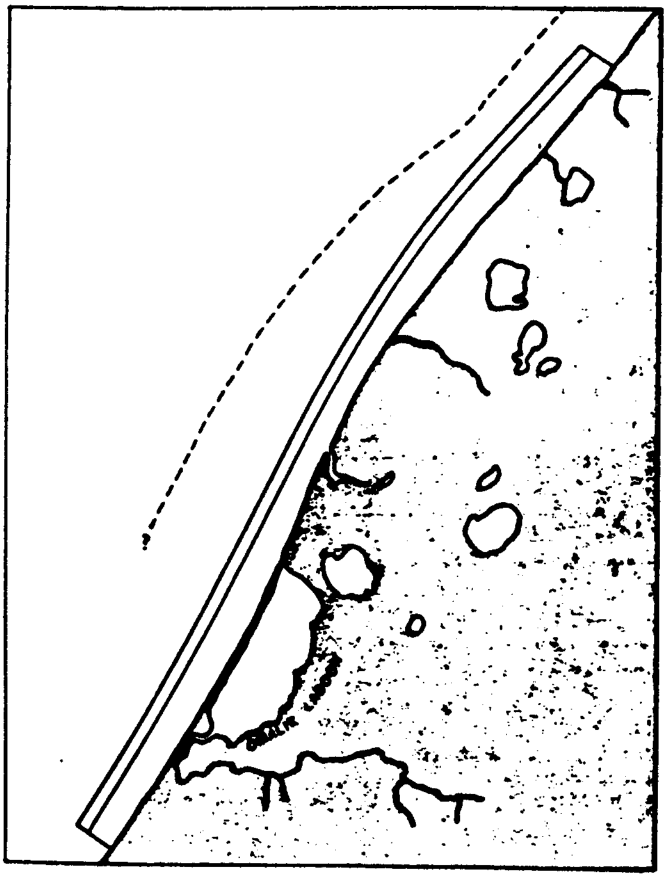

A
A
?
B
C
D
OMALIK LAGOON
*
60



OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX

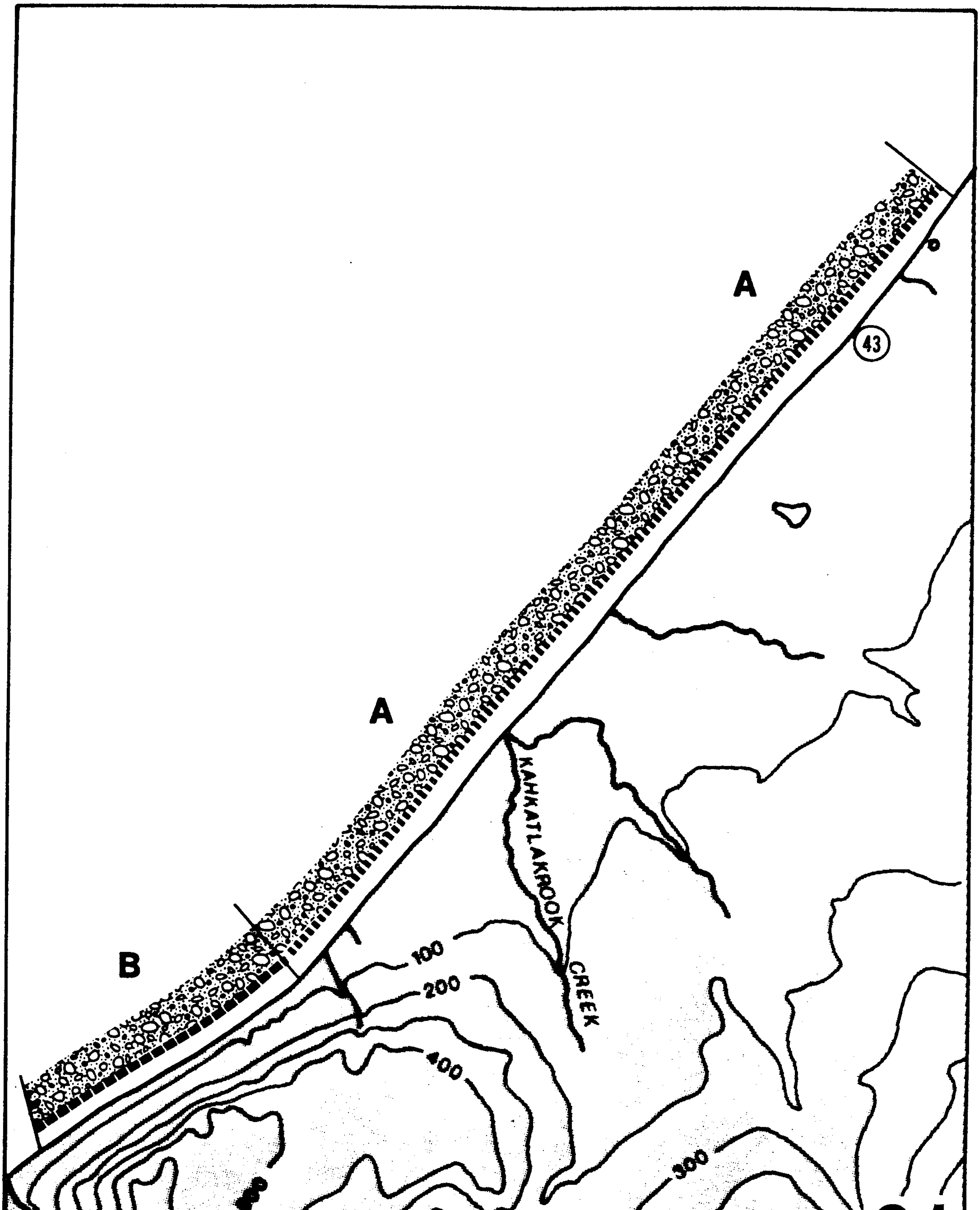


HUMAN USE INDEX

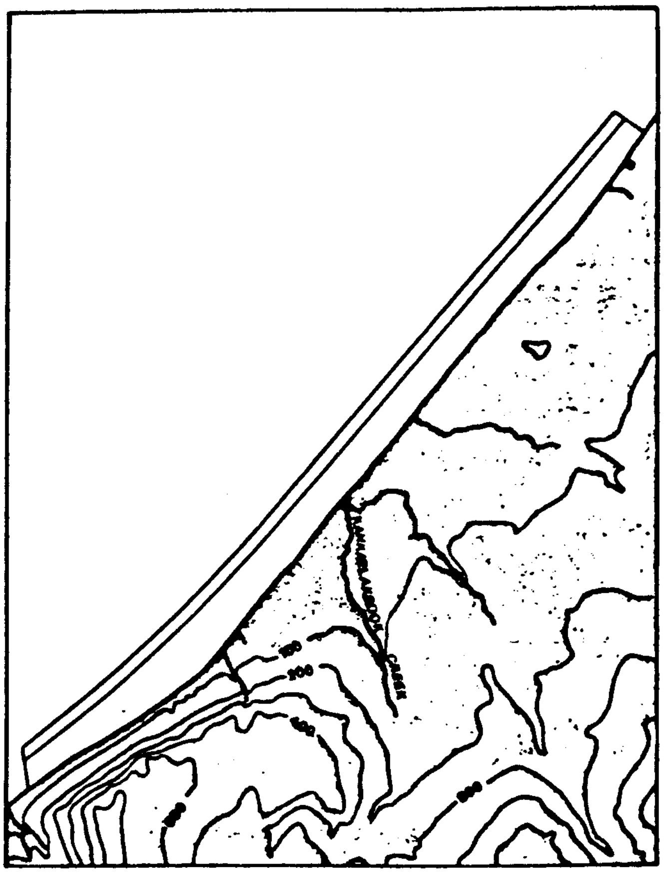
Seasonal Variability of Indices

		SEASON							
			Break-Up/Summer/Freeze-Up						
Identifier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Washover channels; inlet; lagoon				■	■	■	■	
B1	Lagoon and wetland			▨	▨	▨	▨	▨	
	Arctic tern (10 pr) nesting			▨	▨				

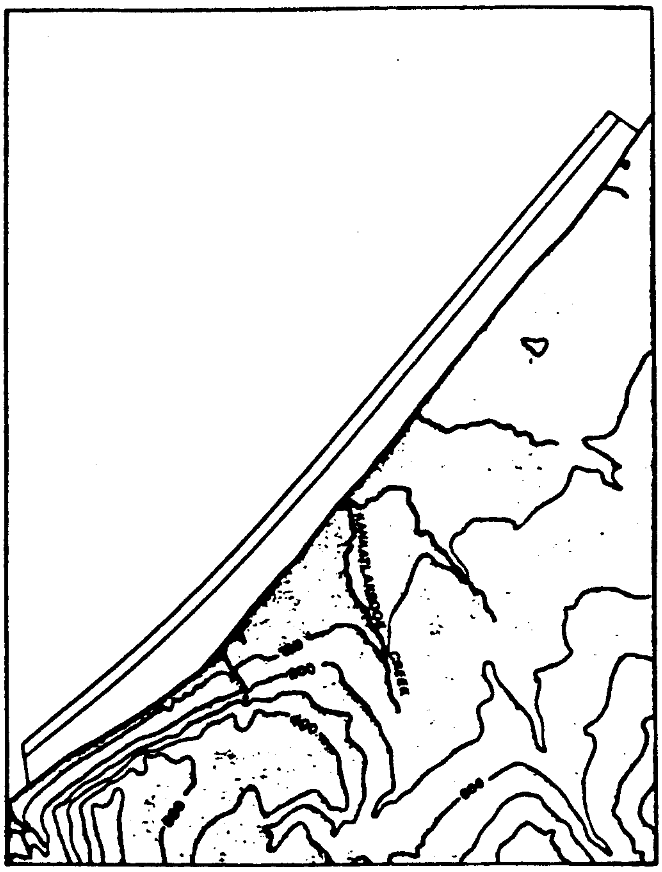
60


A
A
B
43
KAHKATLAKROOK
CREEK
100
200
400
300
800
61

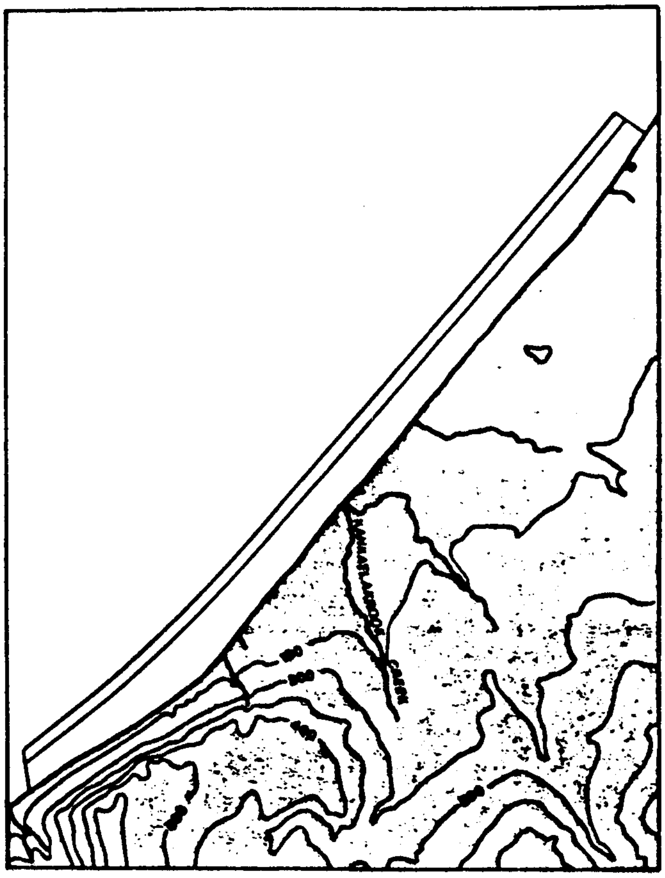
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



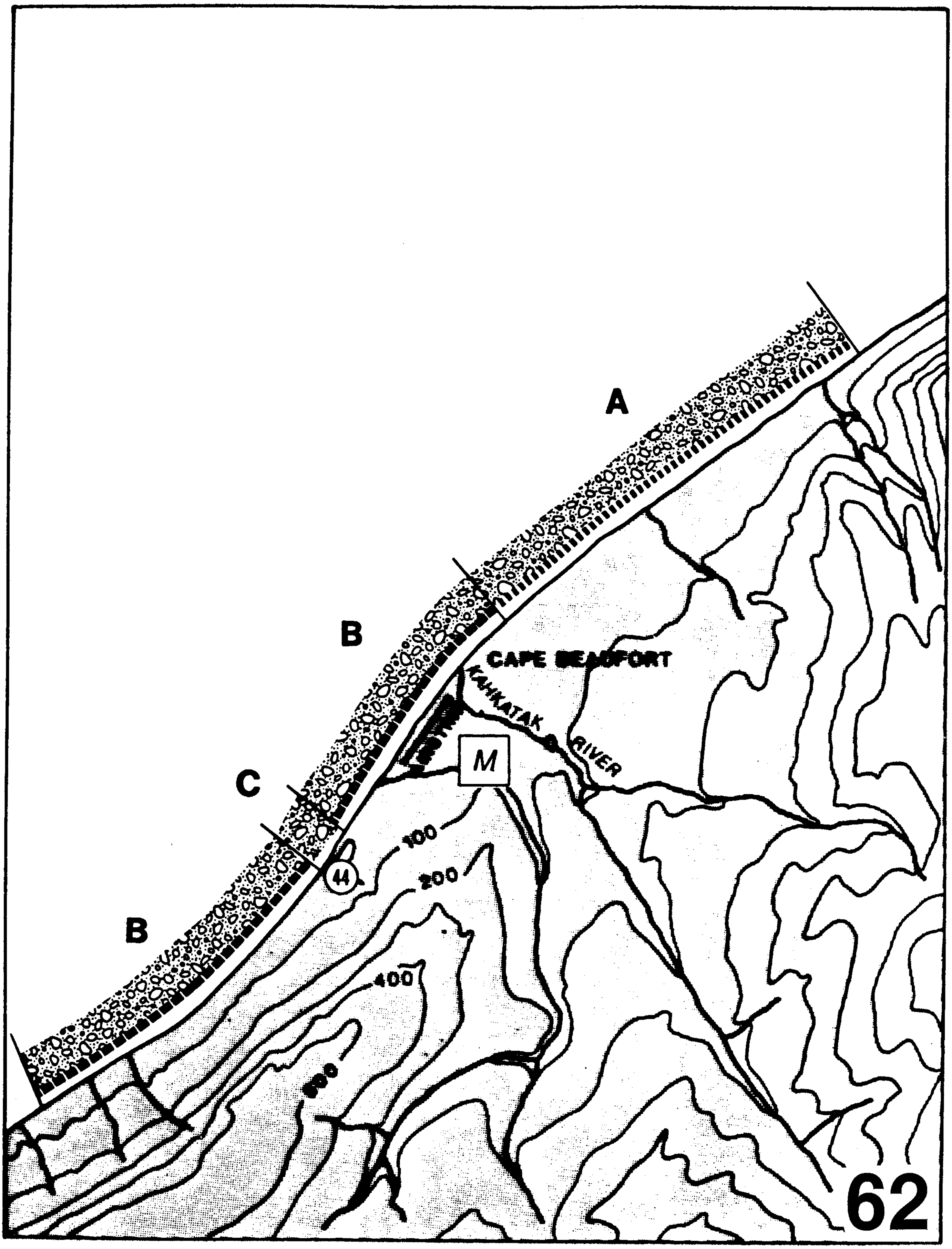
HUMAN USE INDEX



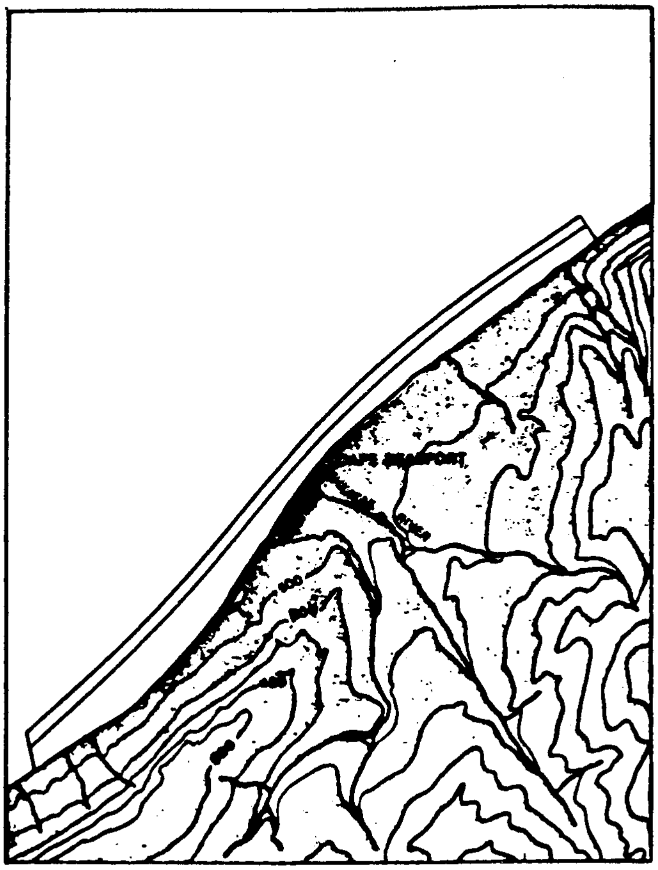
Seasonal Variability of Indices

		SEASON							
			Break-Up/Summer/Freeze-Up						
Identi-fier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
	NO PRIMARY OR SECONDARY SENSITIVITIES								

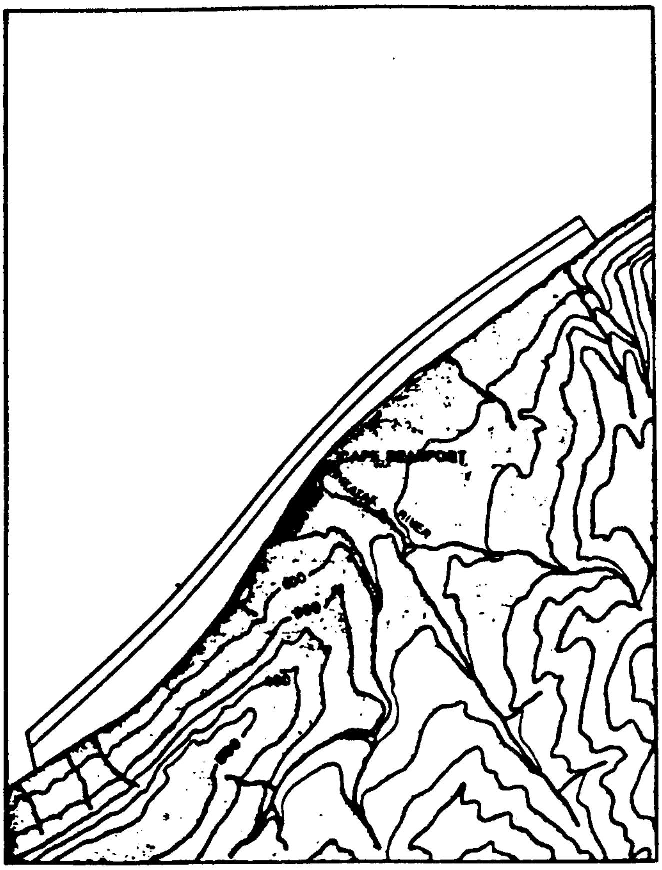
61


A
B
C
B
CAPE BEAUFORT
KAHKATAK R. RIVER
M
44
100
200
400
600
62

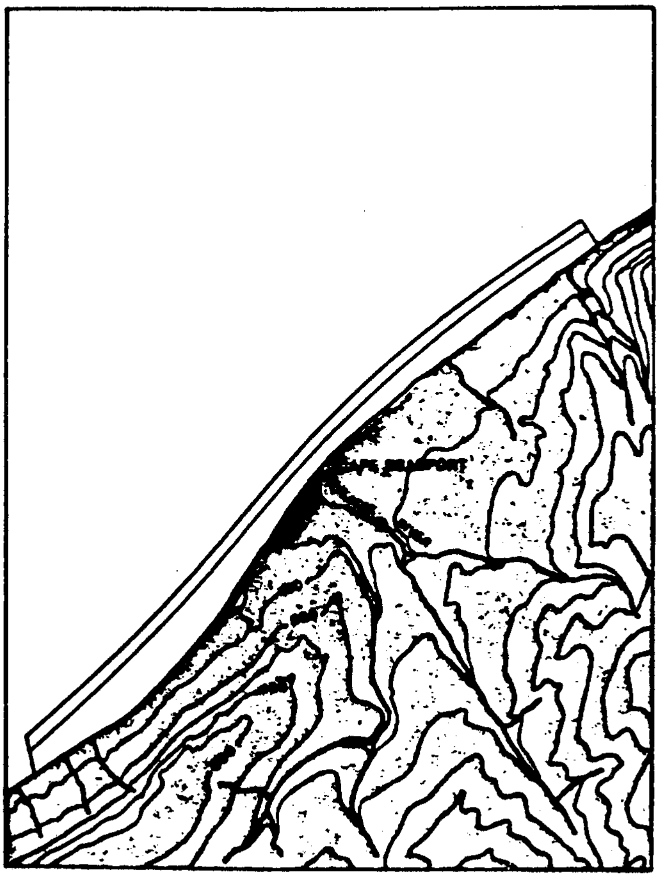
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



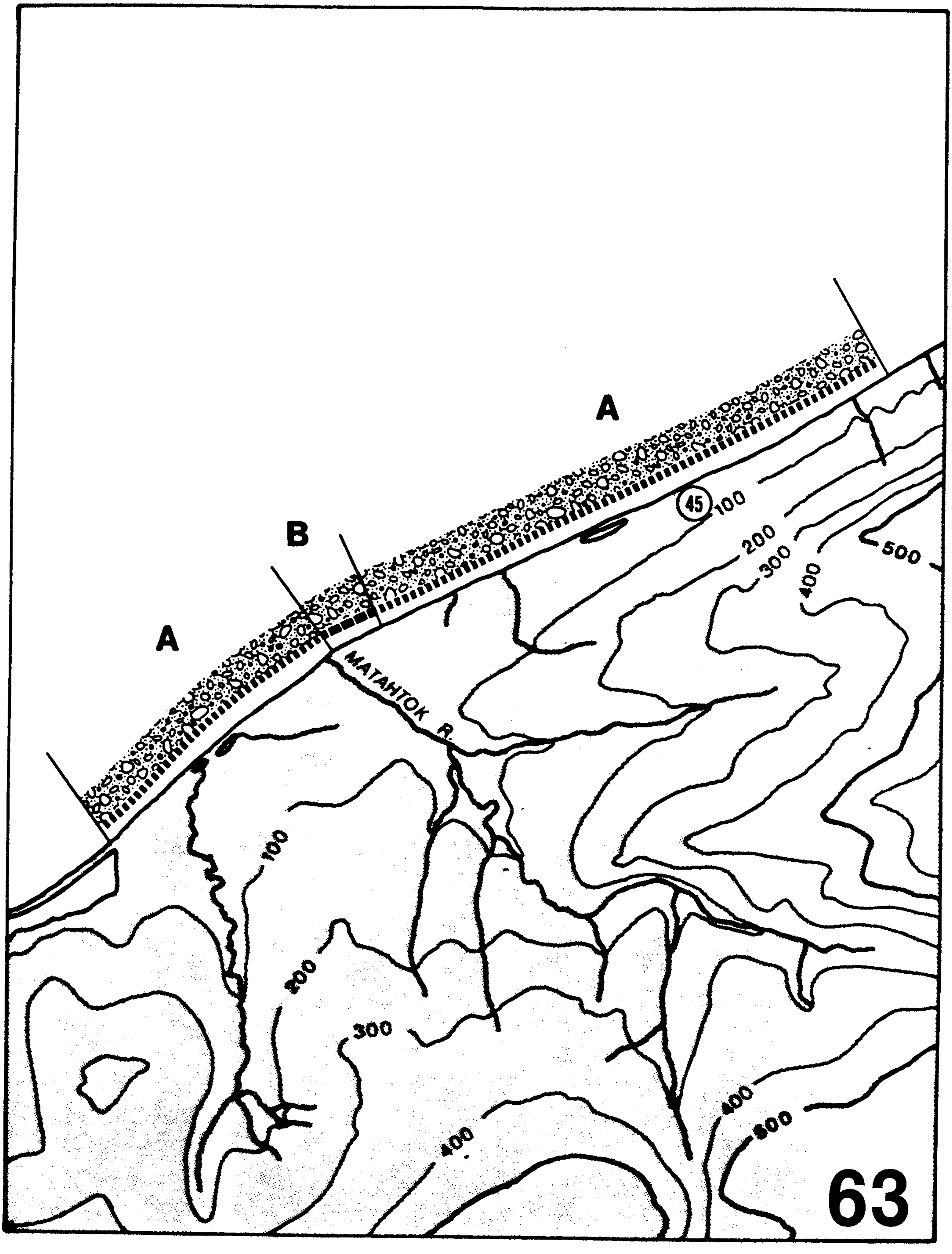
HUMAN USE INDEX



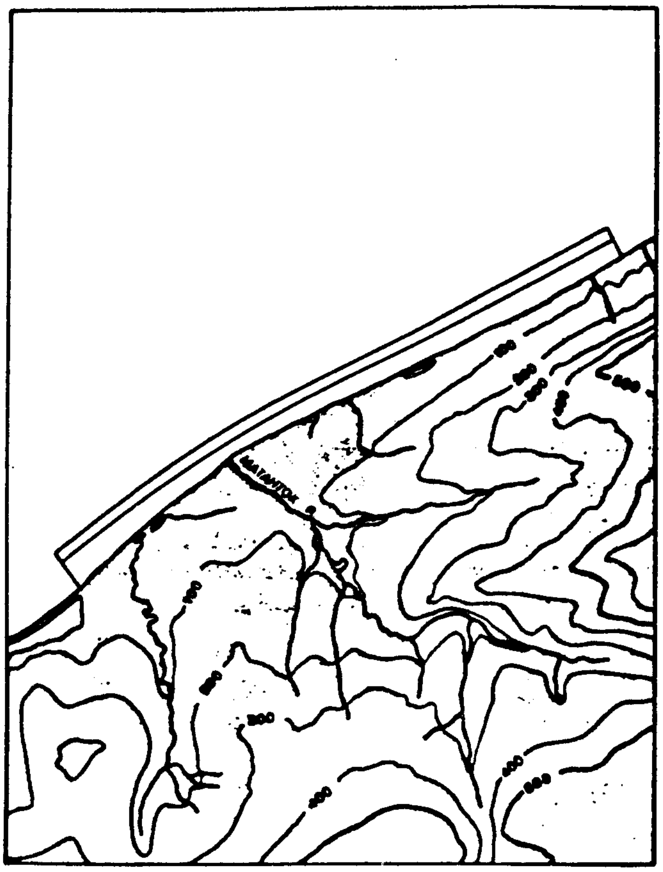
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
	NO PRIMARY OR SECONDARY SENSITIVITIES								

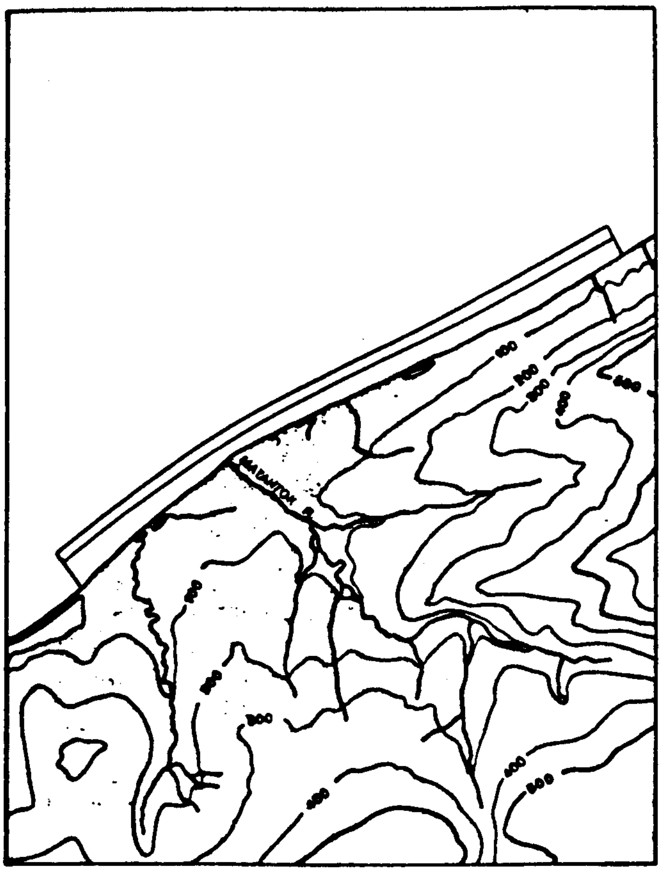
62


A
B
A
45
100
200
300
400
500
MATAHTOK R.
100
200
300
400
400
500
63

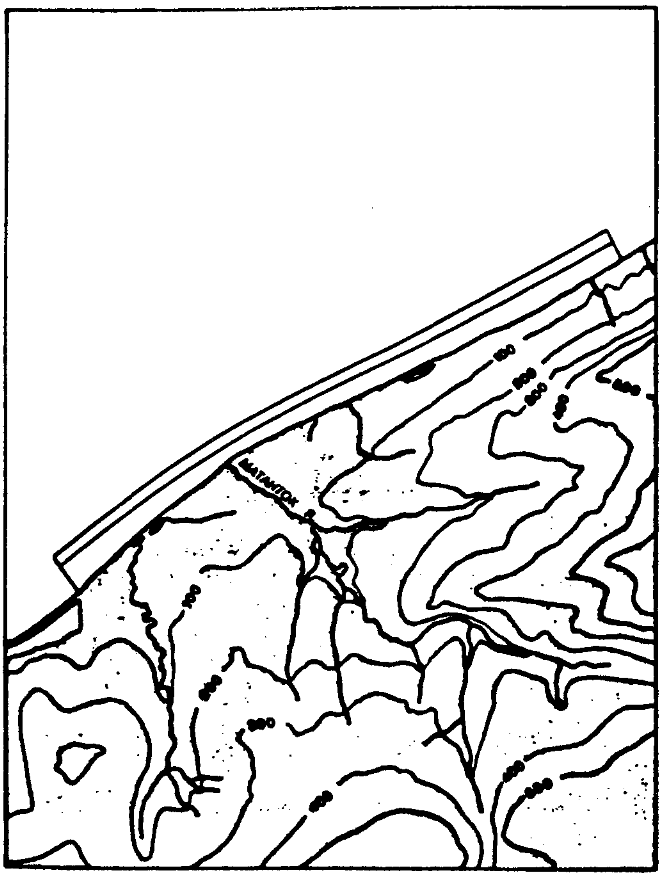
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



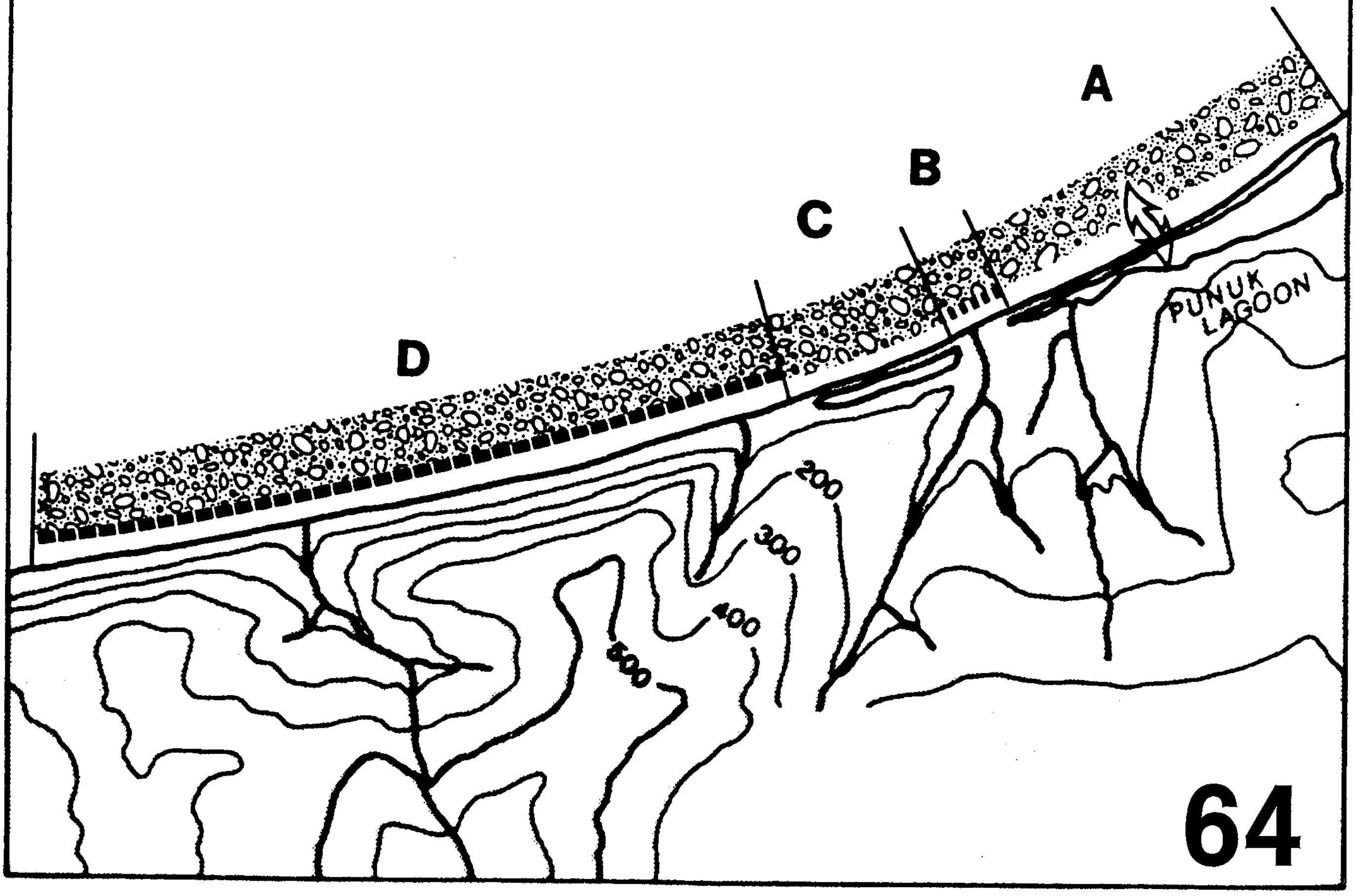
HUMAN USE INDEX



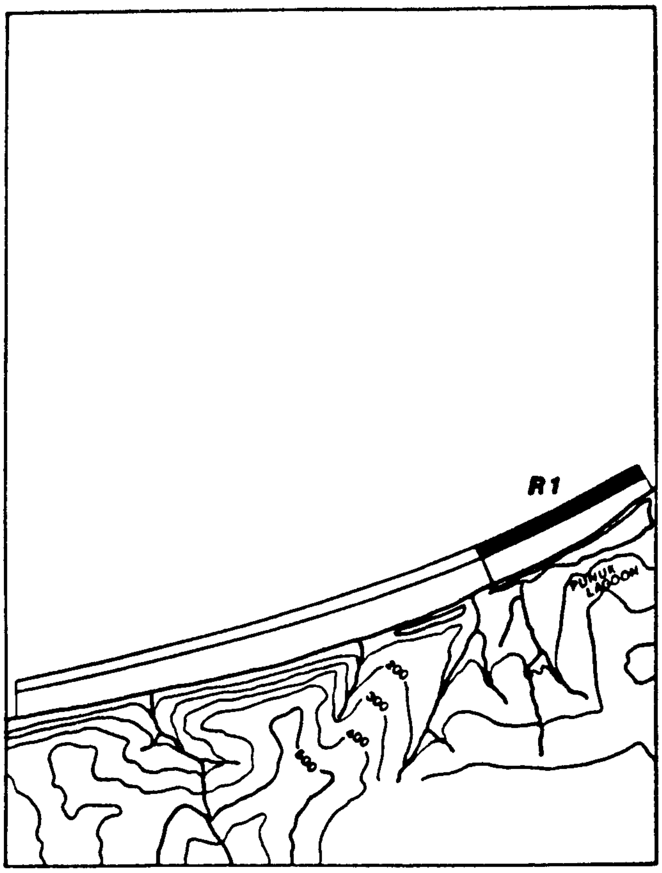
Seasonal Variability of Indices

		SEASON							
Identi-fier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
	NO PRIMARY OR SECONDARY SENSITIVITIES								

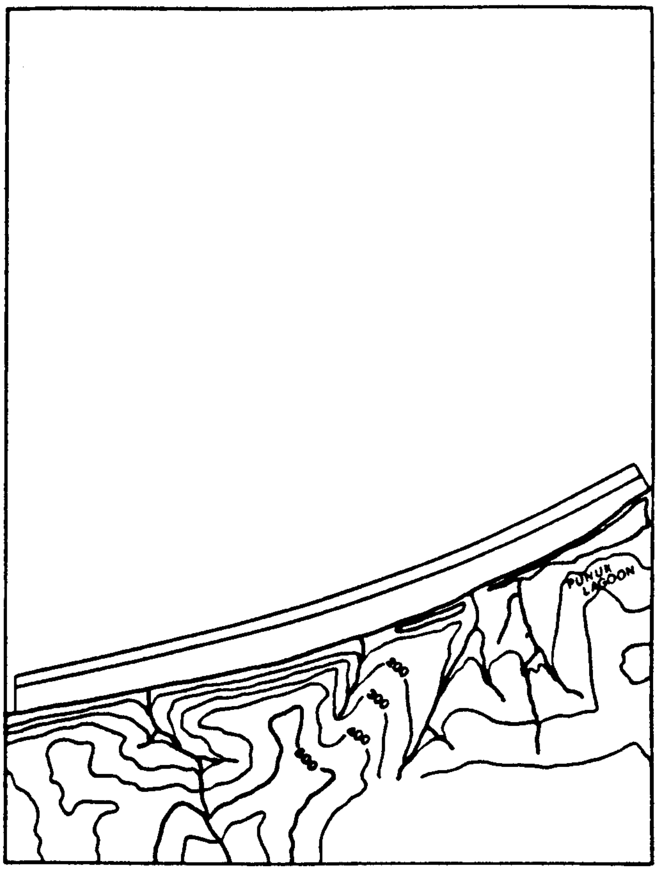
63


A
B
C
D
PUNUK LAGOON
200
300
400
500
64

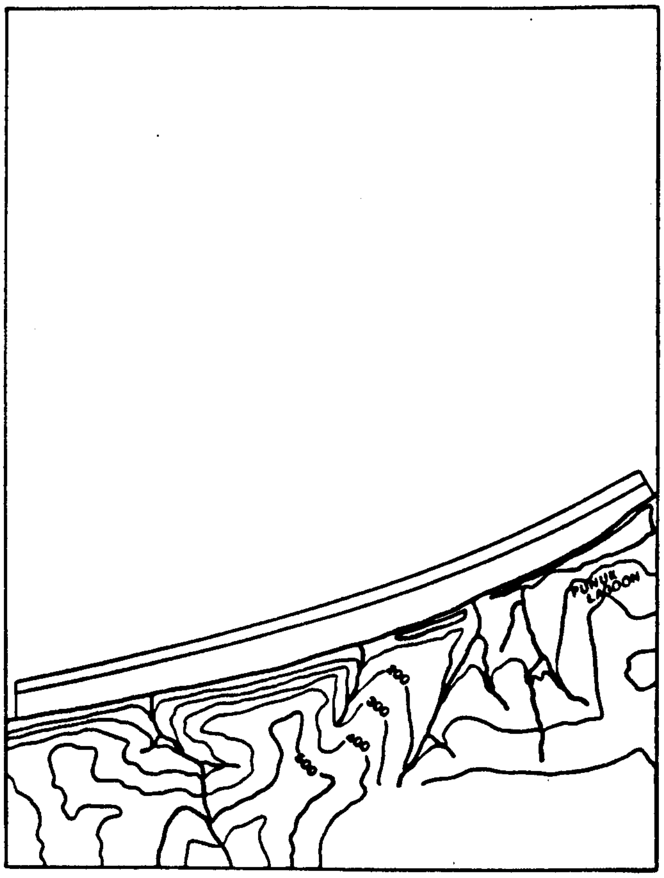
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



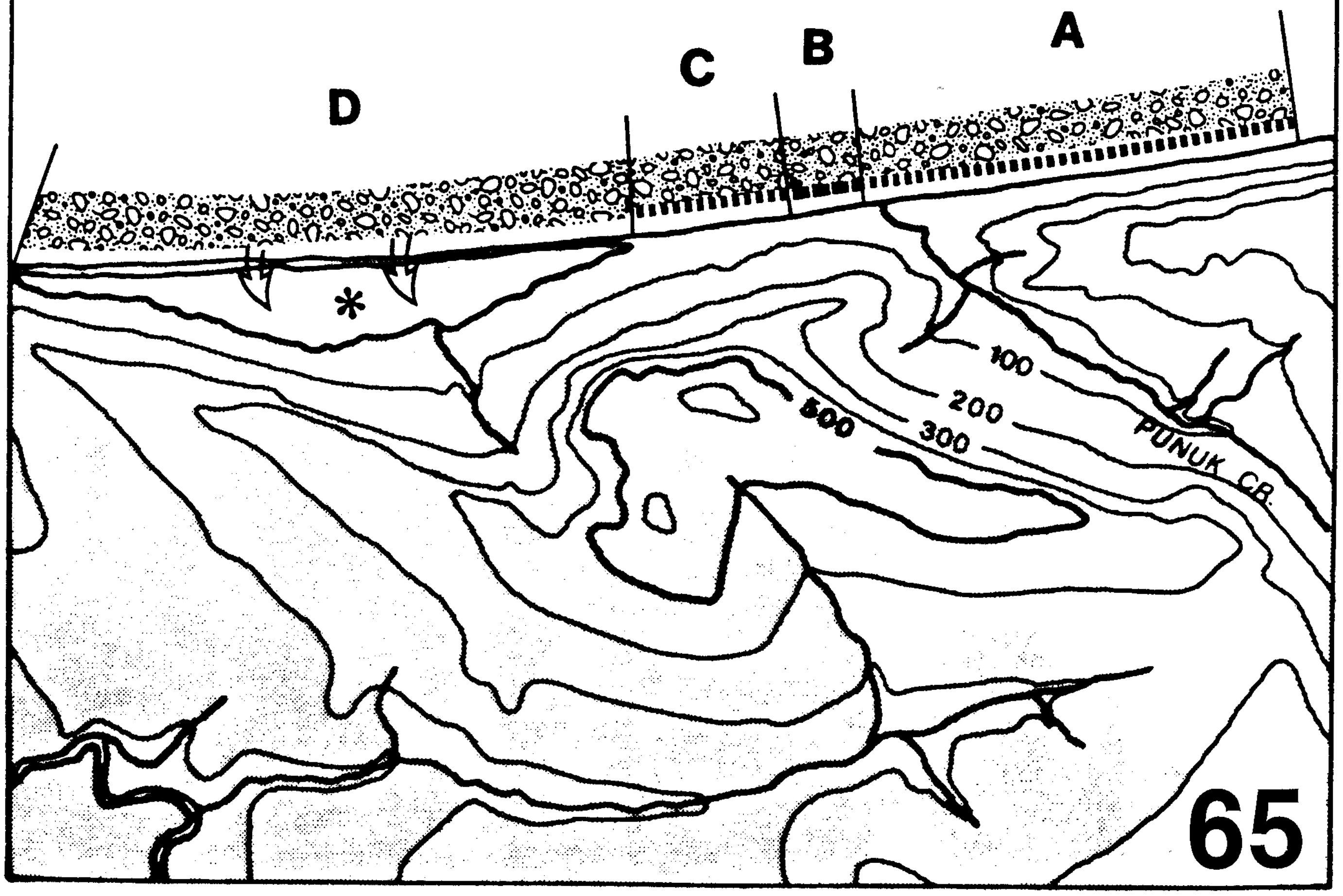
HUMAN USE INDEX



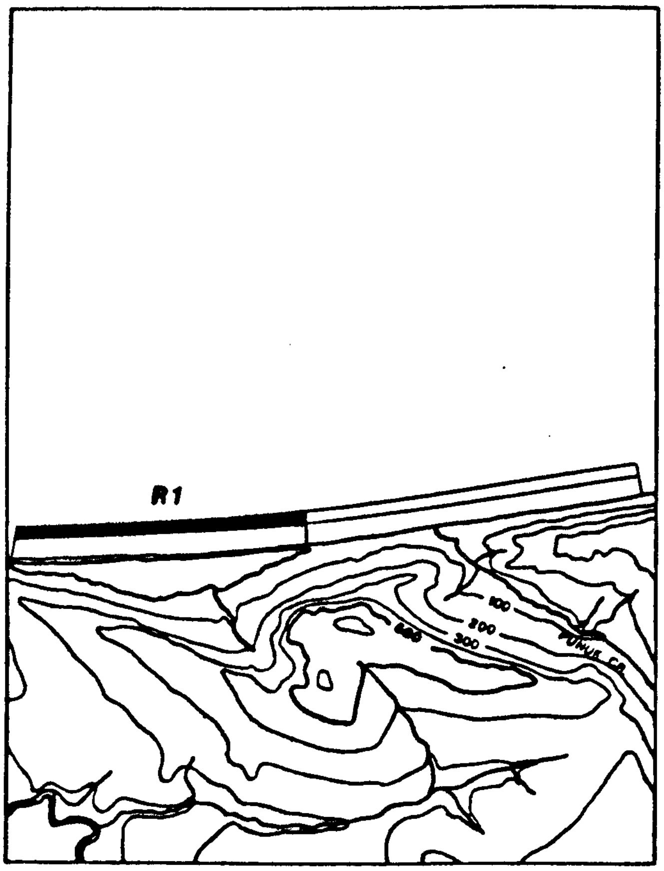
Seasonal Variability of Indices

		SEASON							
Identi-fier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Ephemeral inlet; Lagoon				■	■	■	■	

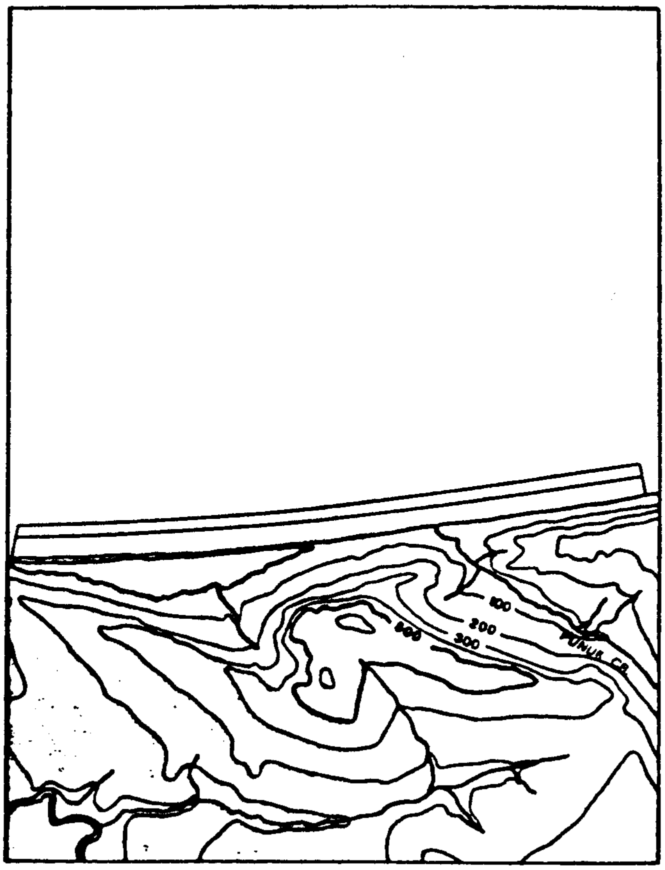
64


A
B
C
D
*
100
200
300
500
PUNUK CR.
65

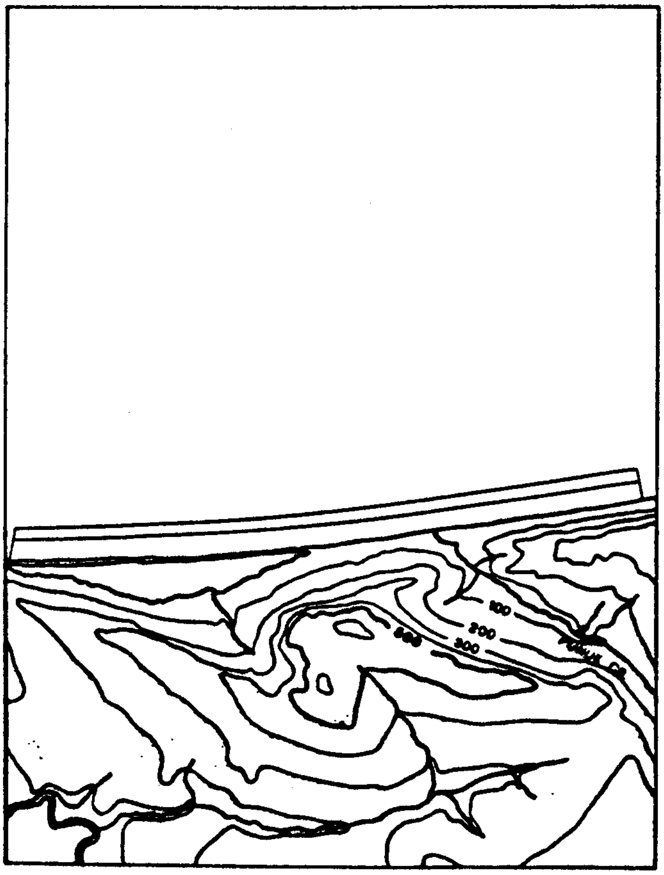
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



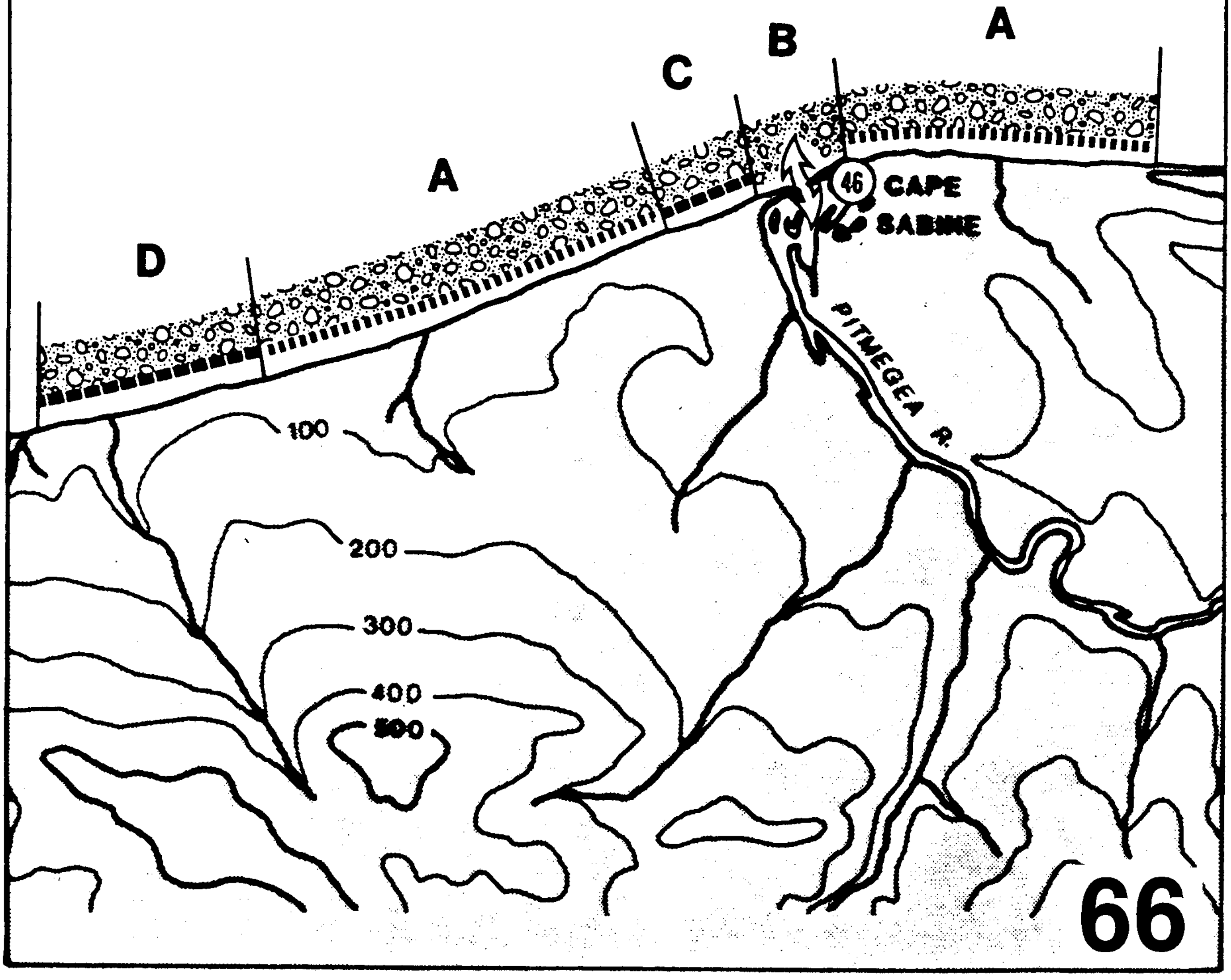
HUMAN USE INDEX



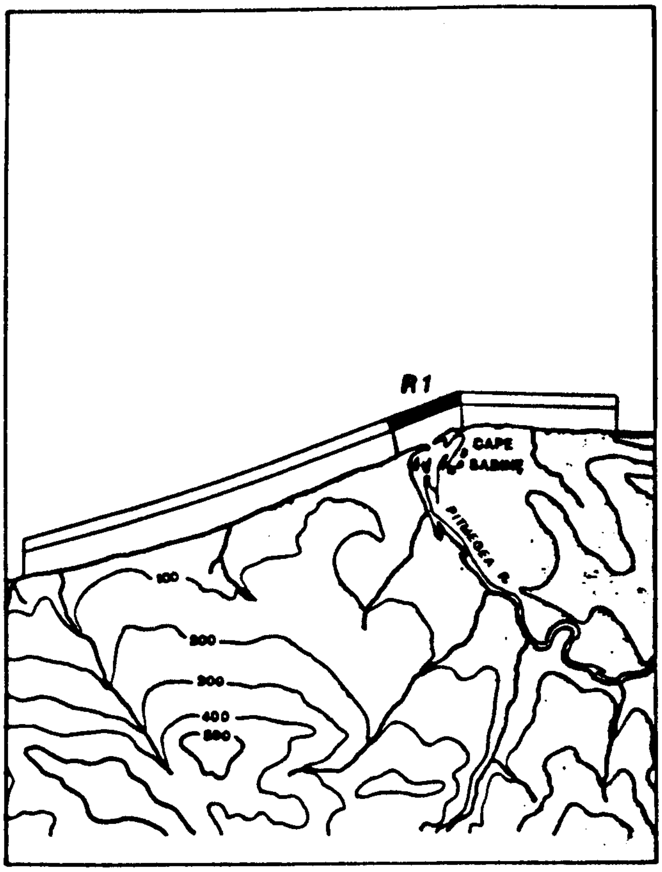
Seasonal Variability of Indices

		SEASON							
			Break-Up/Summer/Freeze-Up						
Identifier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Washover channels; Lagoon				■	■	■	■	

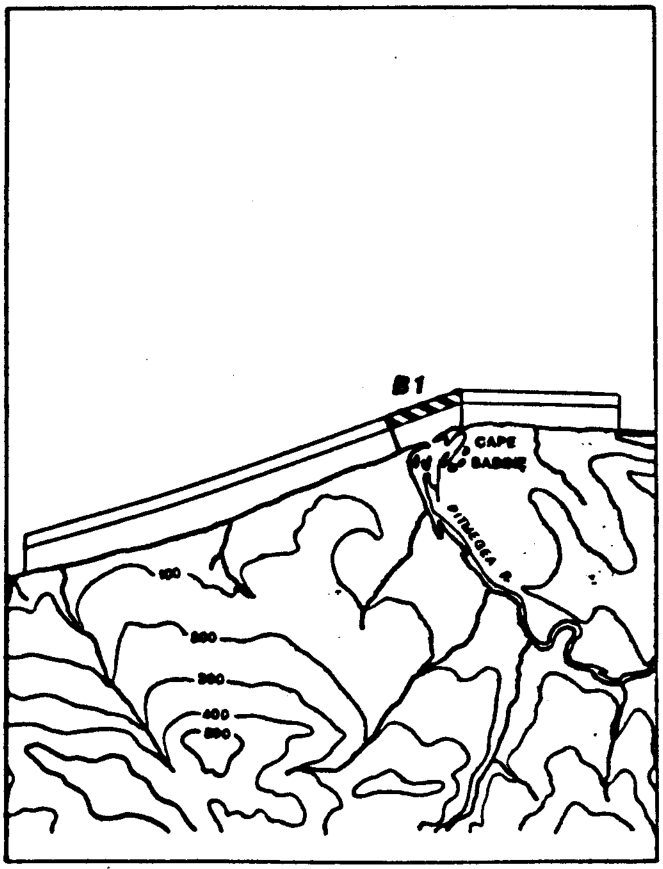
65


A
B
C
A
D
46
CAPE
SABINE
PITMEGEA R.
100
200
300
400
500
66

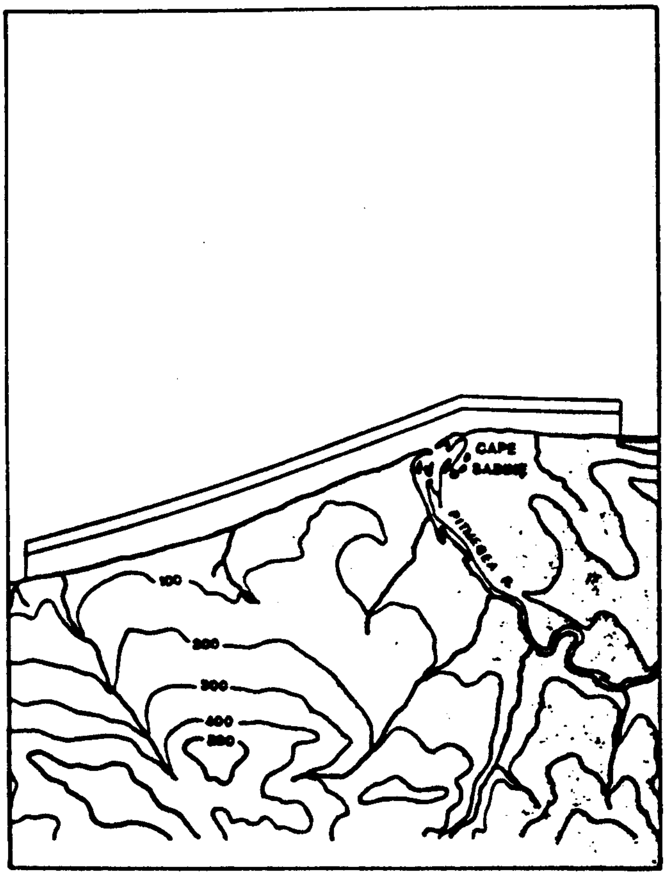
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



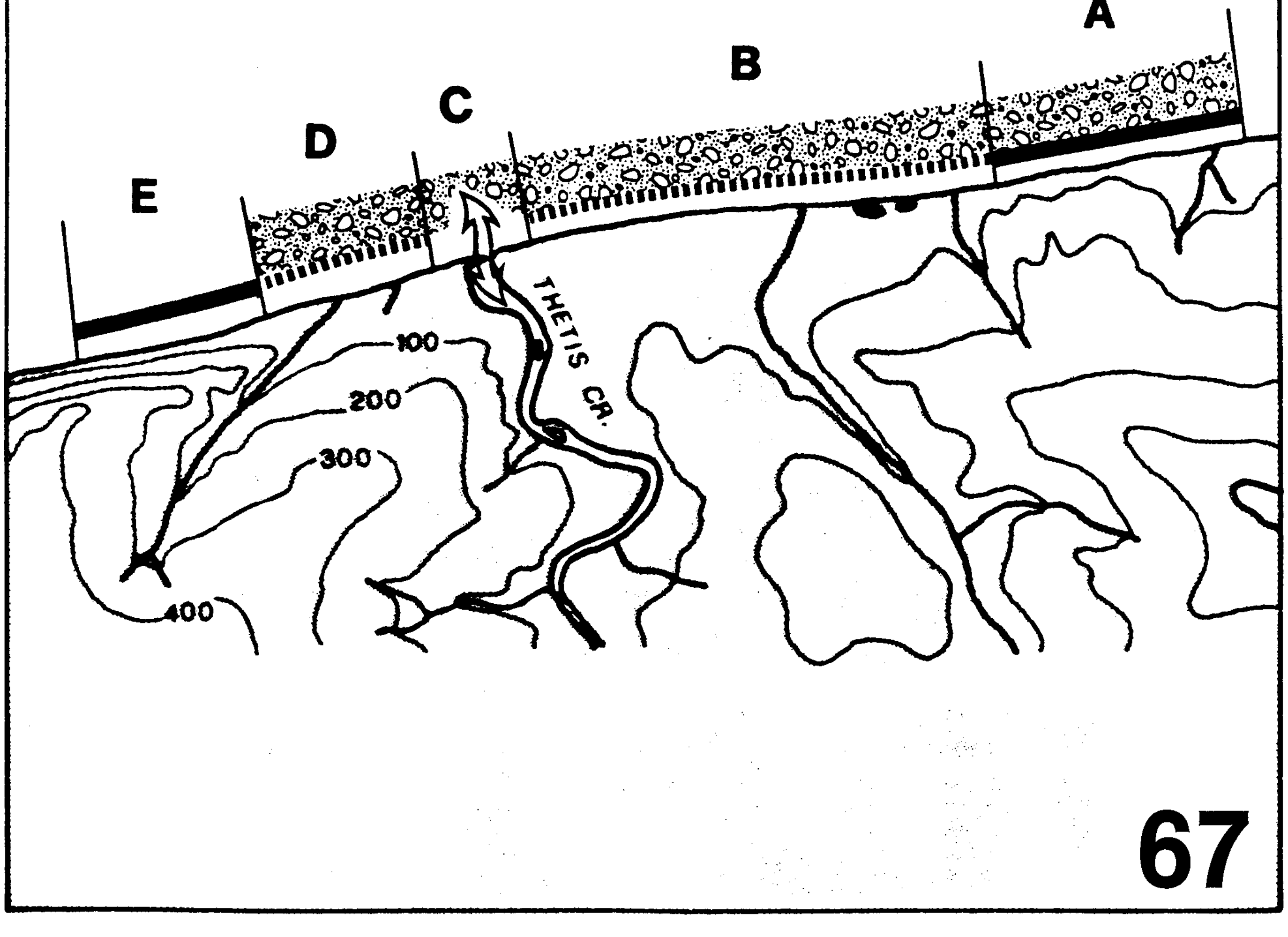
HUMAN USE INDEX



Seasonal Variability of Indices

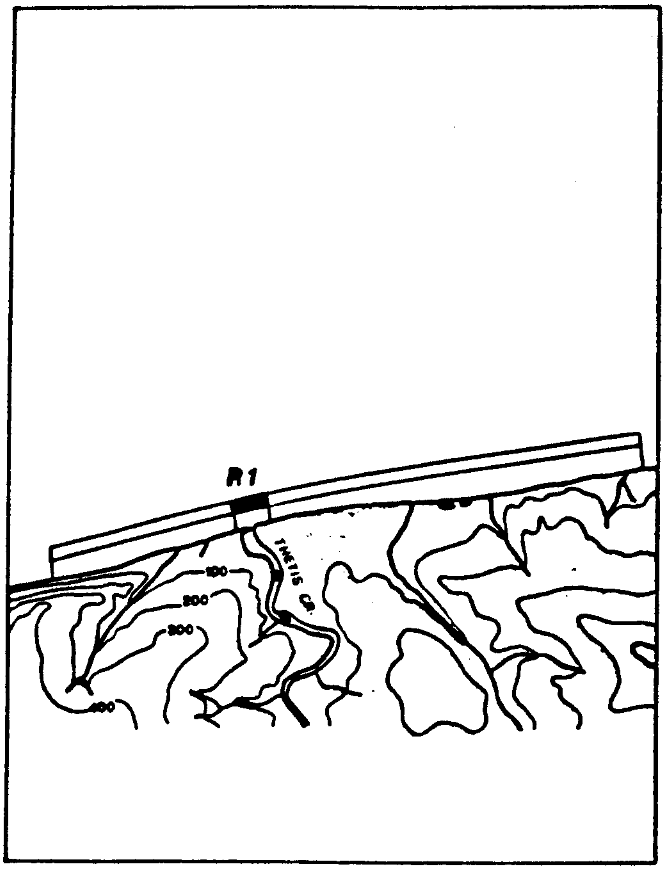
		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Ephemeral inlet; Estuary				▬	▬	▬	▬	
B1	Estuary			▨	▨	▨	▨	▨	

66

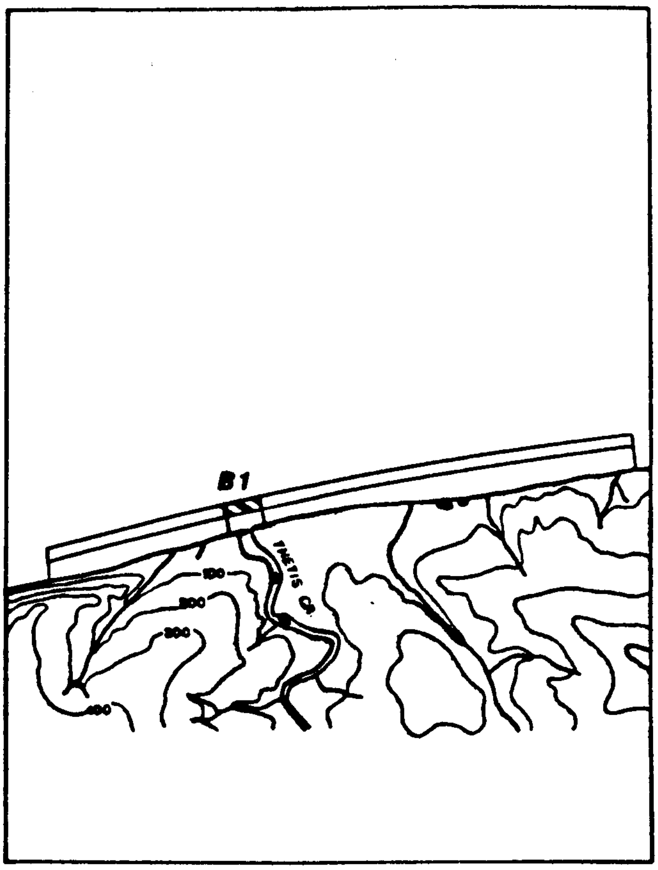


67

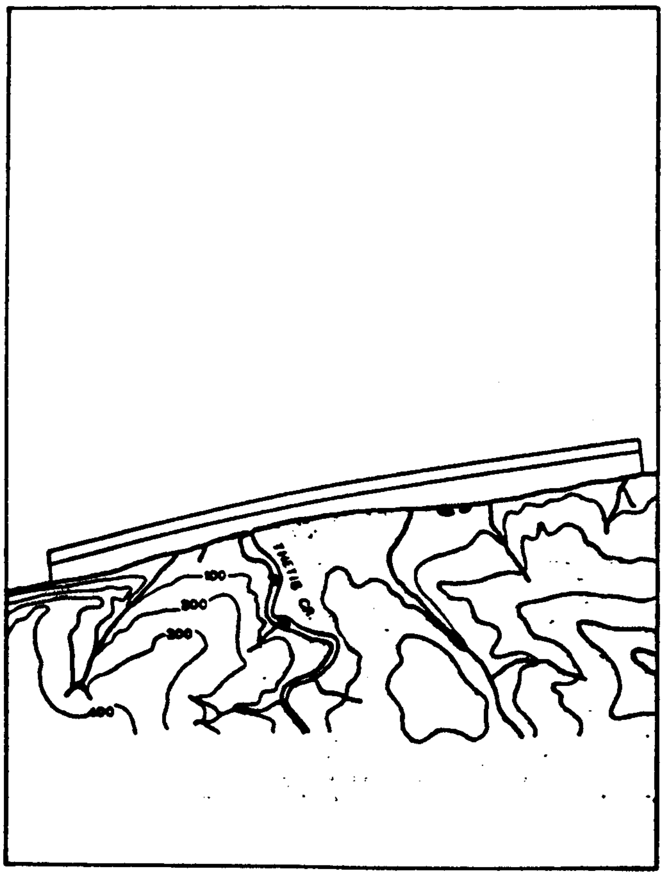
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



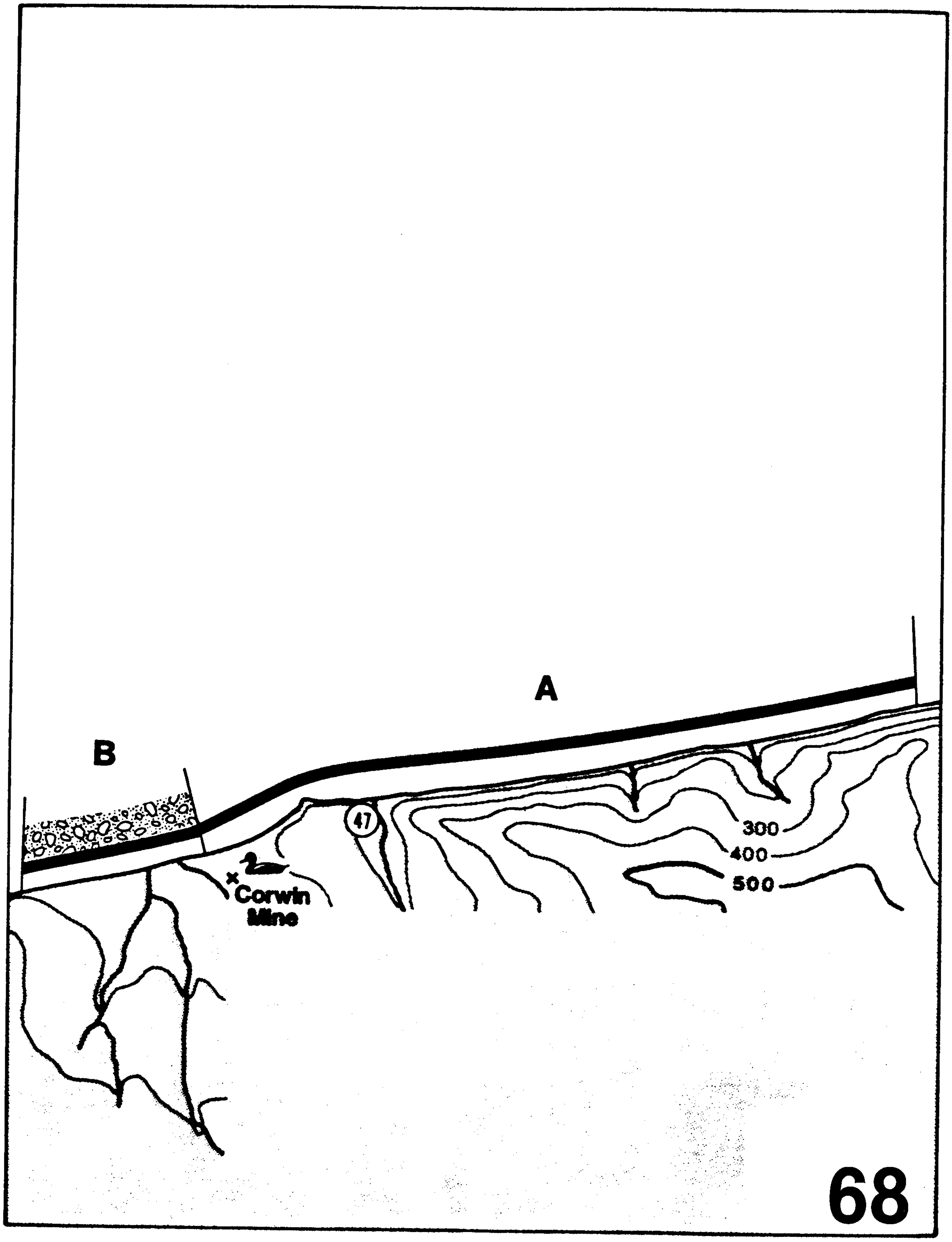
HUMAN USE INDEX



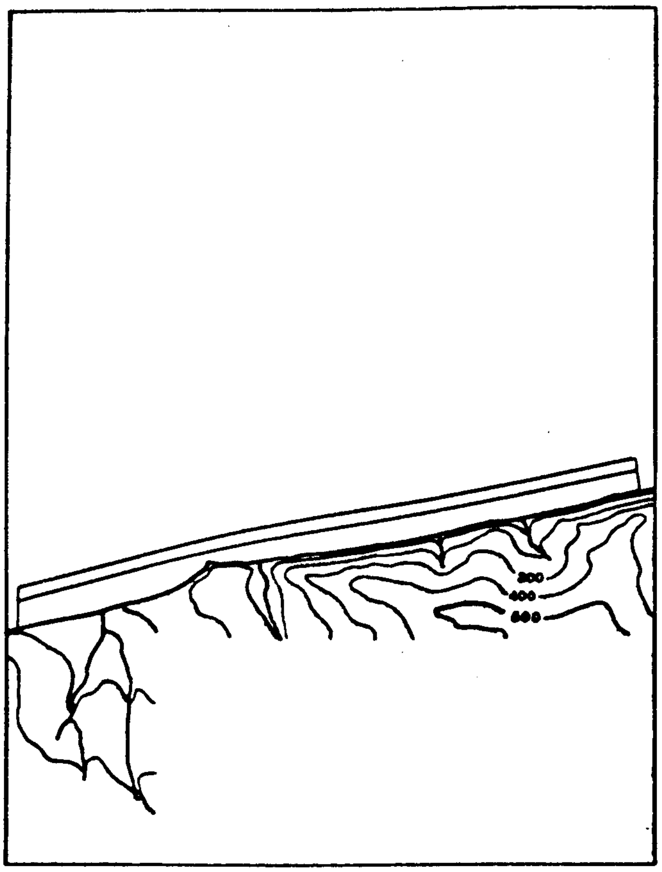
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Ephemeral inlet; Estuary				■	■	■	■	
B1	Estuary			▨	▨	▨	▨	▨	

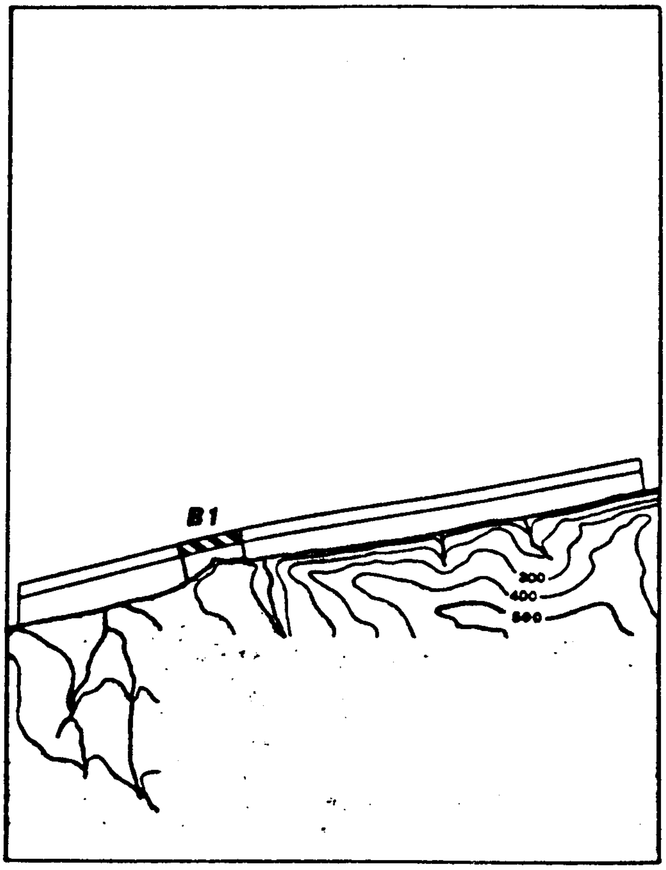
67


A
B
47
300
400
500
× Corwin Mine
68

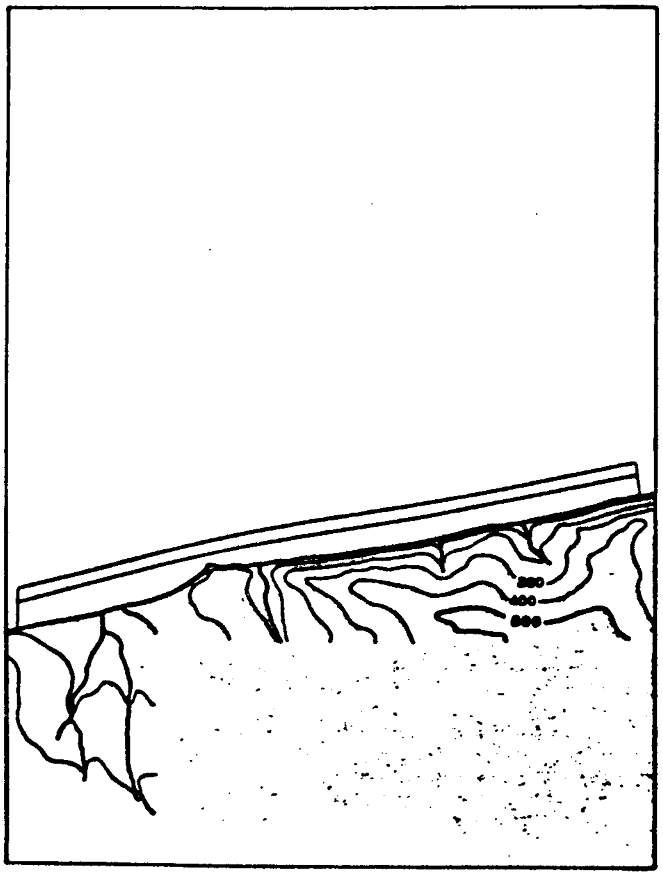
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



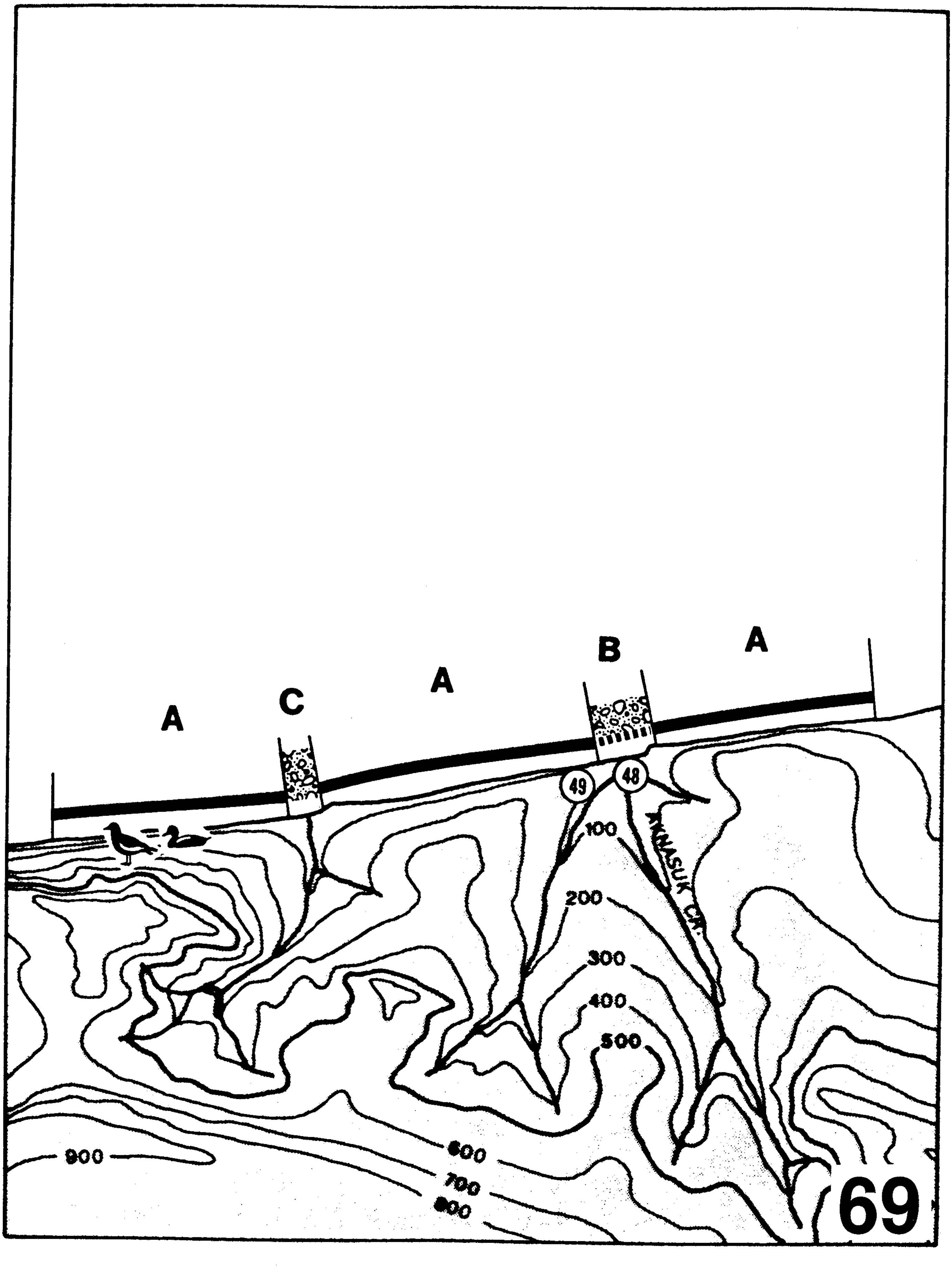
HUMAN USE INDEX



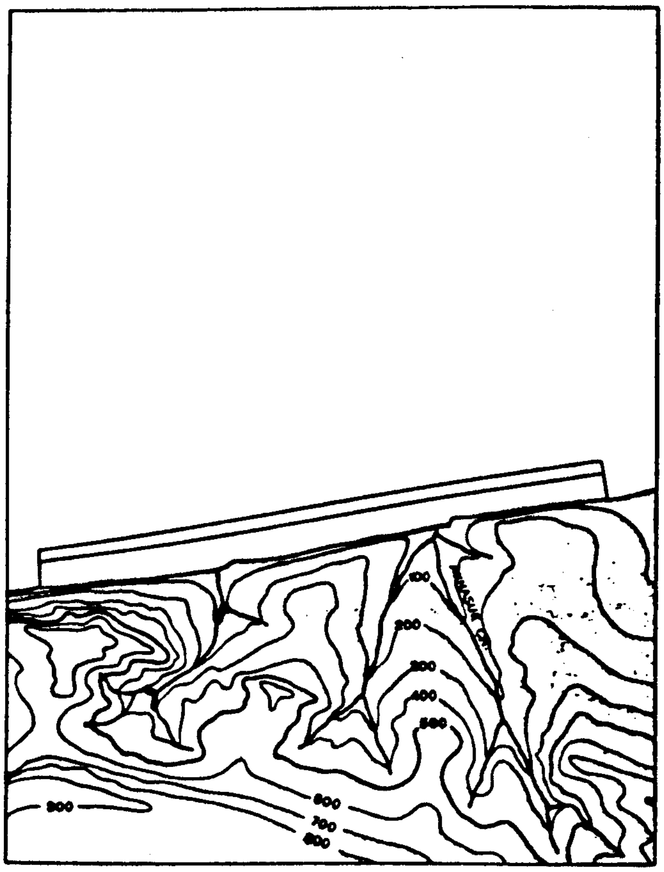
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
B1	Seabird colony; cormorants (33 pr), tufted puffin (3 pr)		▨	▨	▨	▨	▨		

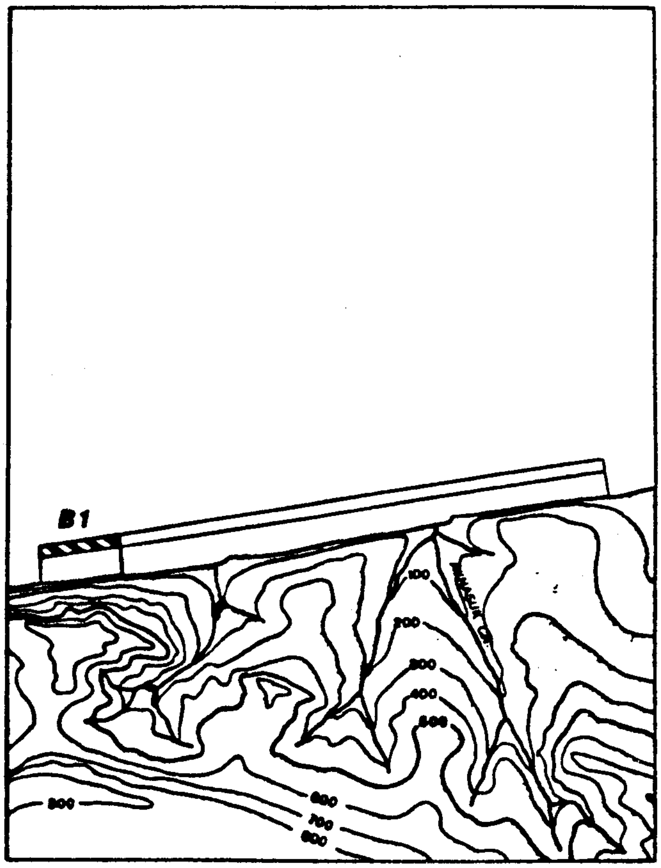
68


A
C
A
B
A
49
48
100
200
300
400
500
600
700
800
900
AYNASUK CR.
69

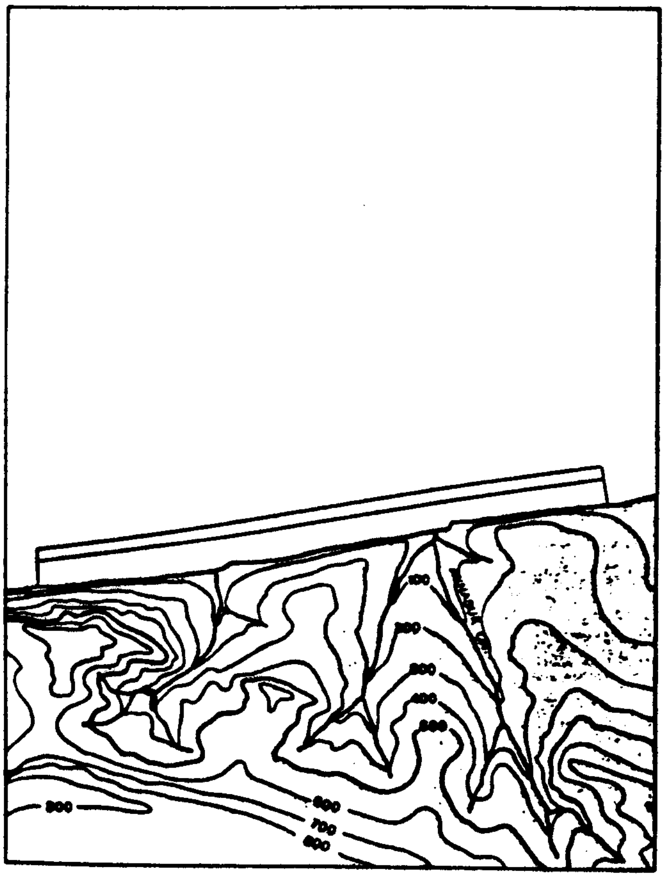
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



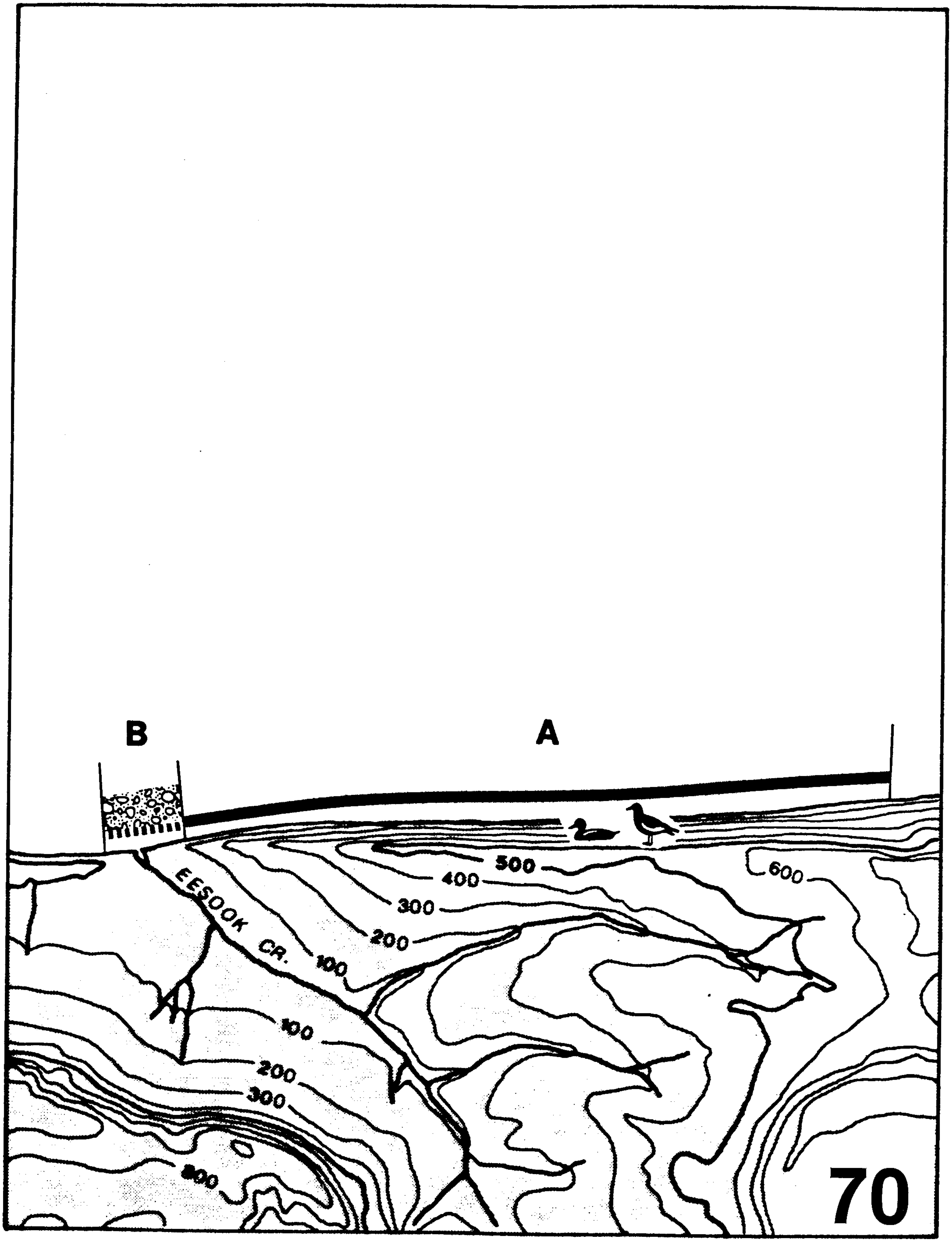
HUMAN USE INDEX

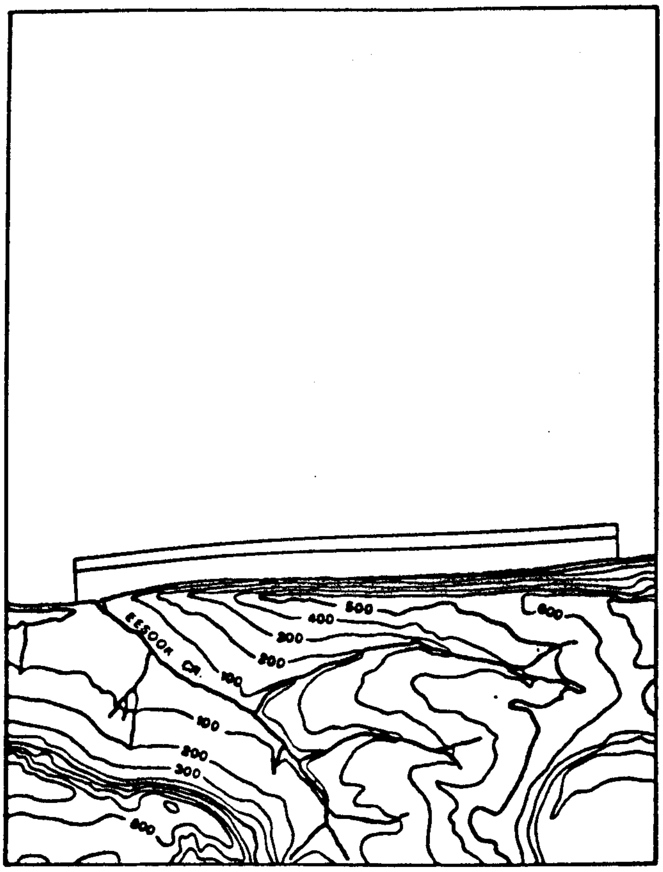


Seasonal Variability of Indices

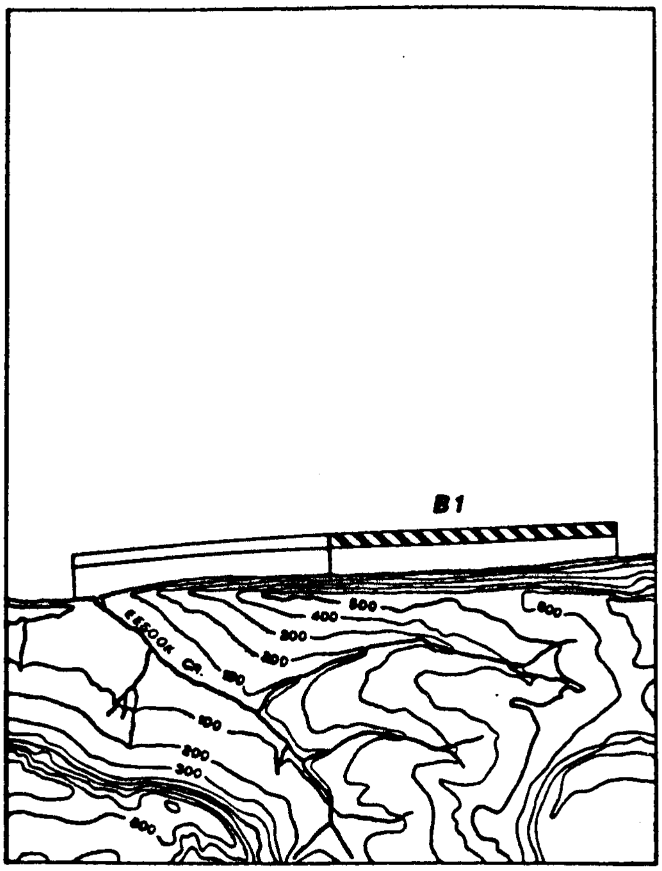
Identi-fier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
B1	Seabird colony; gulls (40 pr), black guillemot (9 pr)		▨	▨	▨	▨	▨		

69

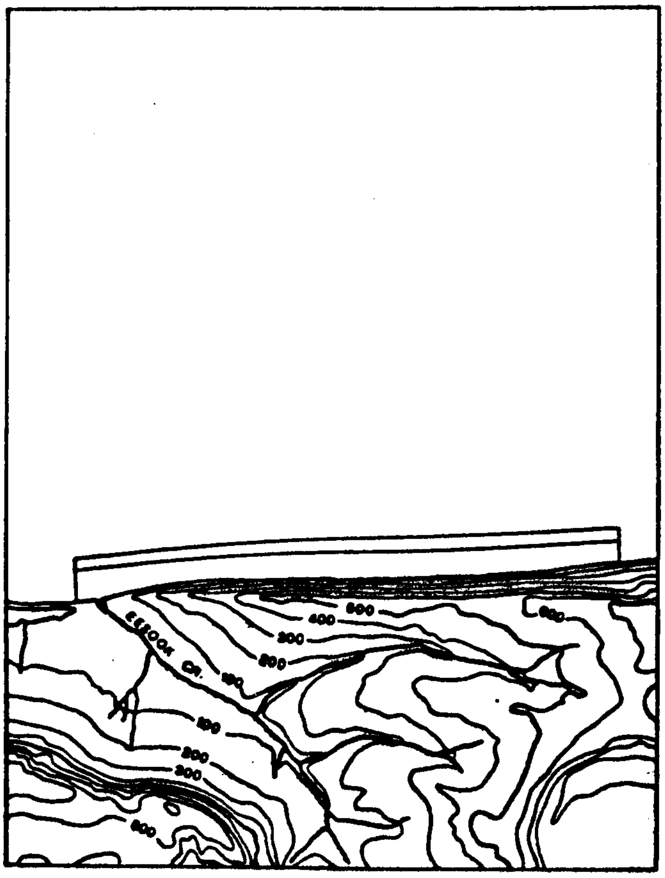

B
A
500
400
300
200
100
600
EESOOK CR.
100
200
300
800
70



OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX

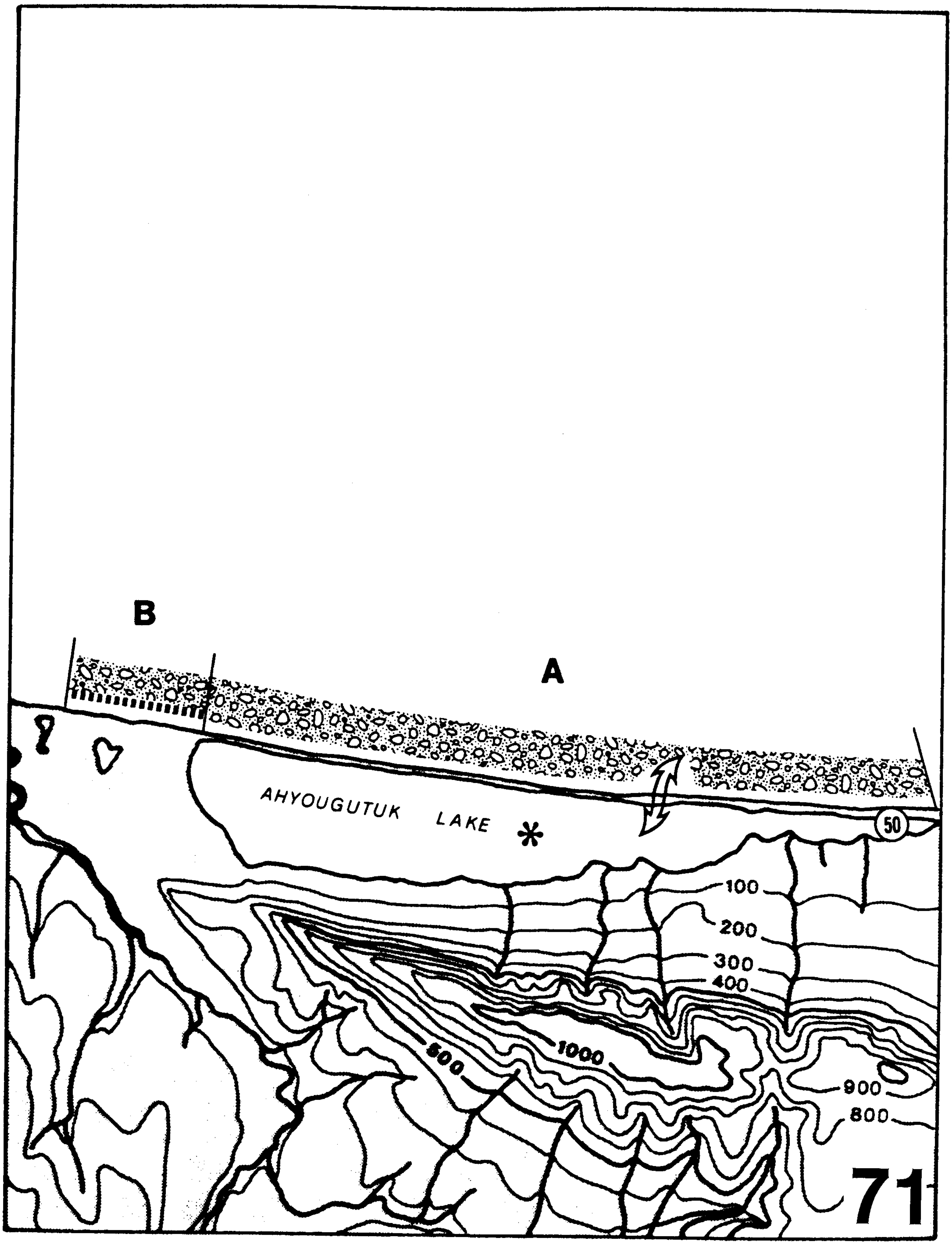


HUMAN USE INDEX

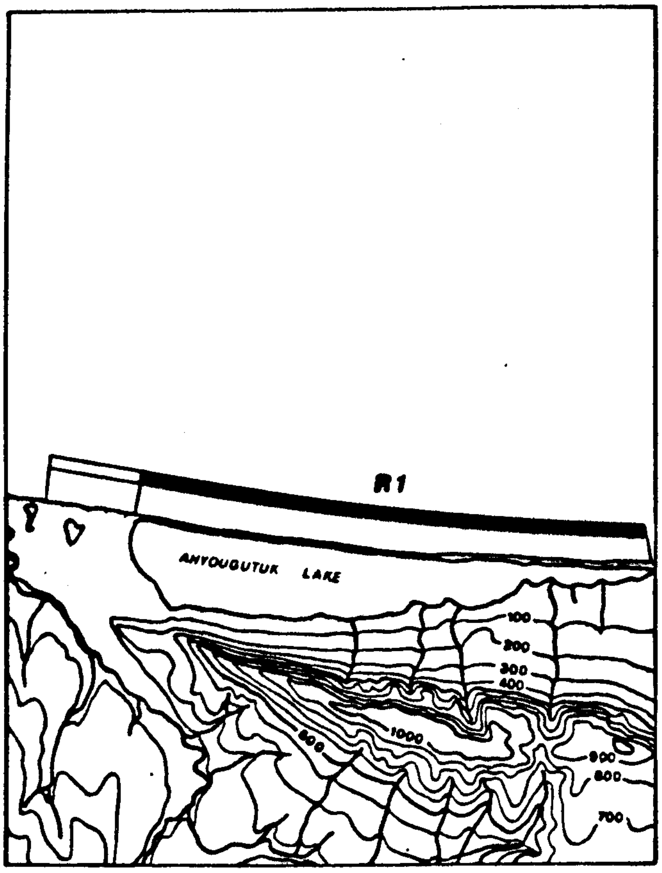
Seasonal Variability of Indices

Identi-fier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
B1	Seabird colony; gulls (40 pr), black guillemot (9 pr)		▨	▨	▨	▨	▨		

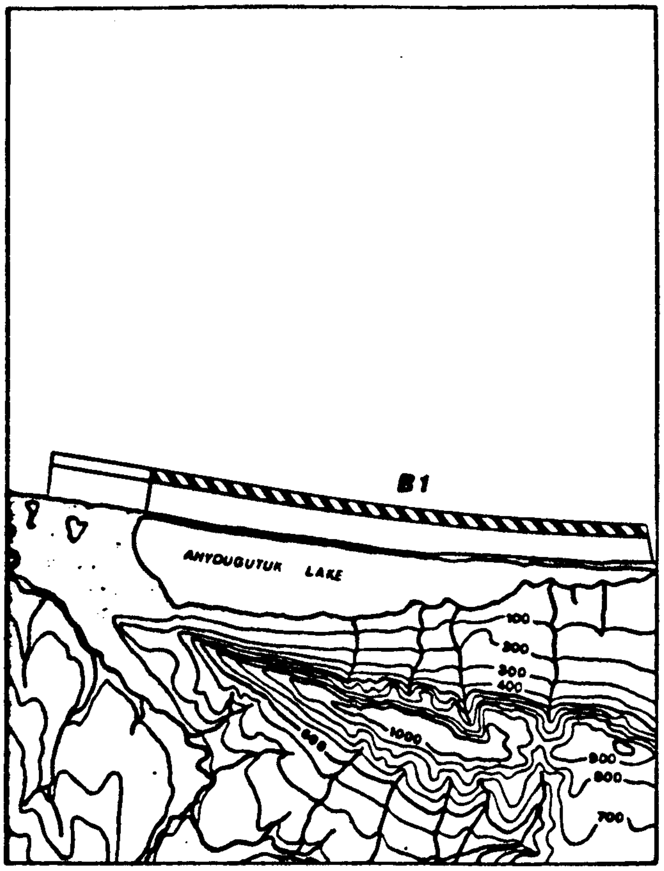
70


B
A
AHYOUGUTUK LAKE
50
100
200
300
400
500
1000
900
800
71

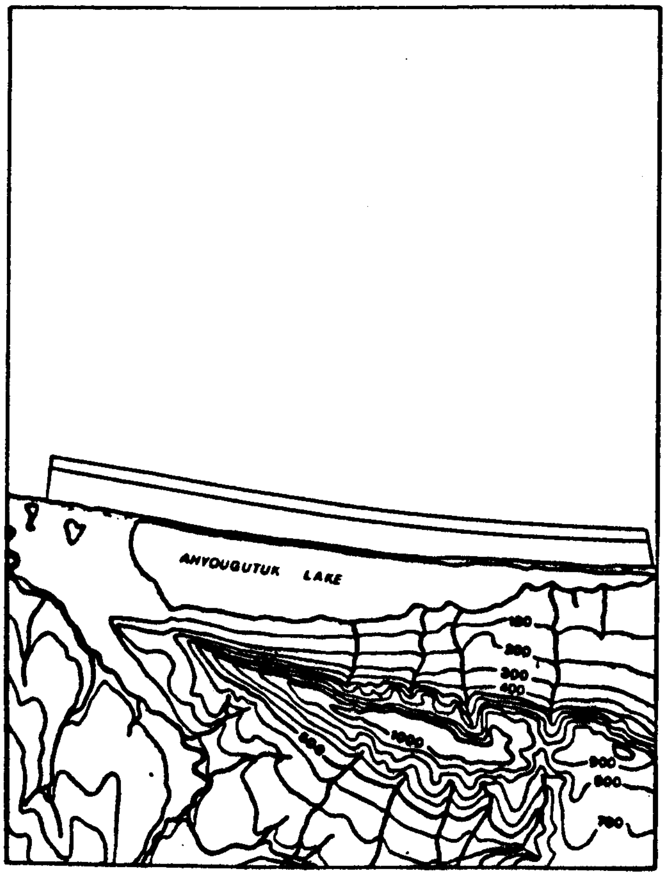
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



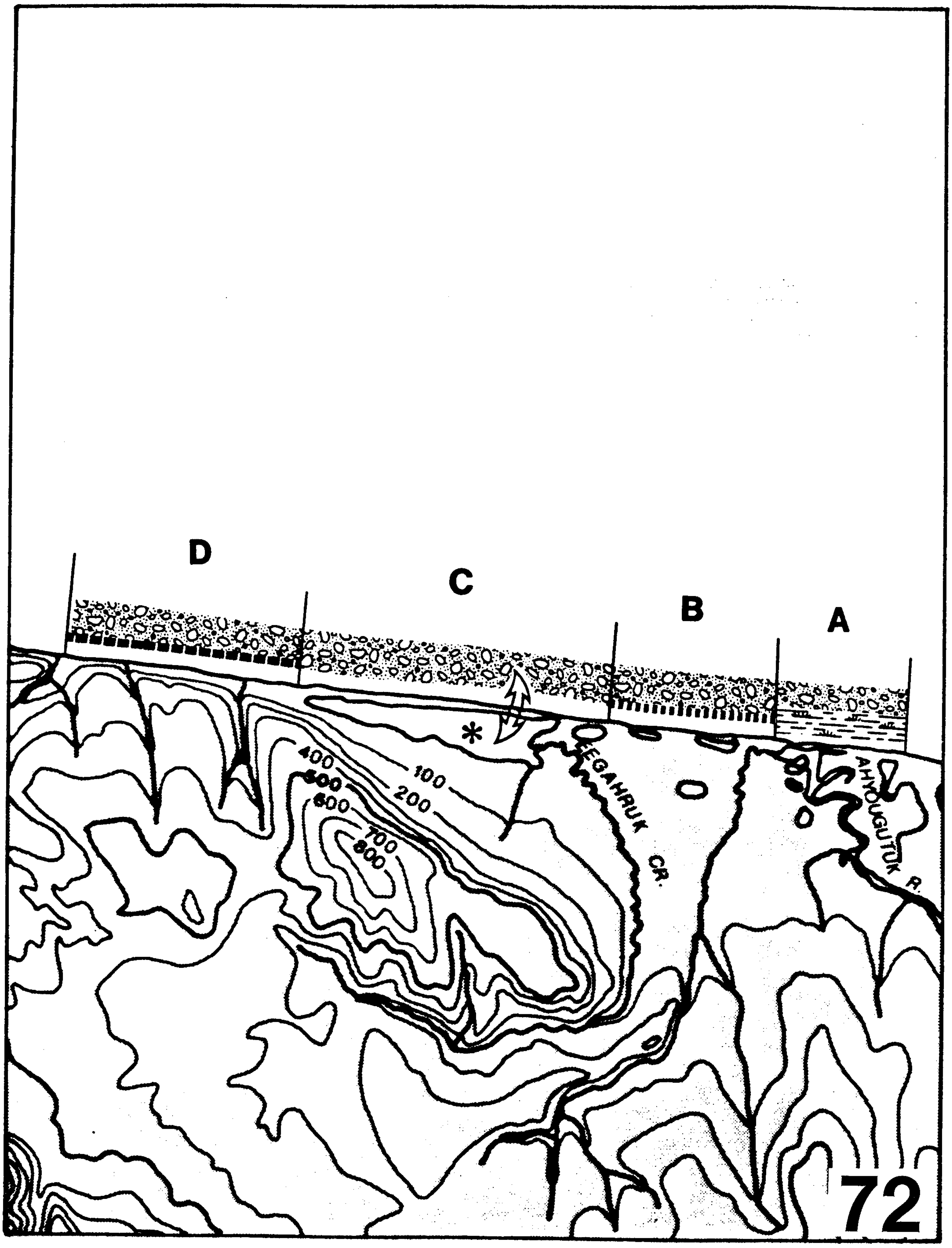
HUMAN USE INDEX



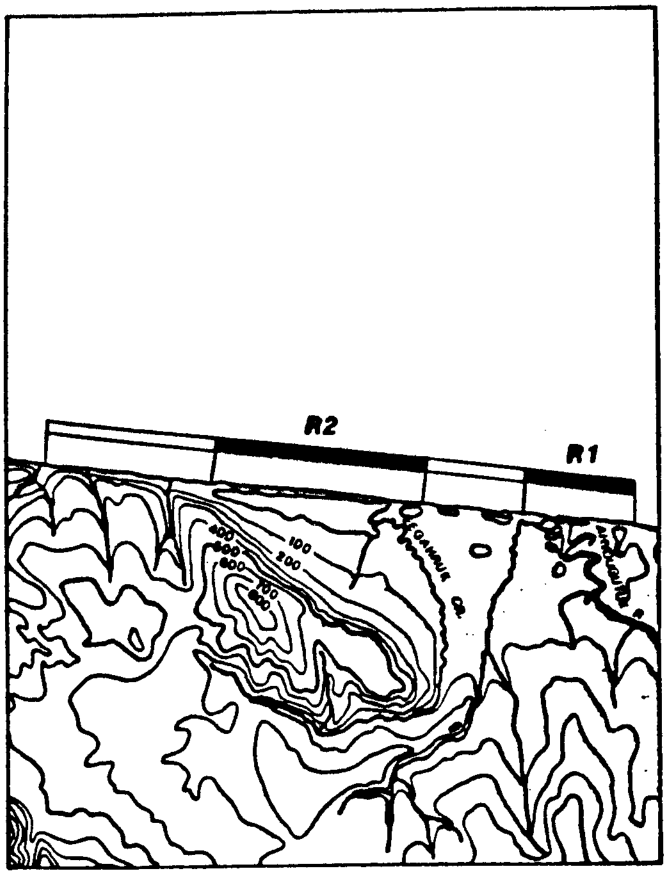
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Ephemeral inlet; Lagoon				■	■	■	■	
B1	Lagoon with wetland		▨	▨	▨	▨	▨		

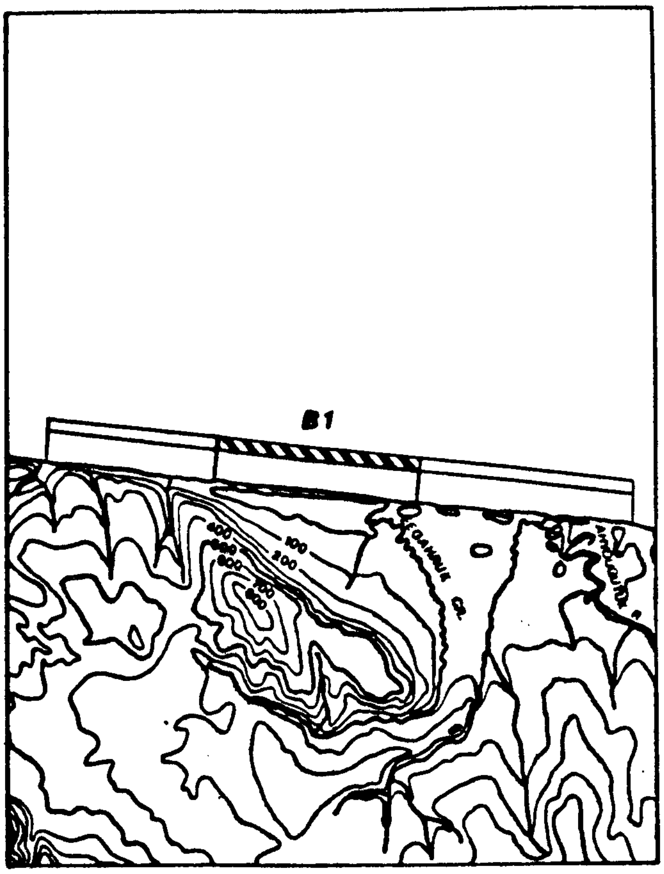
71


D
C
B
A
*
100
200
400
500
600
700
800
EGAHRUK CR.
AHYOUGUTUK R.
72

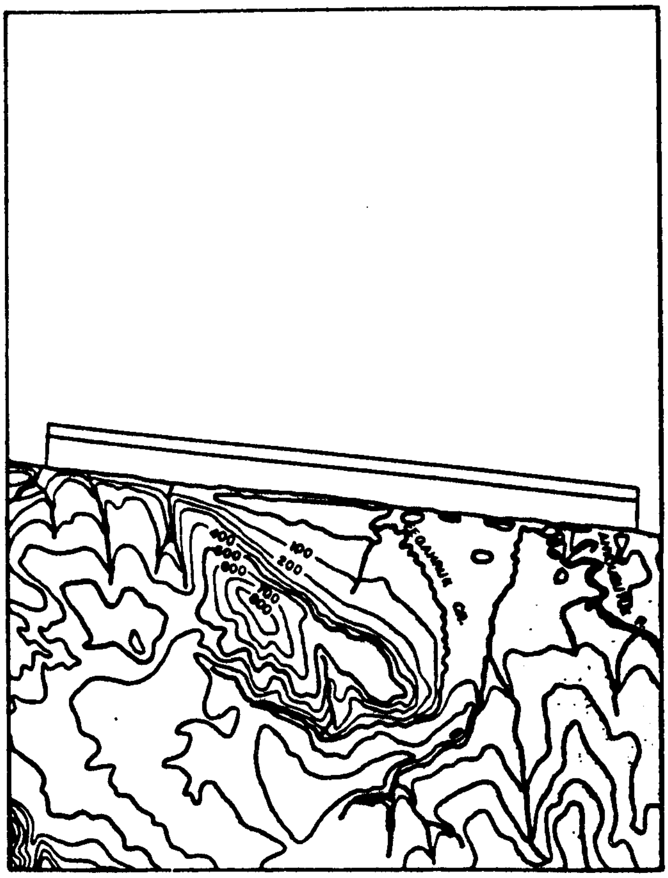
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



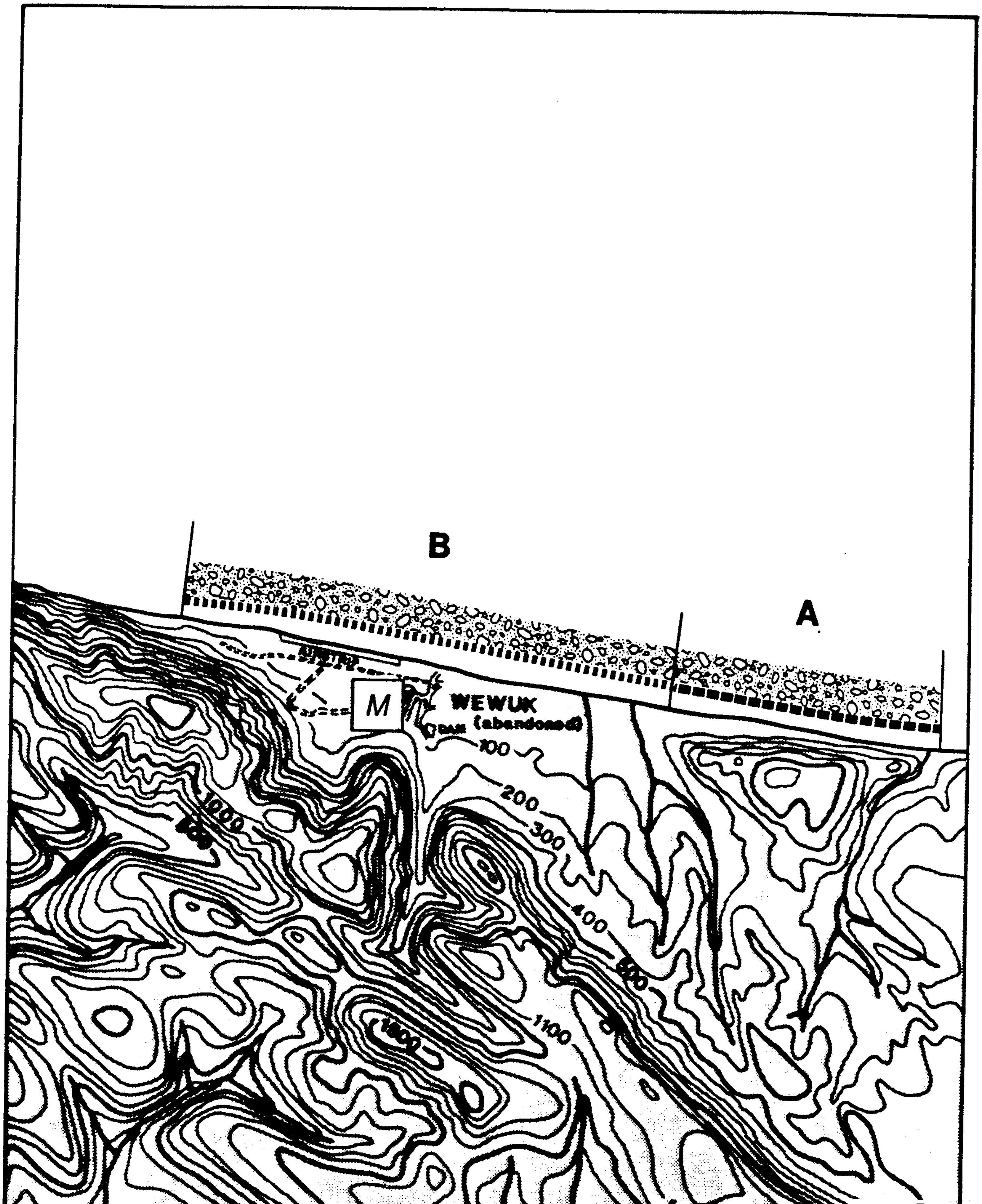
HUMAN USE INDEX



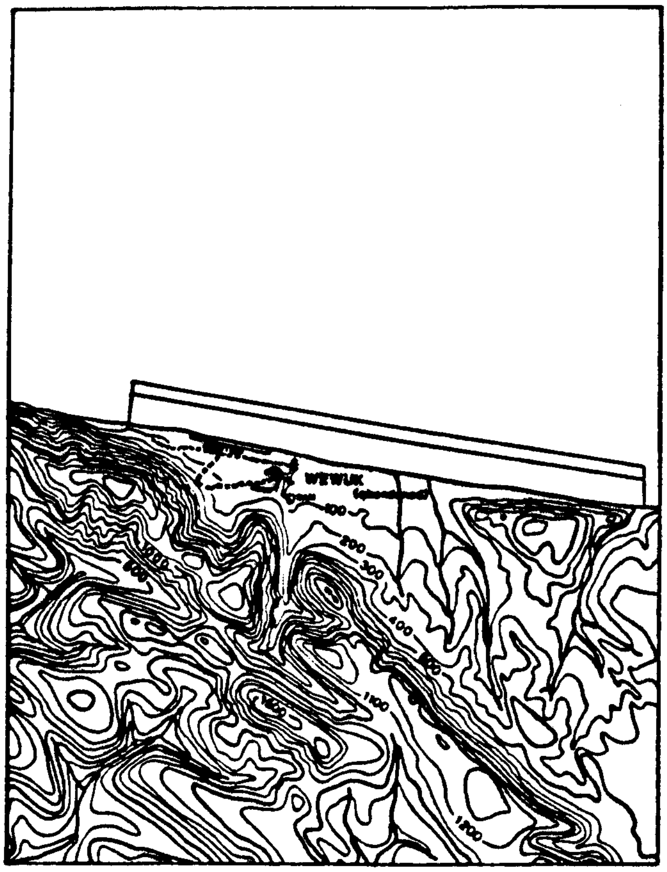
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Estuary				■	■	■	■	
R2	Ephemeral inlet; Lagoon				■	■	■	■	
B1	Lagoon		▨	▨	▨	▨	▨	▨	

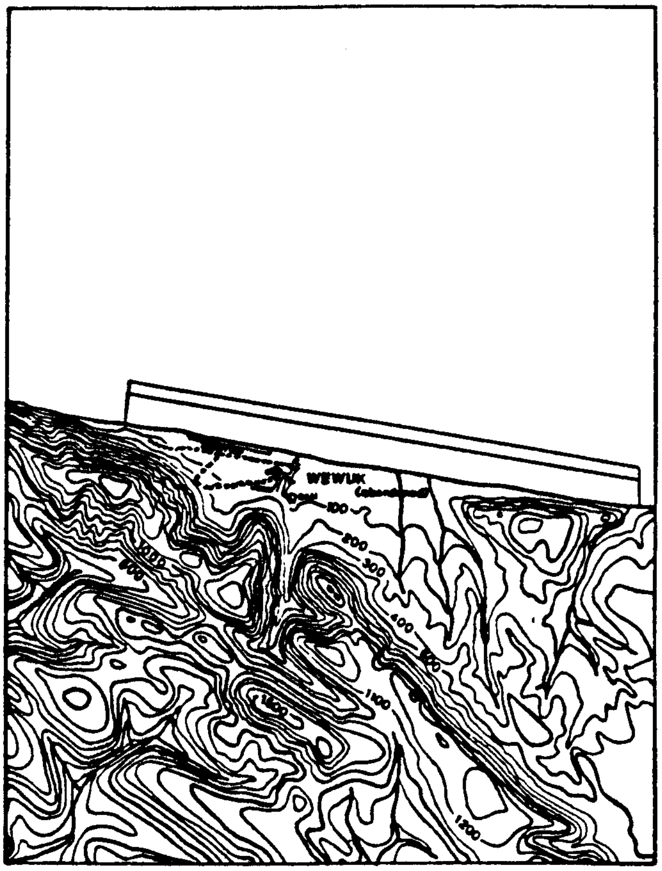
72


B
A
M
WEWUK
DAM
(abandoned)
100
200
300
400
1000
1100
1200
73

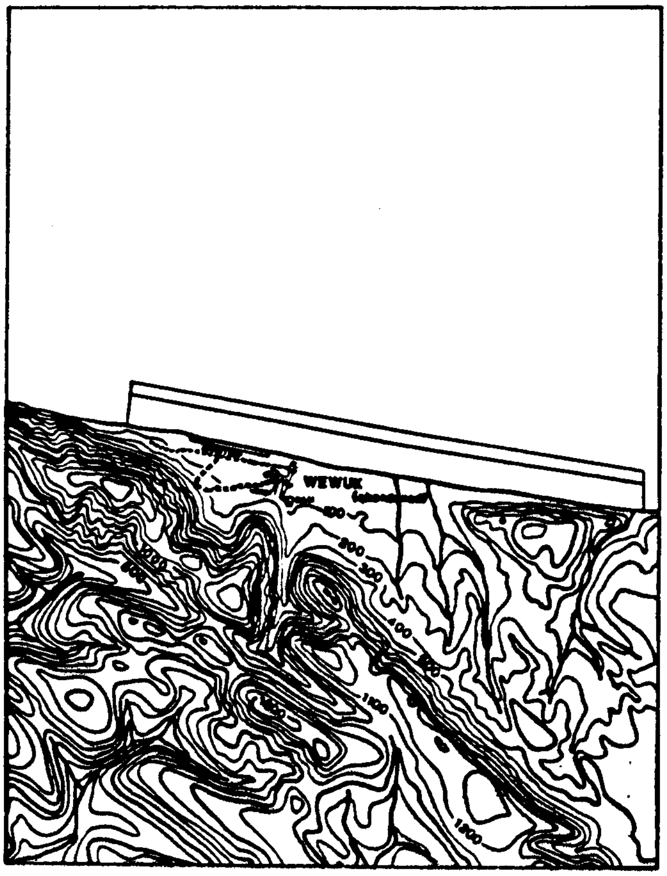
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



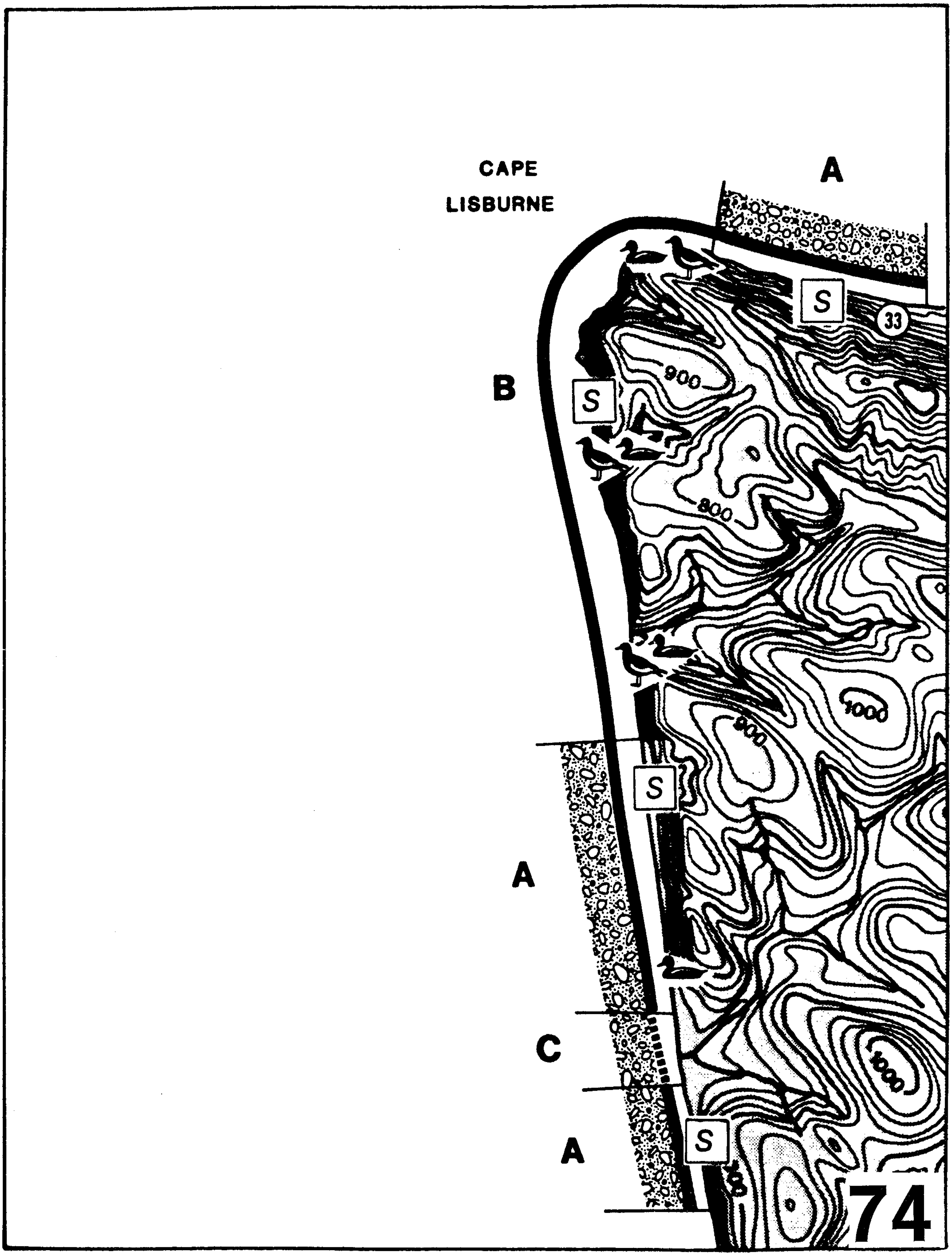
HUMAN USE INDEX



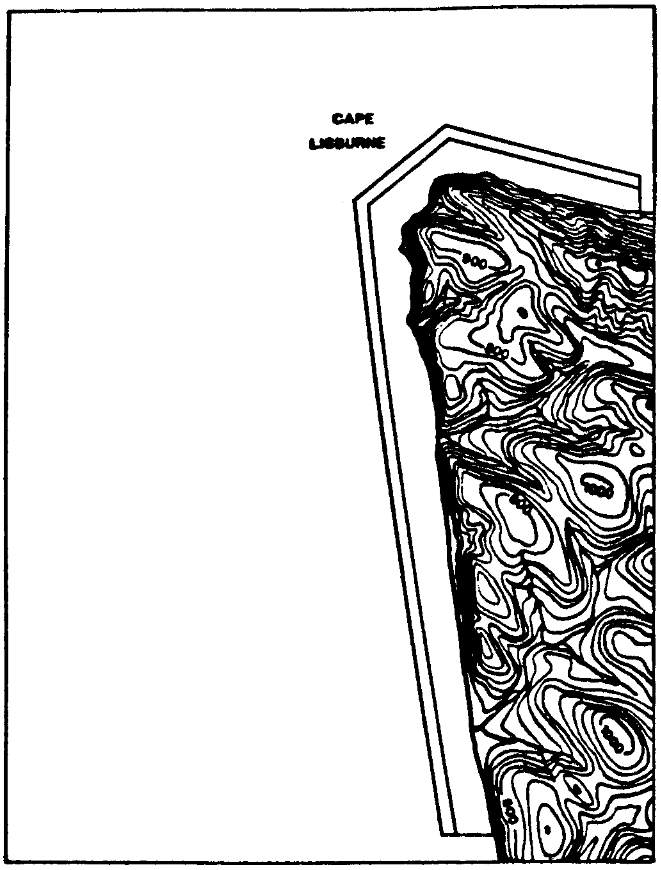
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
	NO PRIMARY OR SECONDARY SENSITIVITIES								

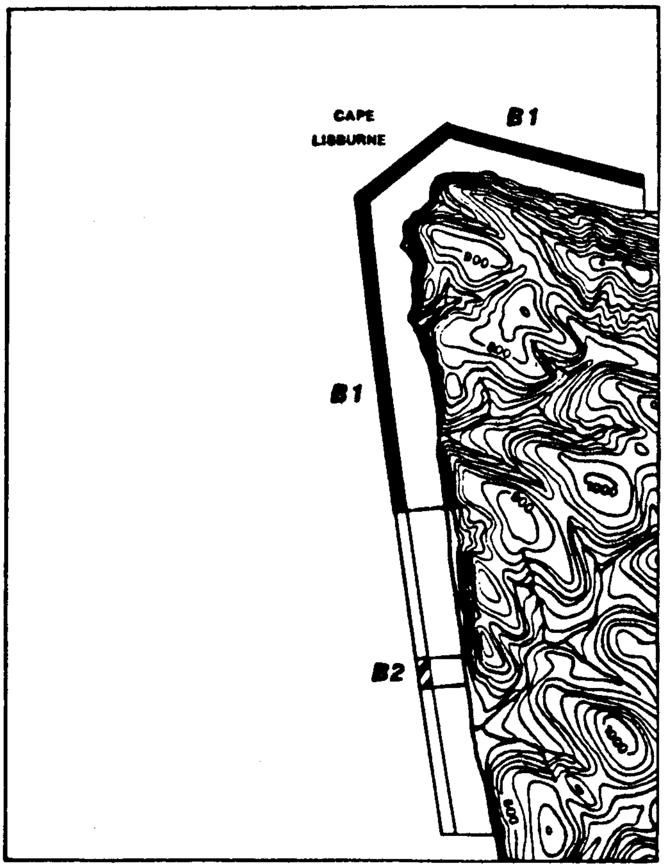
73


CAPE
LISBURNE
A
B
S
S
33
900
800
1000
900
S
A
C
1000
A
S
74

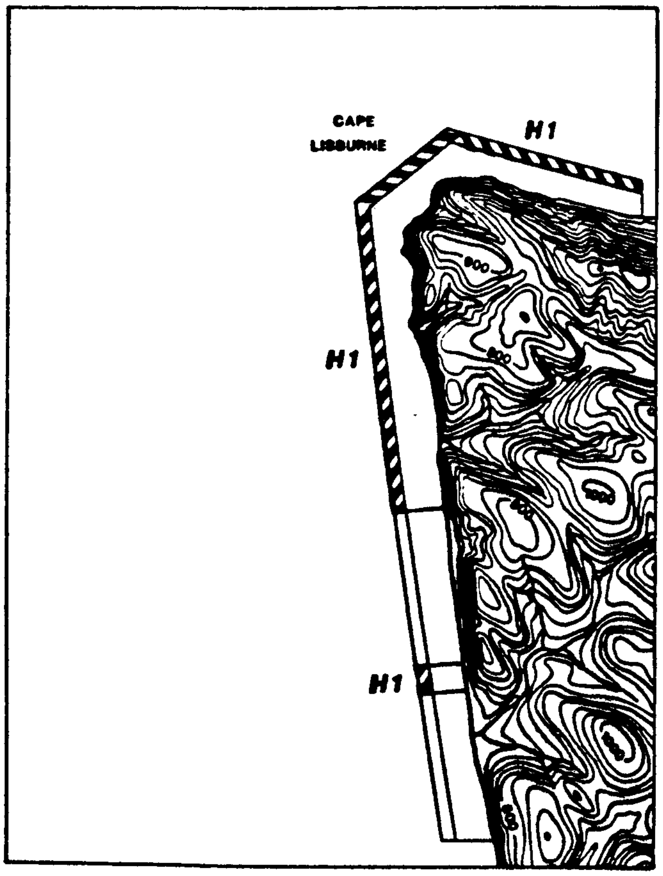
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



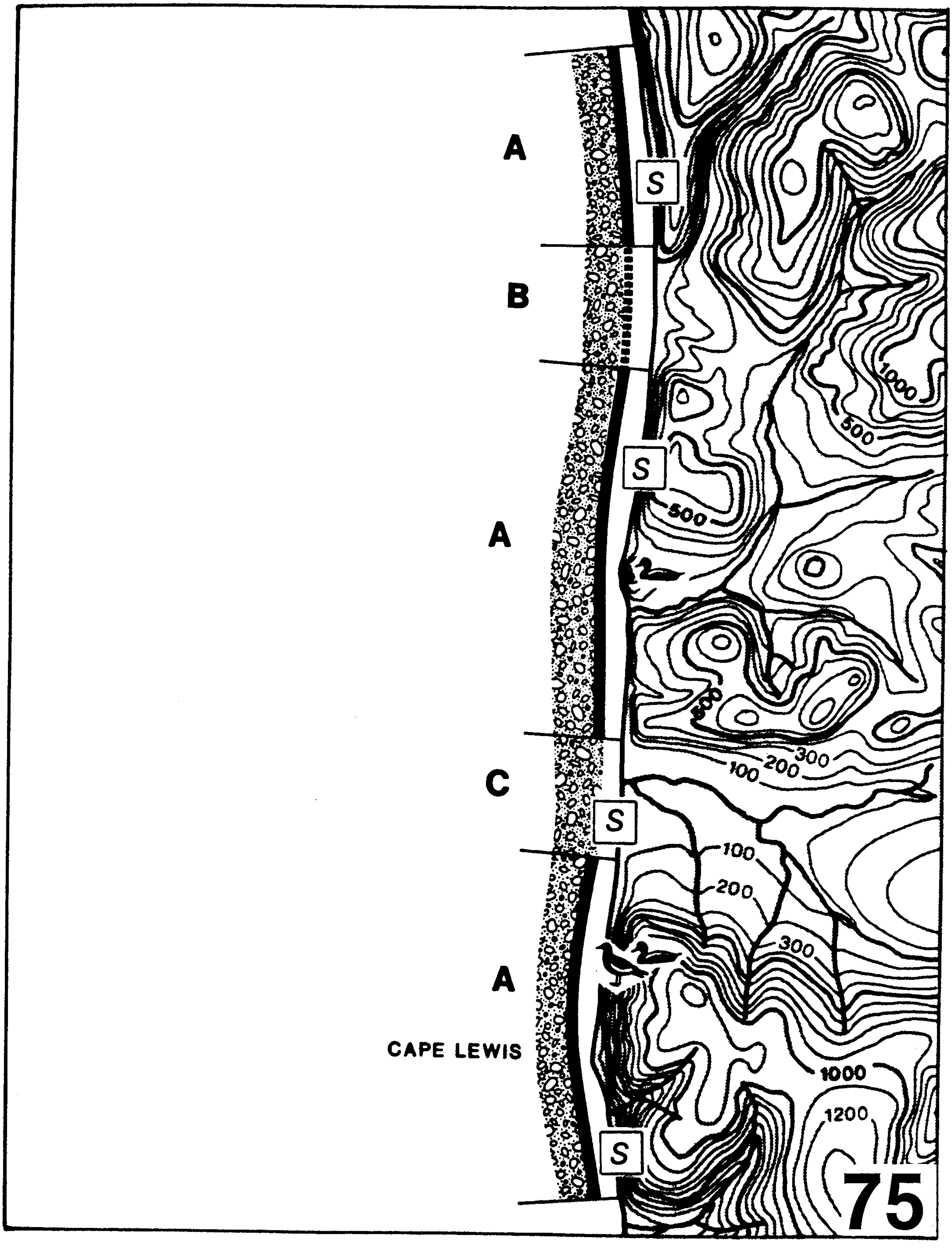
HUMAN USE INDEX



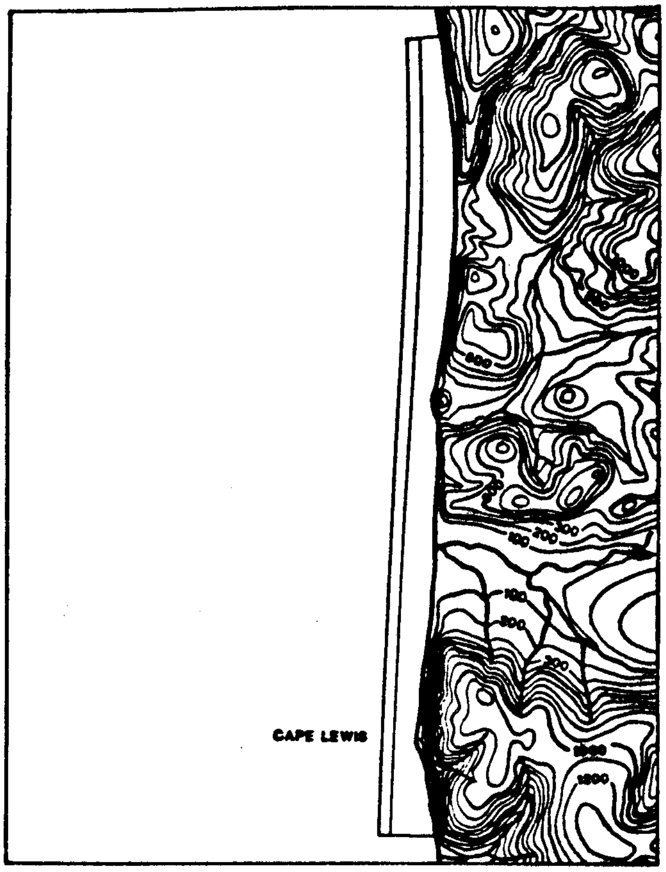
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
B1	Seabird colony; common murre (70,000 pr), thick-billed murre (30,000 pr), kittiwake (25,000 pr), horned puffin (1,450 pr), others (540 pr)		■	■	■	■	■		
B2	Pelagic cormorant (6 pr) nesting		▨	▨	▨	▨	▨		
H1	Egg gathering			▨	▨				

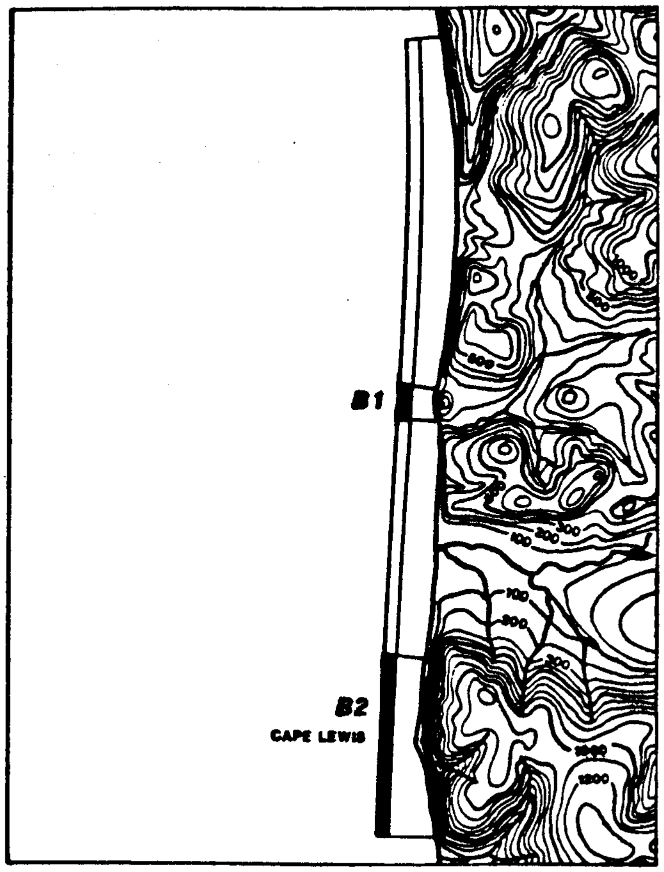
74


A
S
B
1000
500
S
500
A
300
200
100
C
S
100
200
300
A
CAPE LEWIS
1000
1200
S
75

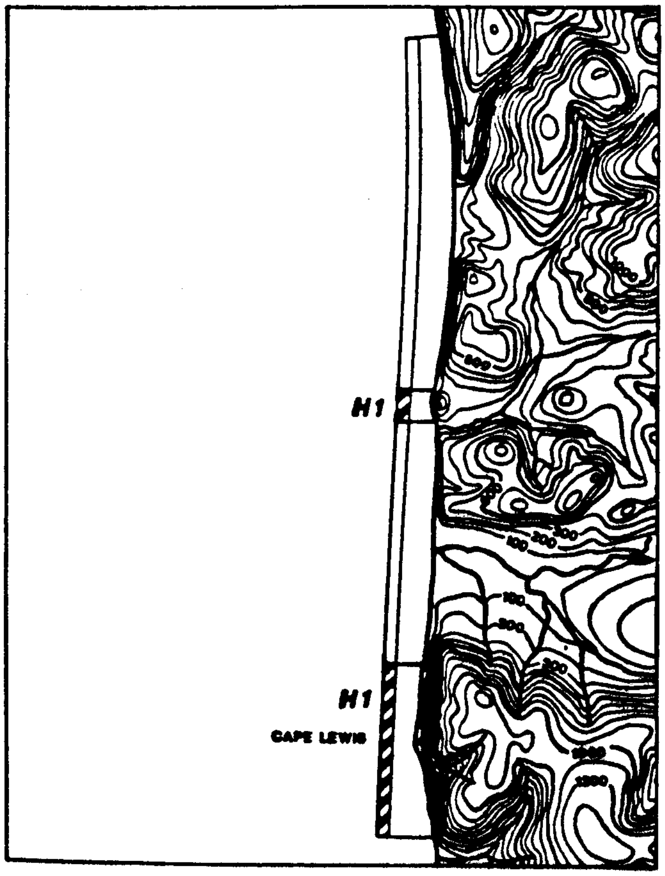
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



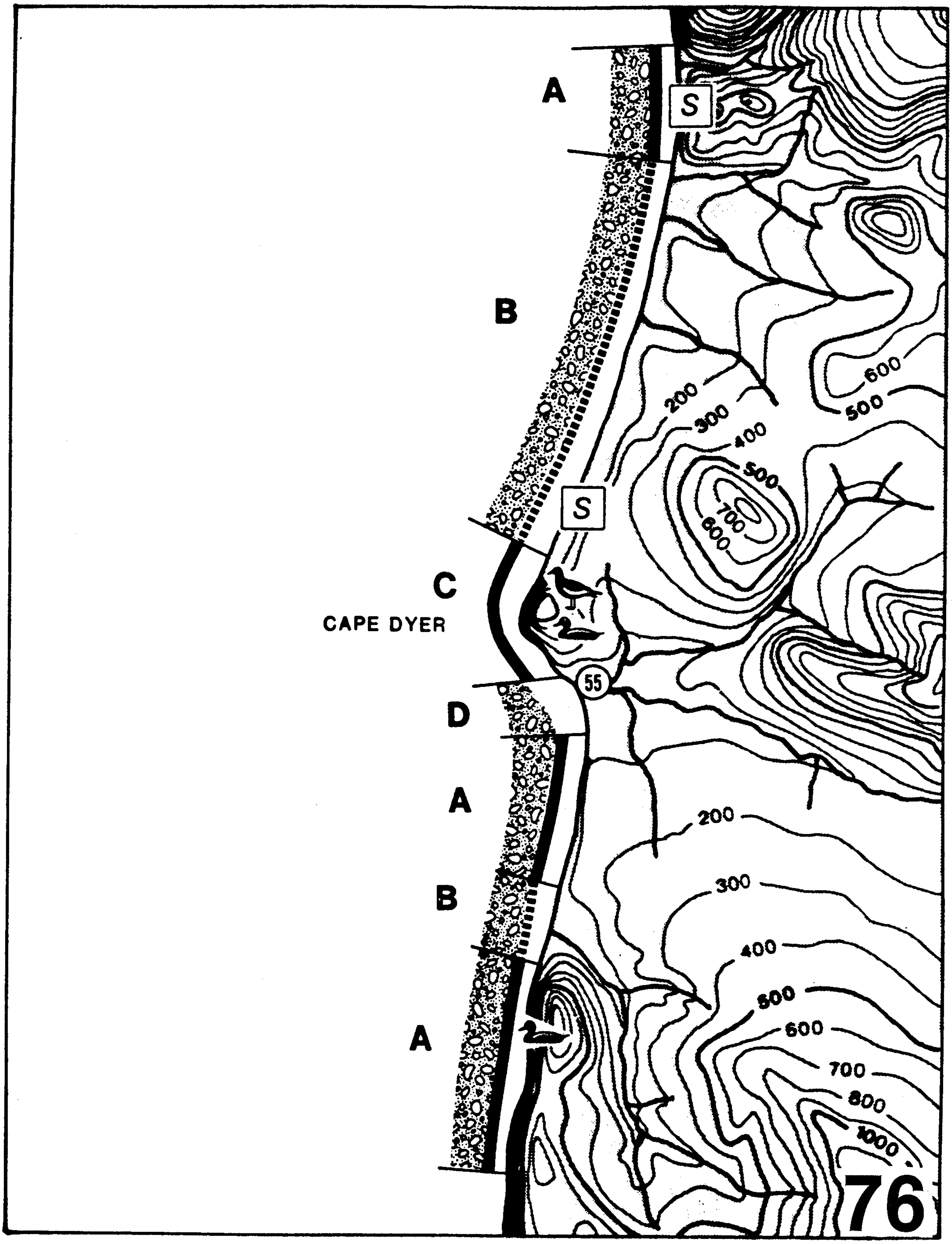
HUMAN USE INDEX



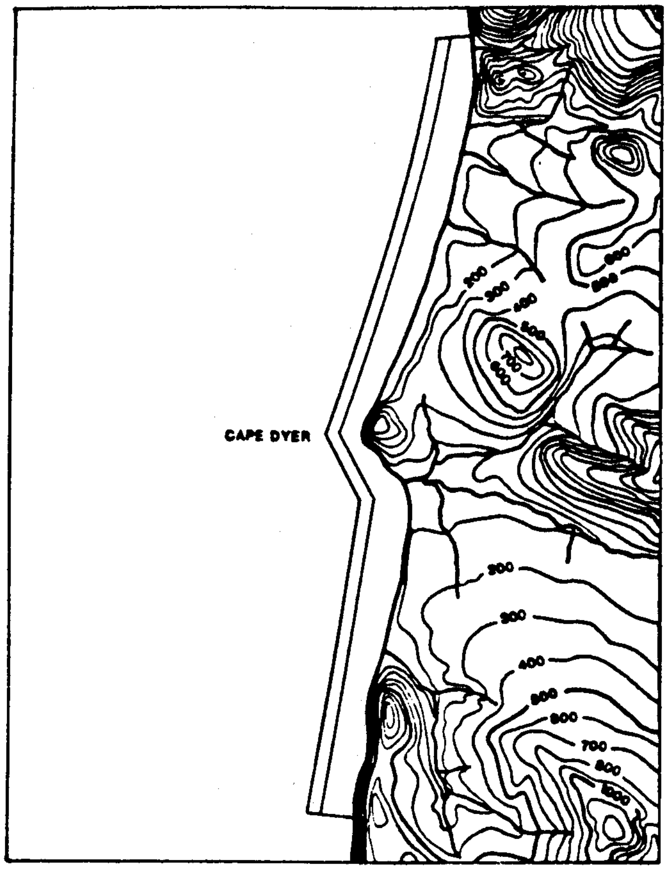
Seasonal Variability of Indices

		SEASON							
Identi-fier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
B1	Seabird colony; horned and tufted puffins (50 pr), murres (20 pr), cormorants (9 pr)		■	■	■	■	■		
B2	Seabird colony; murres (25,000 pr), Kittiwakes (3,000 pr), puffins (300 pr), others (150 pr)		■	■	■	■	■		
H1	Egg gathering			▨	▨				

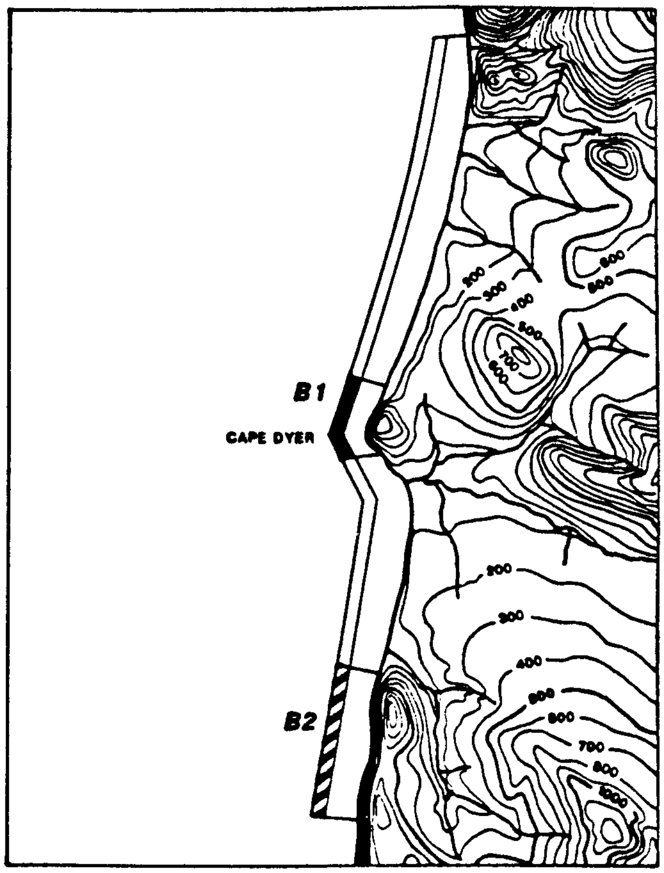
75


A
S
B
200
300
400
500
600
700
600
500
S
C
CAPE DYER
55
D
A
200
B
300
400
500
A
600
700
800
1000
76

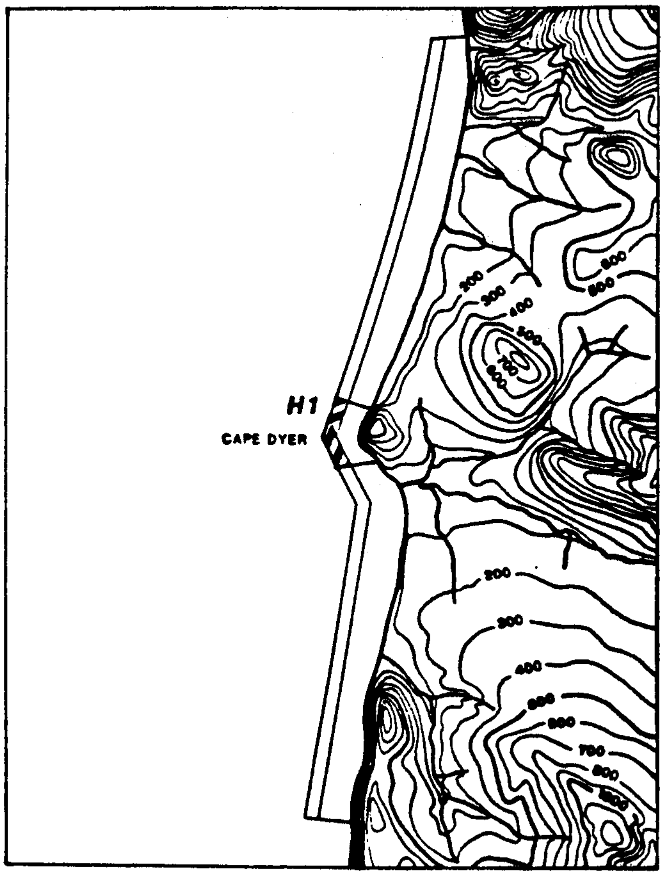
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



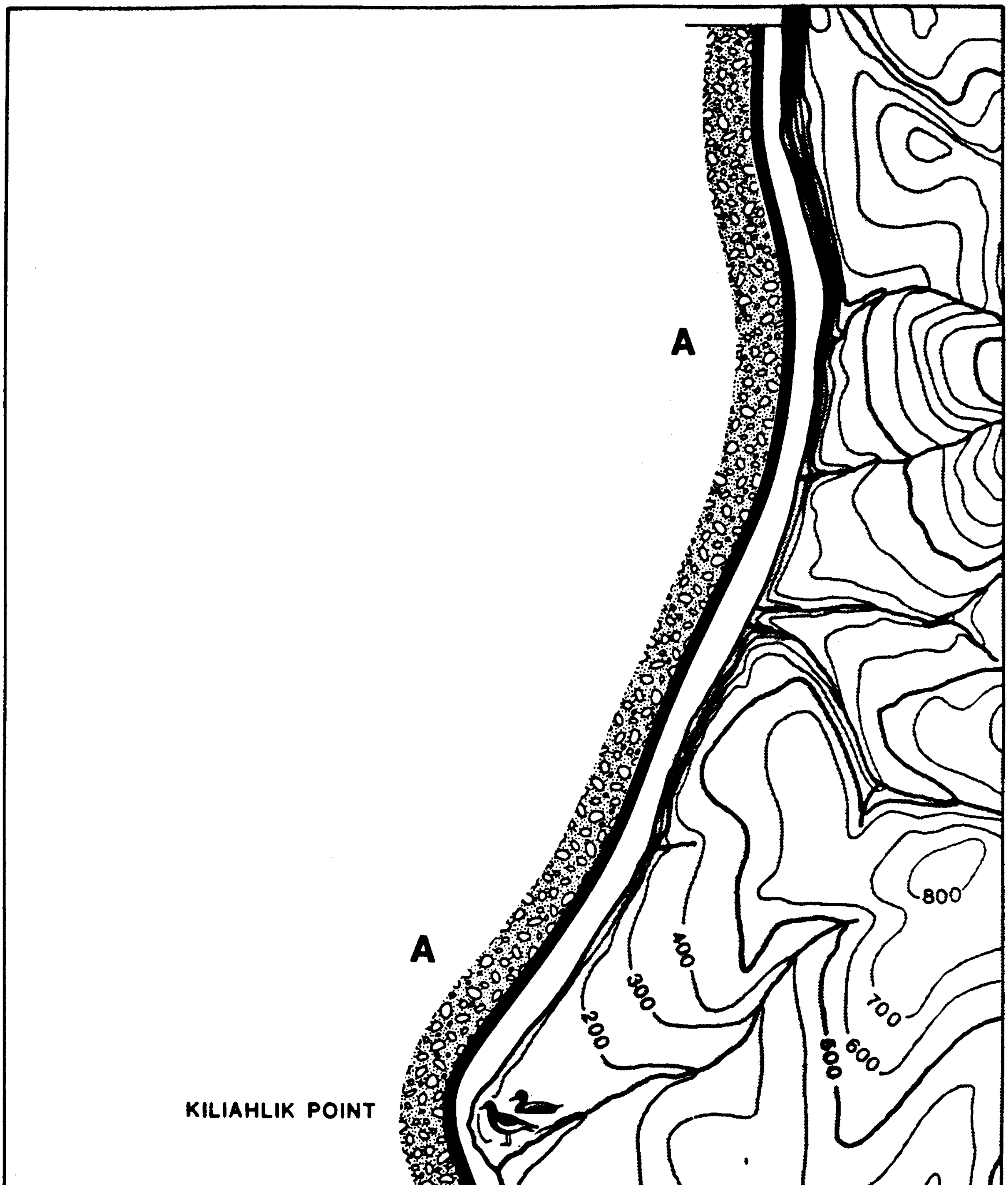
HUMAN USE INDEX



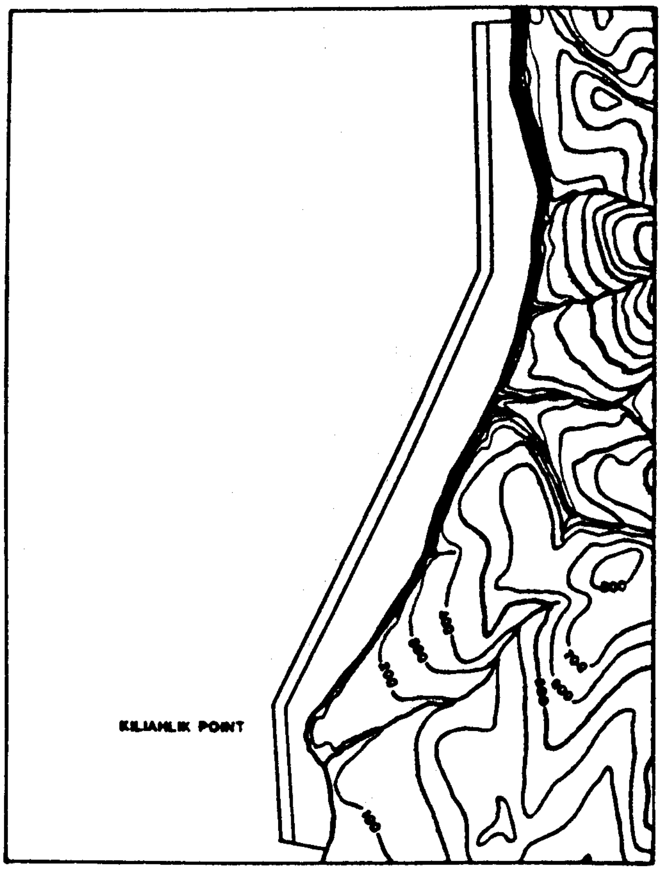
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
B1	Seabird colony; gulls (48 pr), puffins (28 pr), cormorant (26 pr)		■	■	■	■	■		
B2	Murre colony (20 pr)		▨	▨	▨	▨	▨		
H1	Egg gathering			▨	▨				

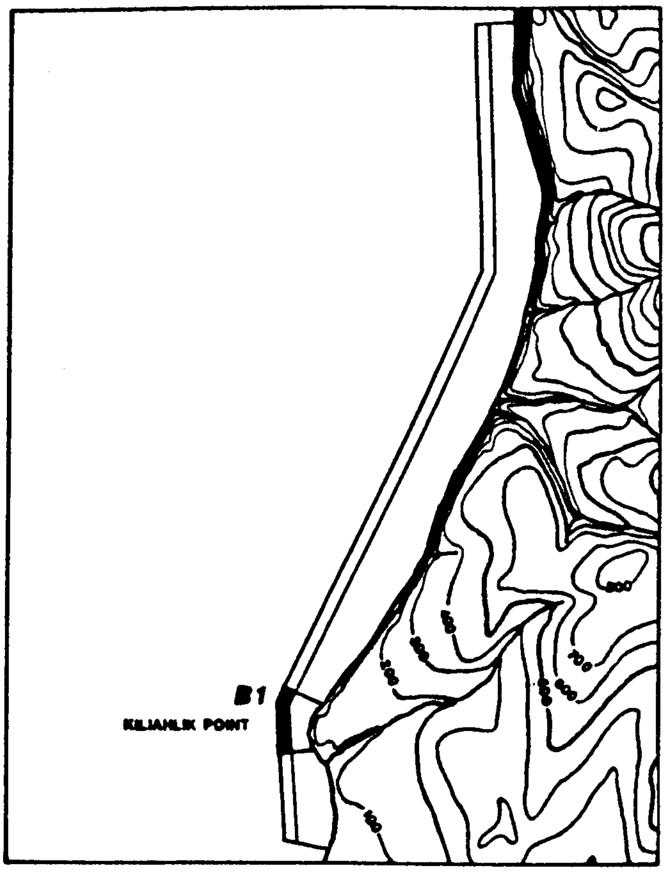
76


A
A
KILIAHLIK POINT
800
400
300
200
700
600
500
100
77

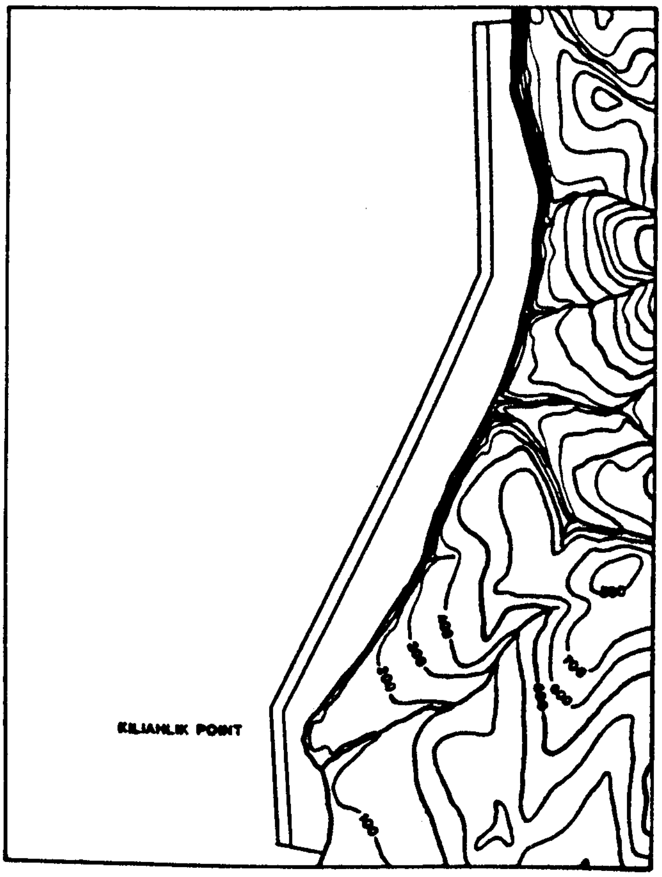
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



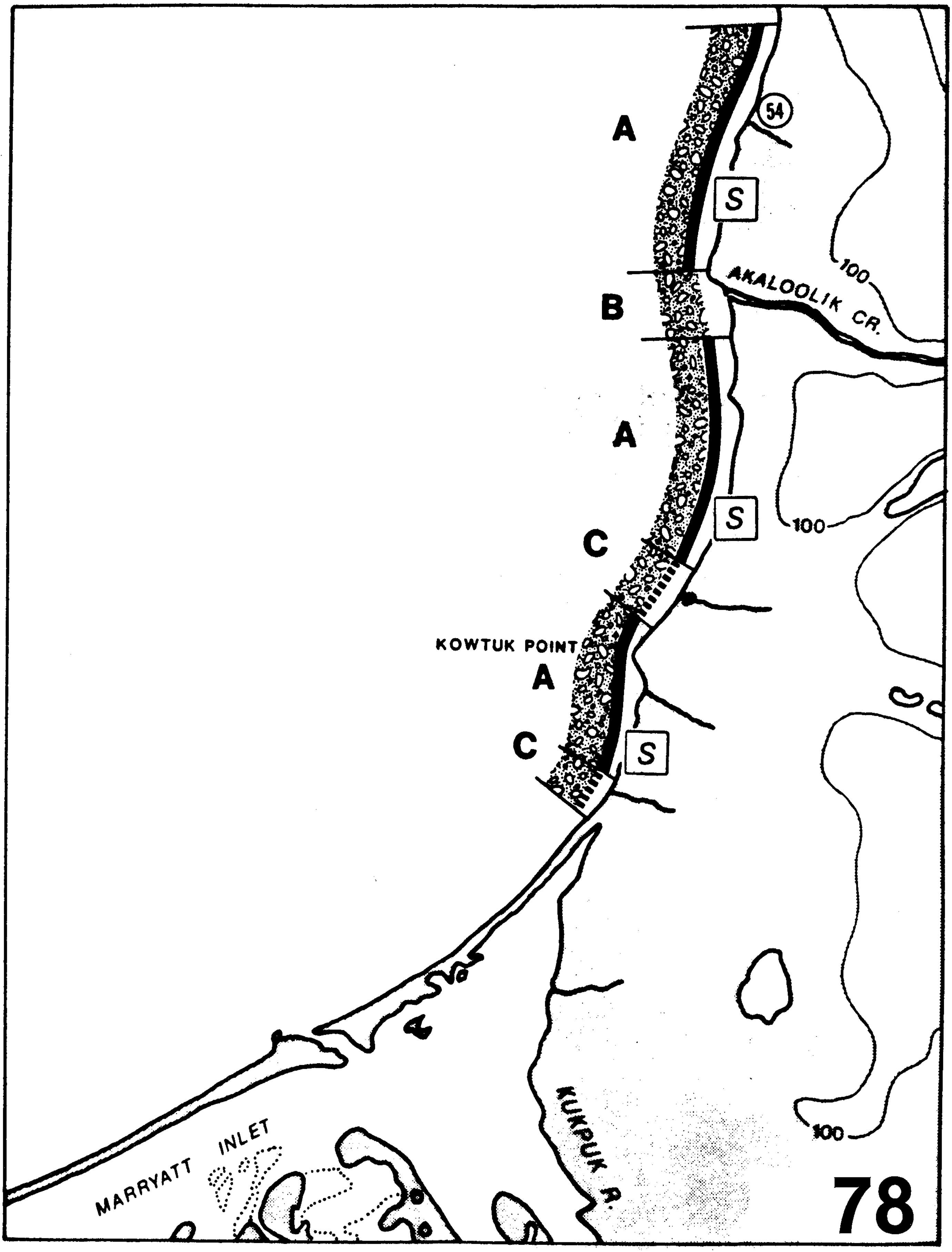
HUMAN USE INDEX



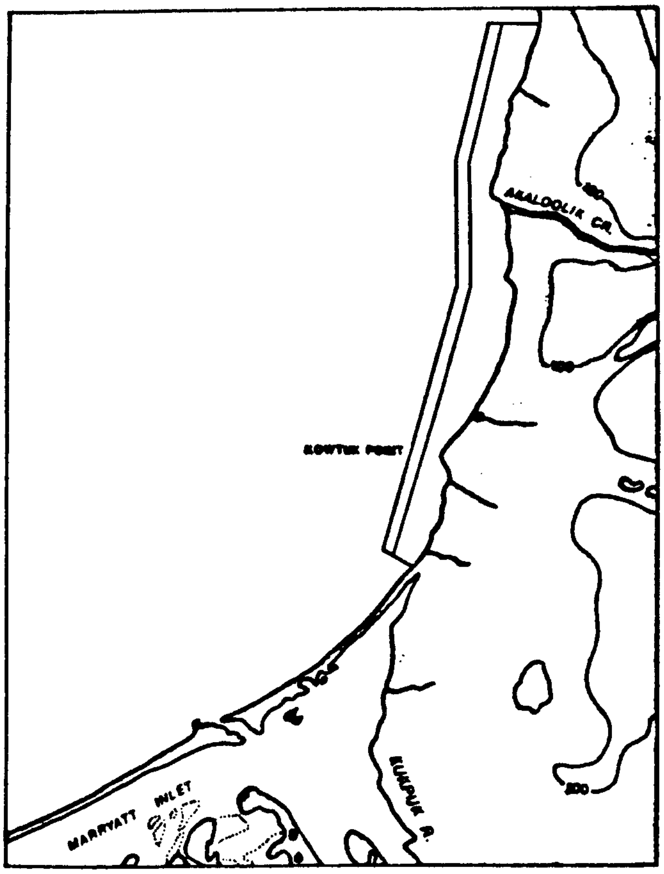
Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
B1	Seabird colony; cormorants (100 pr), gulls (40 pr)		■	■	■	■	■		

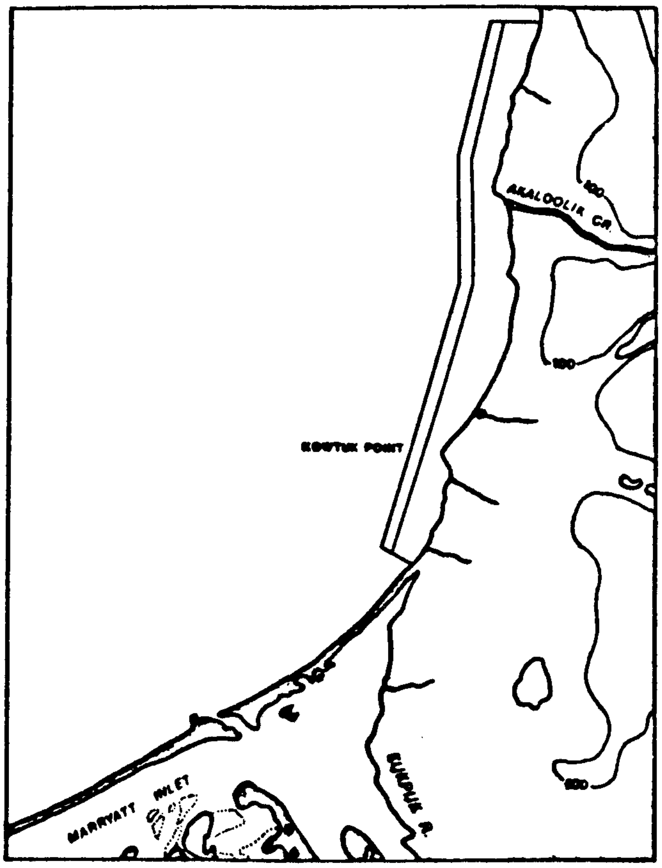
77


54
A
S
100
AKALOOLIK CR.
B
A
S
100
C
KOWTUK POINT
A
C
S
MARRYATT INLET
KUKPUK R.
100
78

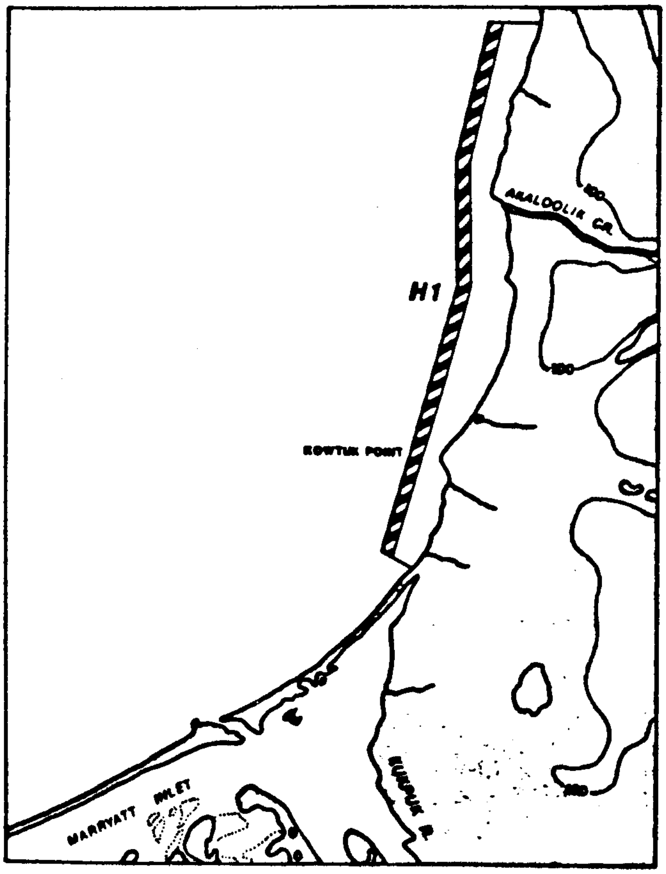
OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



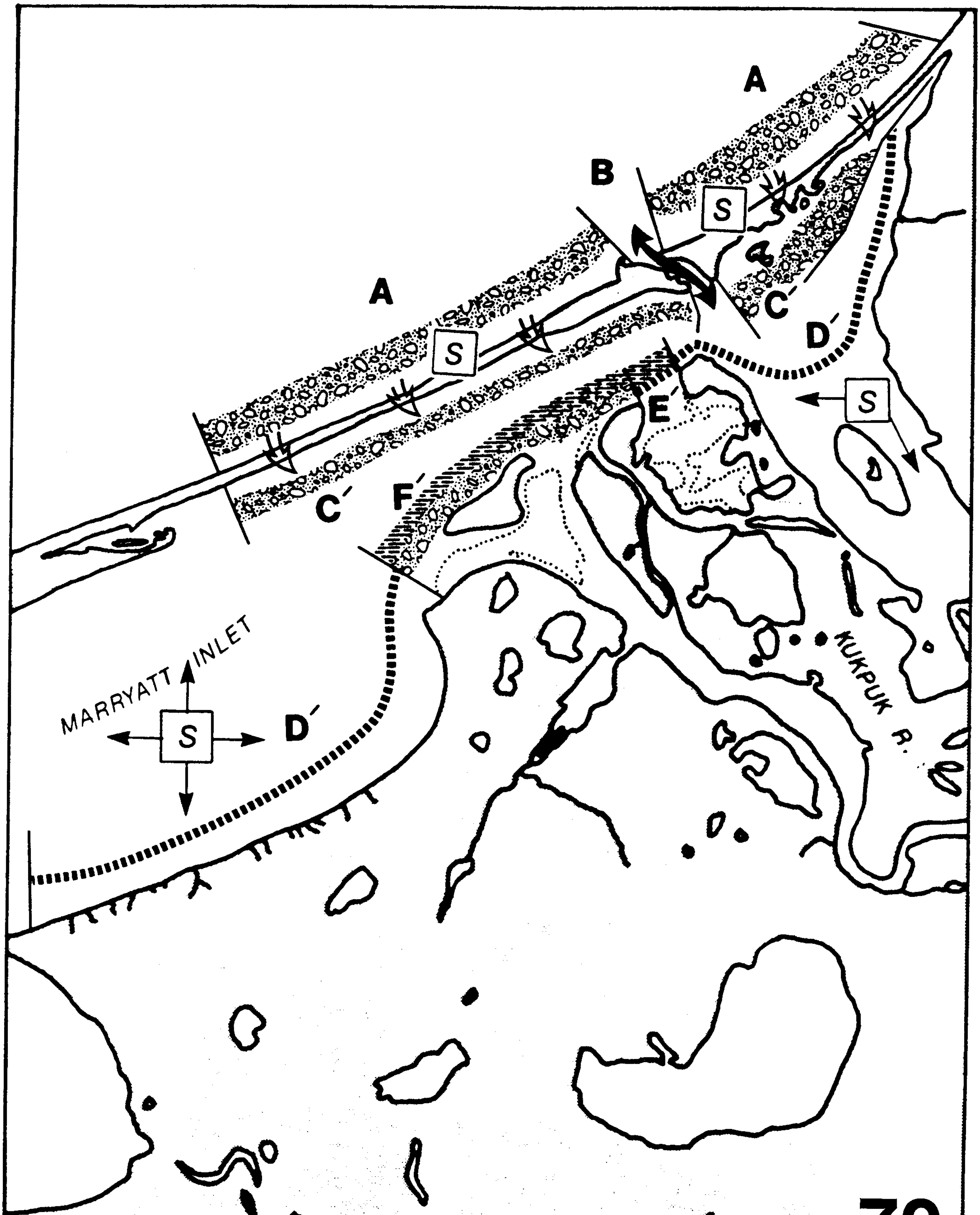
HUMAN USE INDEX

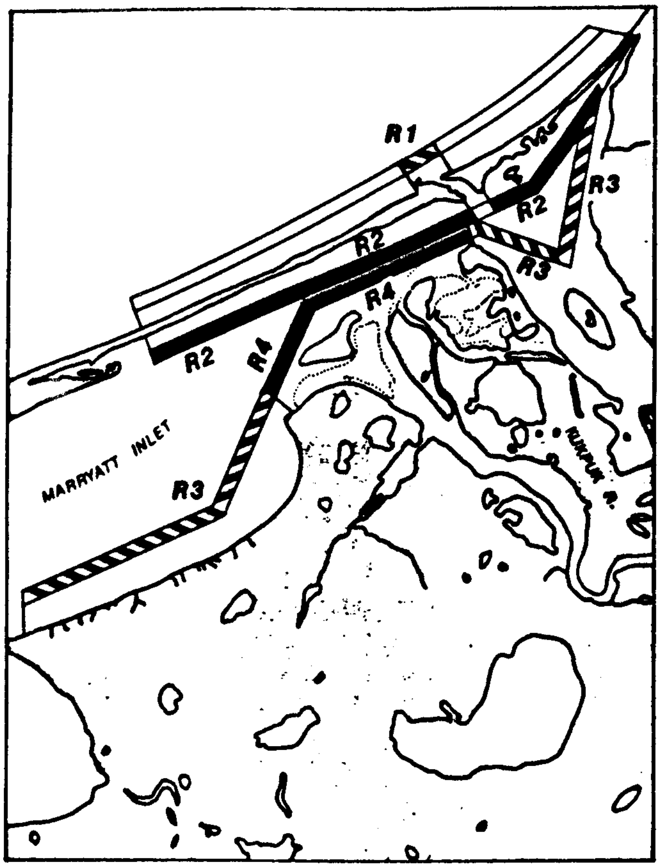


Seasonal Variability of Indices

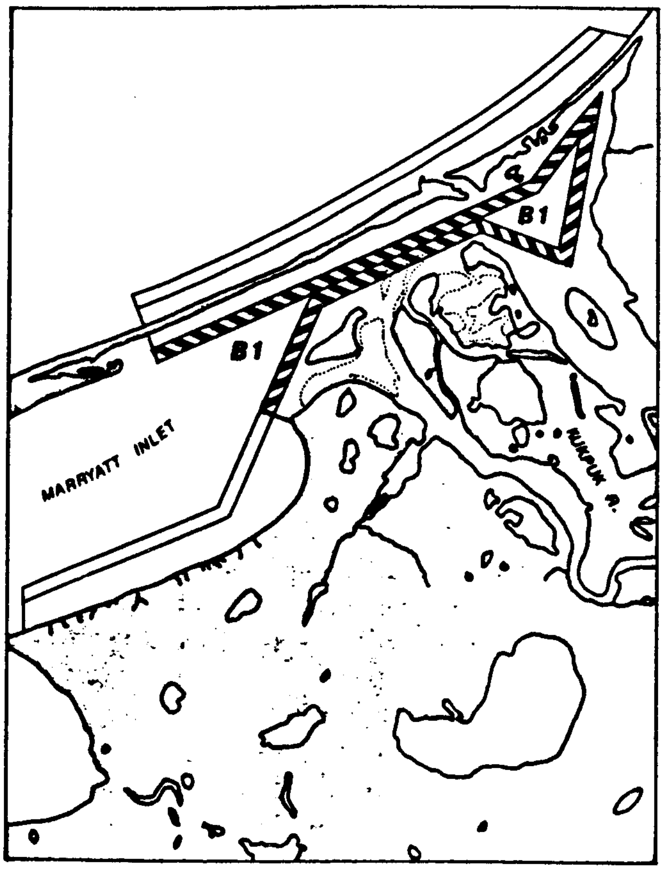
		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
H1	Fishing			▨	▨	▨	▨		

78

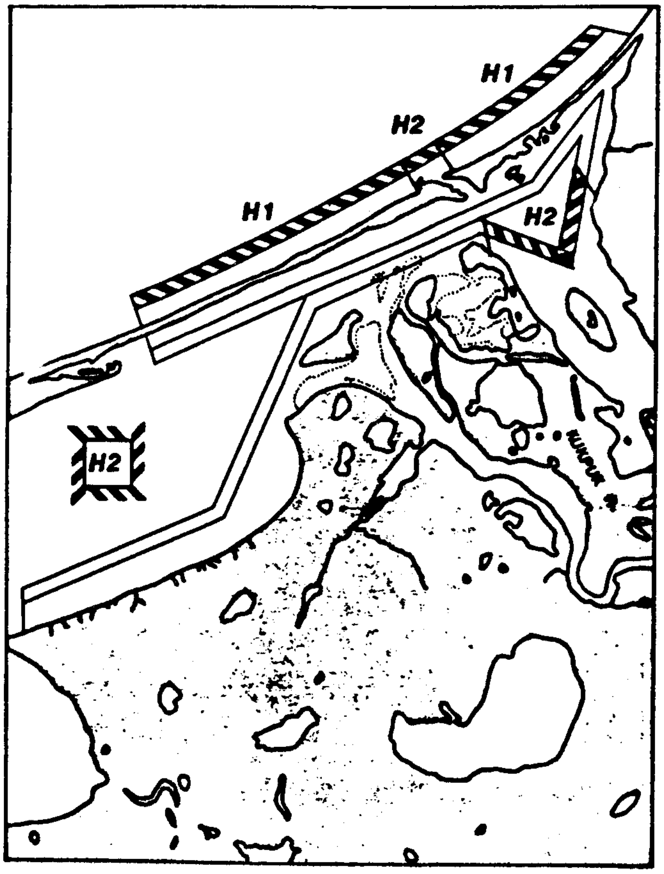

A
B
S
A
S
C´
D´
E´
C´
F´
S
MARRYATT INLET
S
D´
KUKPUK R.
79



OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX

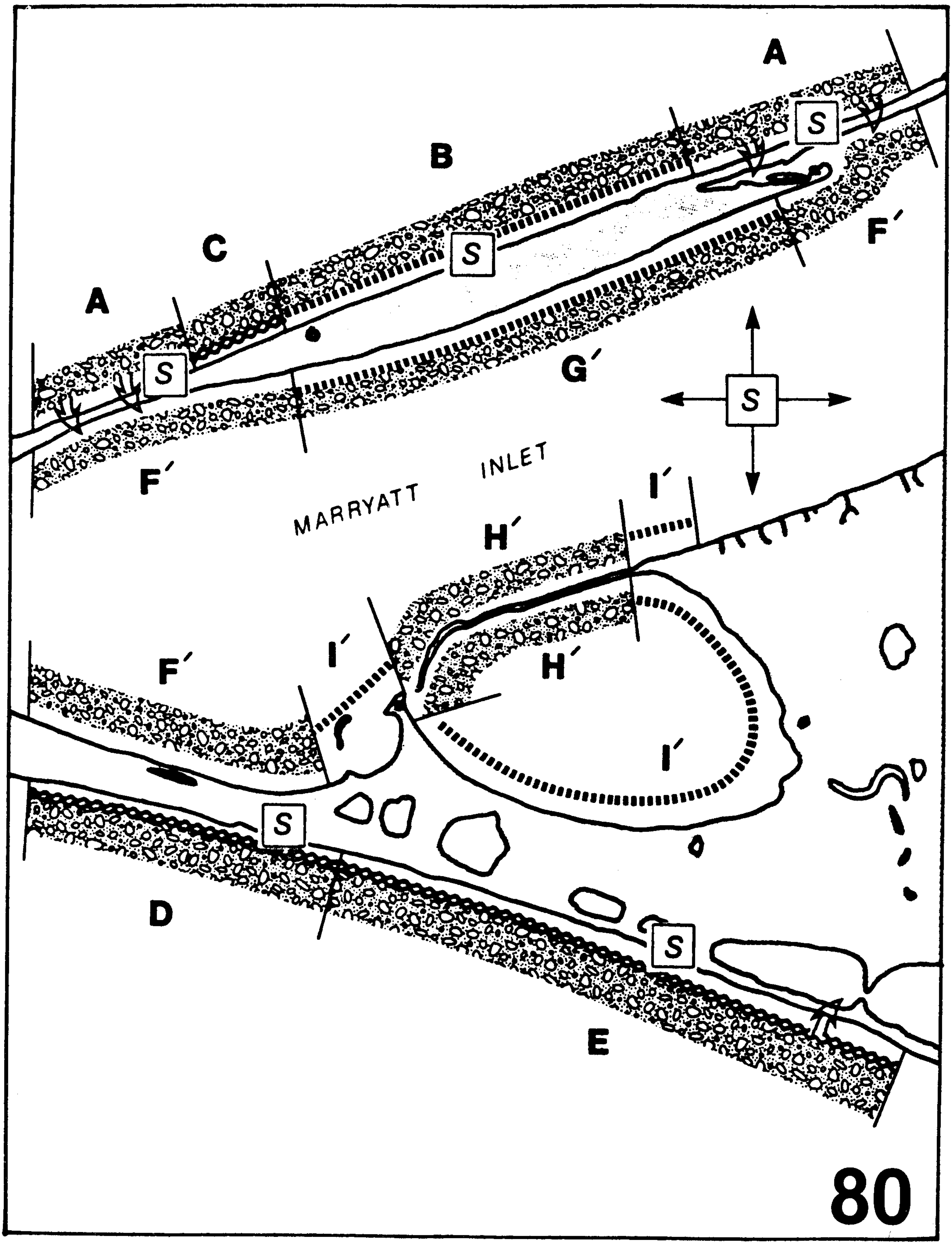


HUMAN USE INDEX

Seasonal Variability of Indices

		SEASON							
			Break-Up/Summer/Freeze-Up						
Identifier	RESOURCE	Winter	May	Jun	Jul	Aug	Sep	Oct	Winter
R1	Permanent inlet; Recurve spits			▨	▨	▨	▨	▨	
R2	Low energy beach			■	■	■	■		
R3	Protected tundra cliff			▨	▨	▨	▨		
R4	Tidal flats; delta front			■	■	■	■		
B1	Shorebirds migration; staging				▨	▨			
	Waterfowl migration; staging		▨	▨	▨	▨	▨		
H1	Fishing			▨	▨	▨	▨		
H2	Beluga whale hunting				▨	▨			
	Fishing			▨	▨	▨	▨		

79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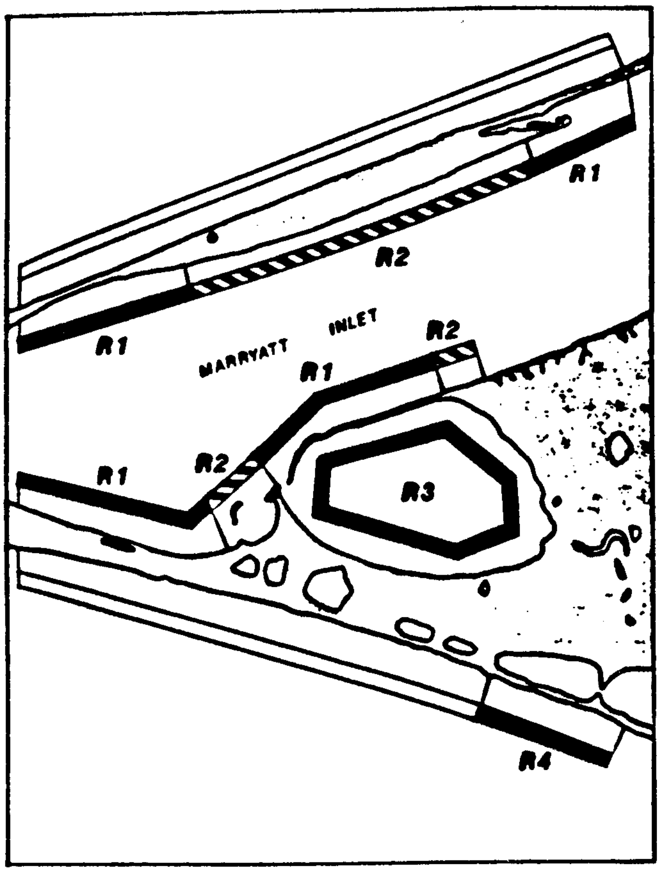
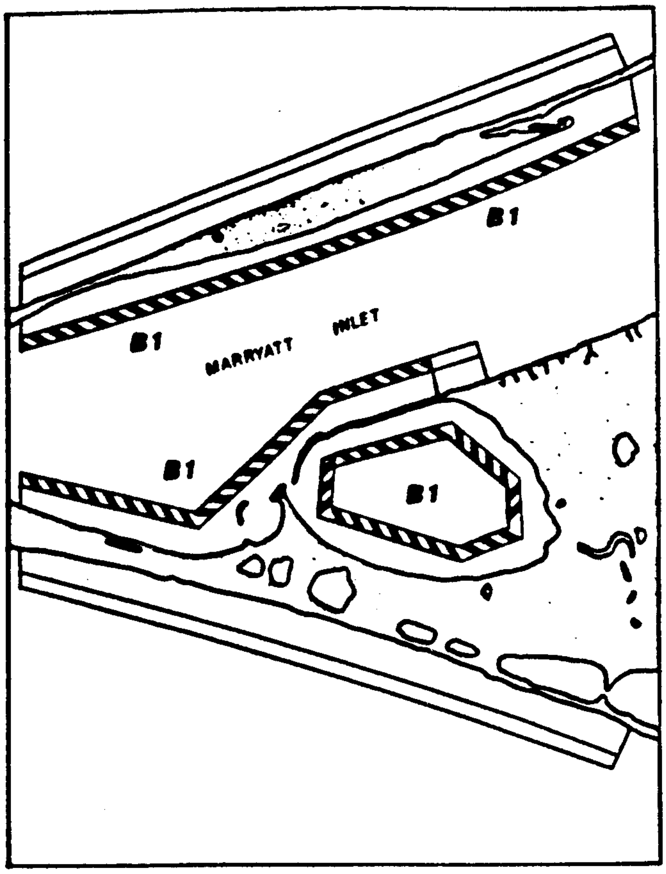
80

OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



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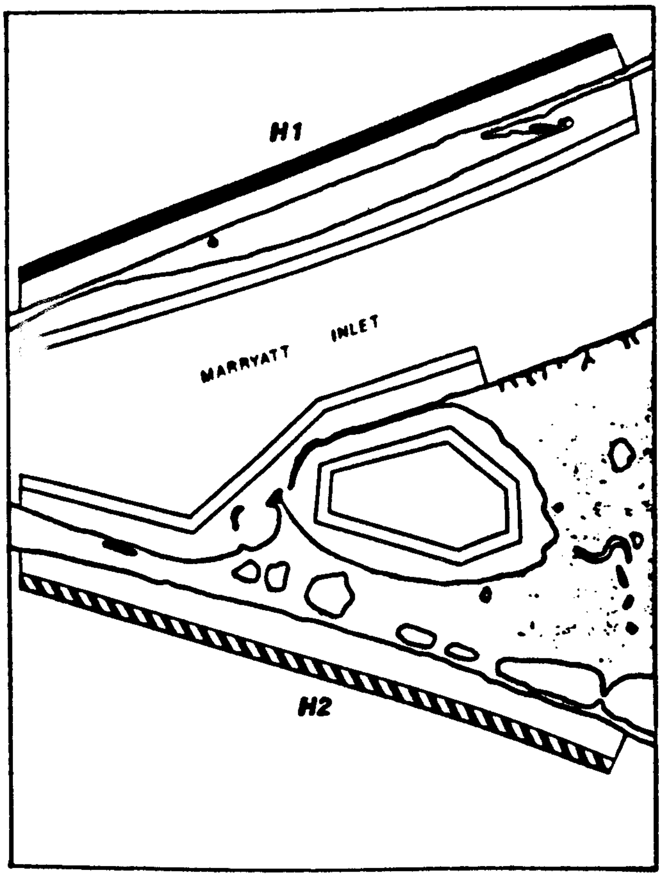
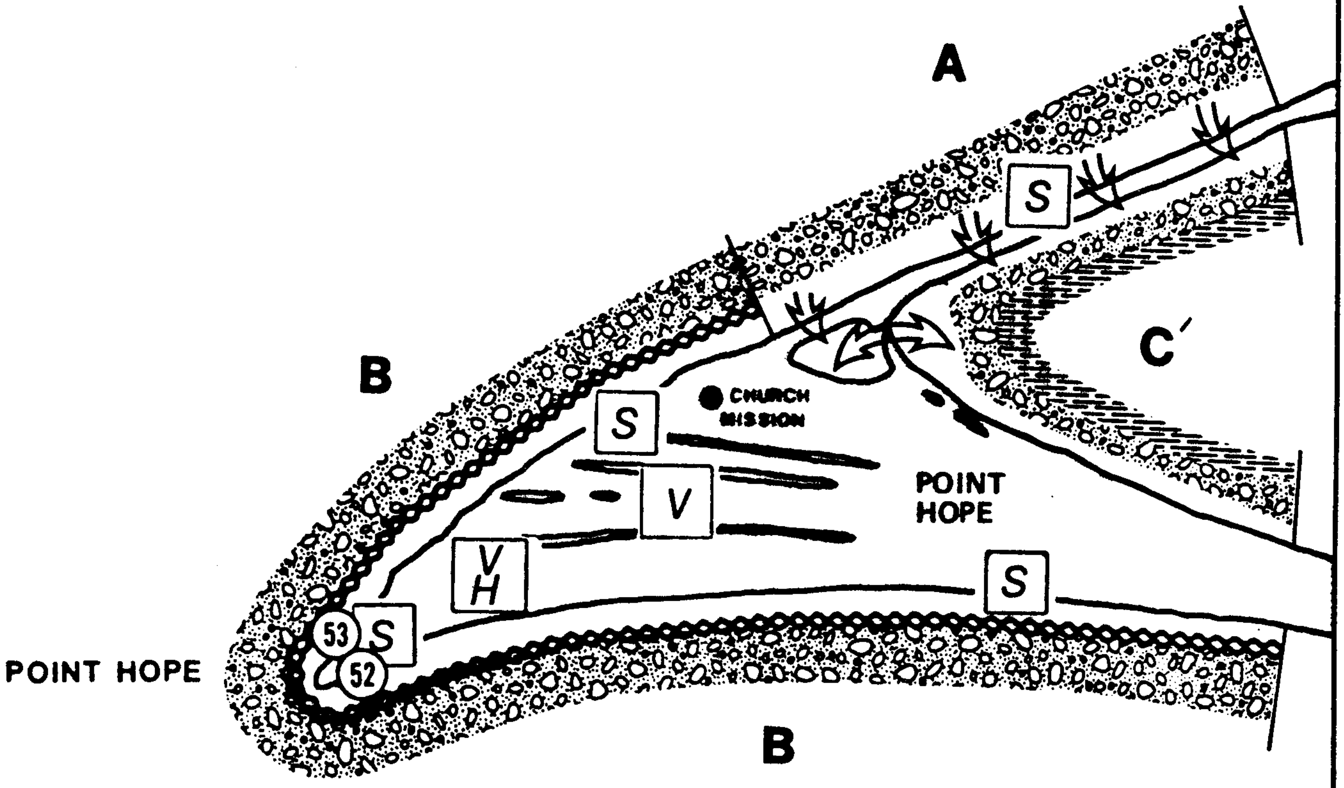


Seasonal Variability of Indices

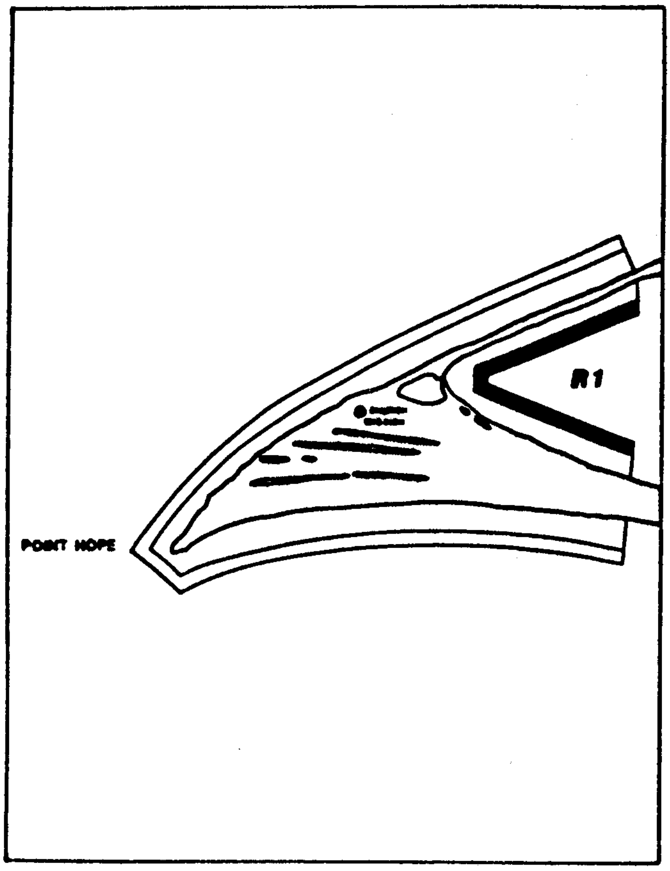
Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach			■	■	■	■		
R2	Protected tundra cliff			▨	▨	▨	▨		
R3	Very protected tundra cliff; Beach			■	■	■	■		
R4	Washover channel; Lagoon			■	■	■	■		
B1	Shorebirds migration; staging				▨	▨			
	Waterfowl migration; staging			▨	▨	▨	▨		
H1	Waterfowl hunting			■	■				
	Fishing			▨	▨	▨	▨		
H2	Fishing			▨	▨	▨	▨		

80

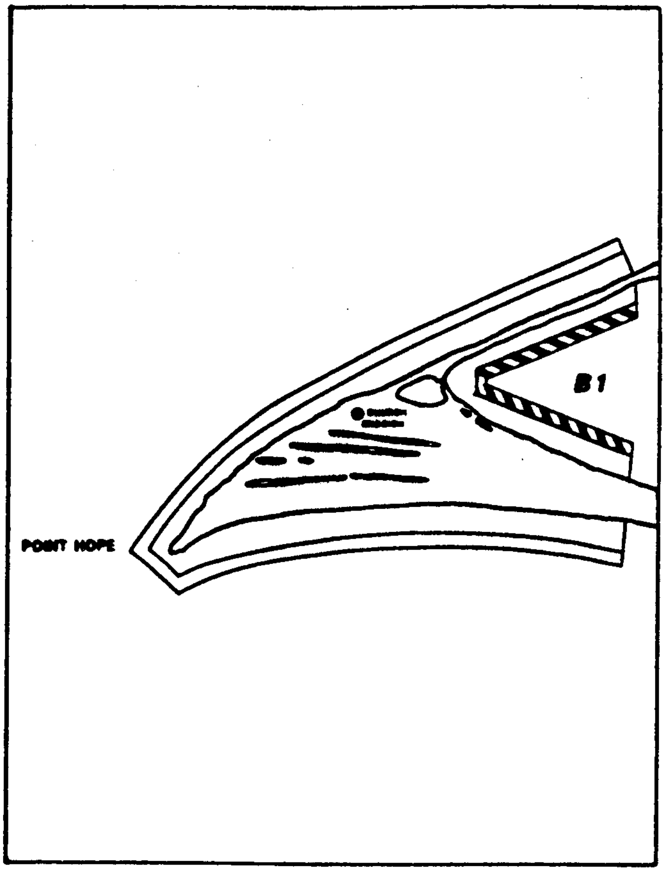


81

OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



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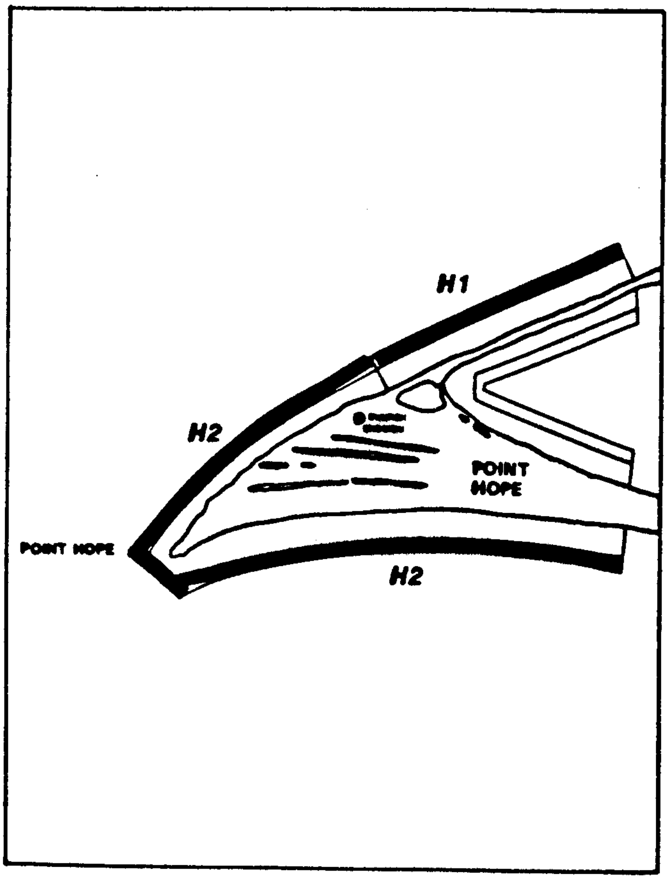
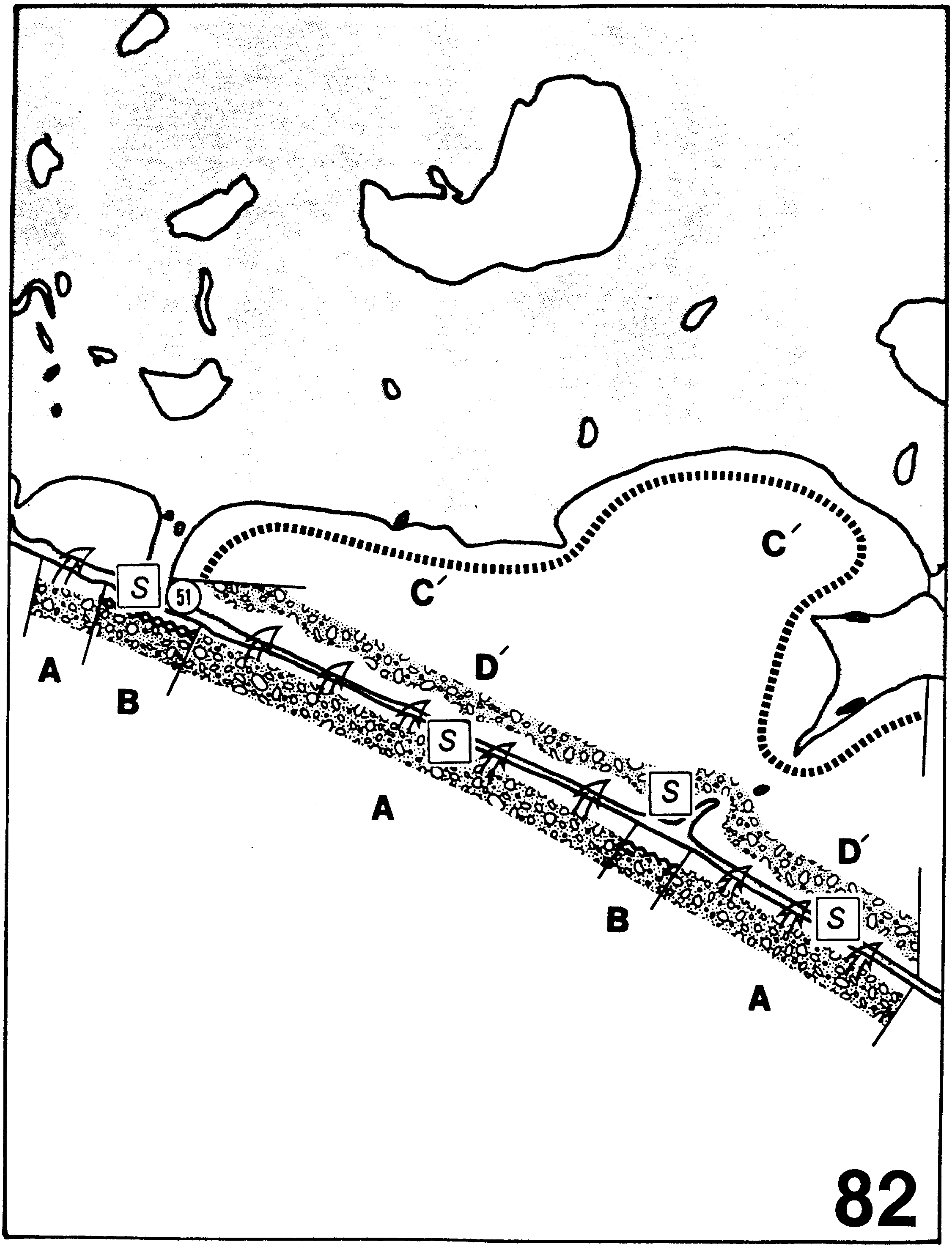


Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach			■	■	■	■		
B1	Shorebirds migration; staging				▨	▨			
	Waterfowl migration; staging			▨	▨	▨	▨		
H1	Fishing			▨	▨	▨	▨		
	Subsistence access			■	■	■	■	■	
	Resident recreation			■	■	■	■	■	
H2	Village of Point Hope			■	■	■	■	■	
	Subsistence access			■	■	■	■	■	
	Resident recreation								
	Fishing			▨	▨	▨	▨		

81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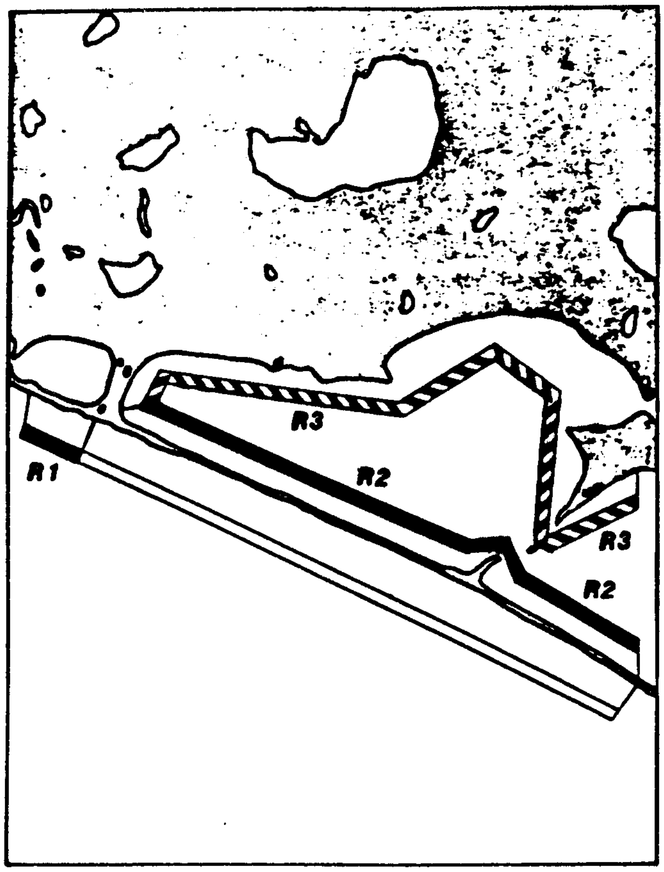
82

OIL RESIDENCE INDEX



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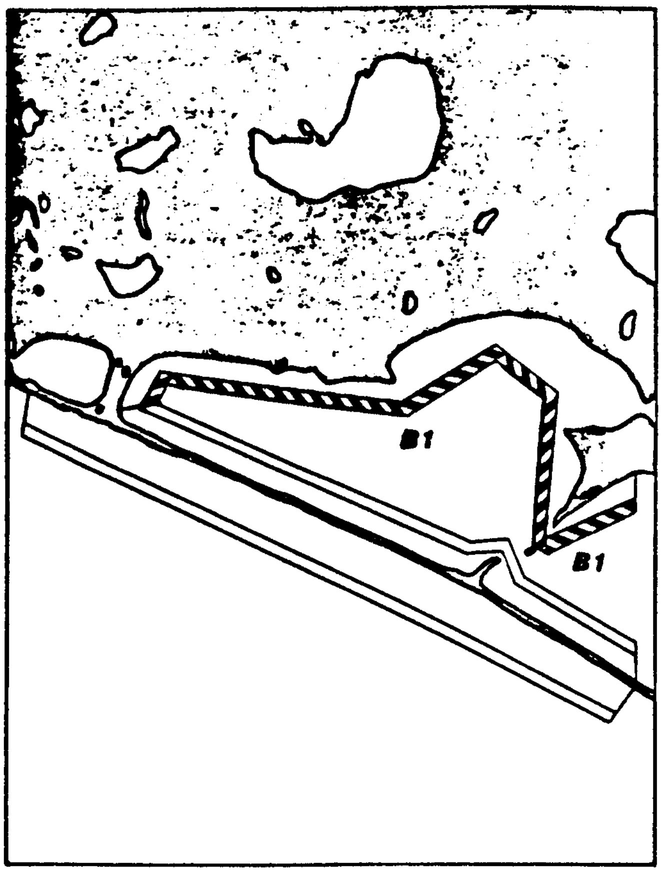

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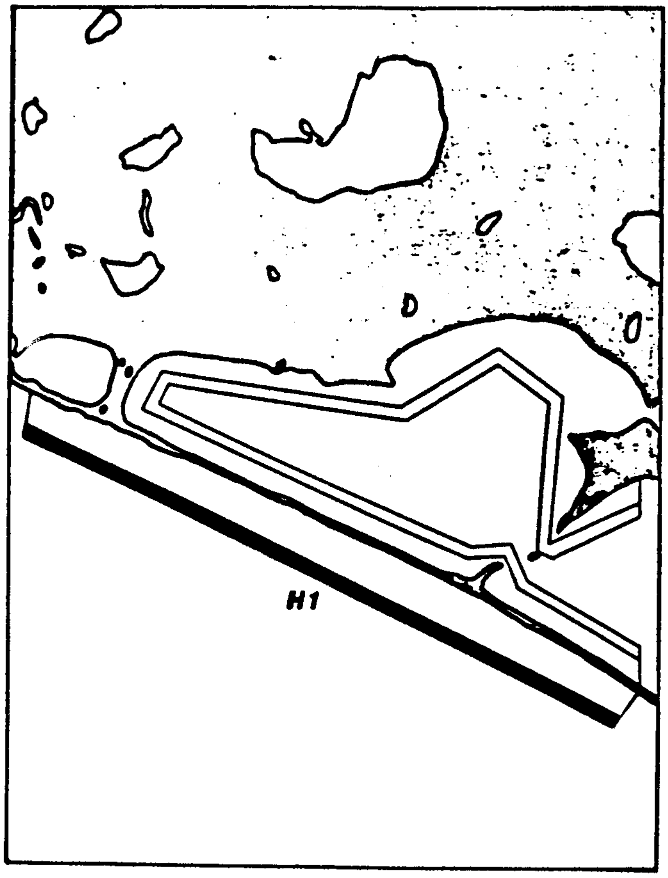
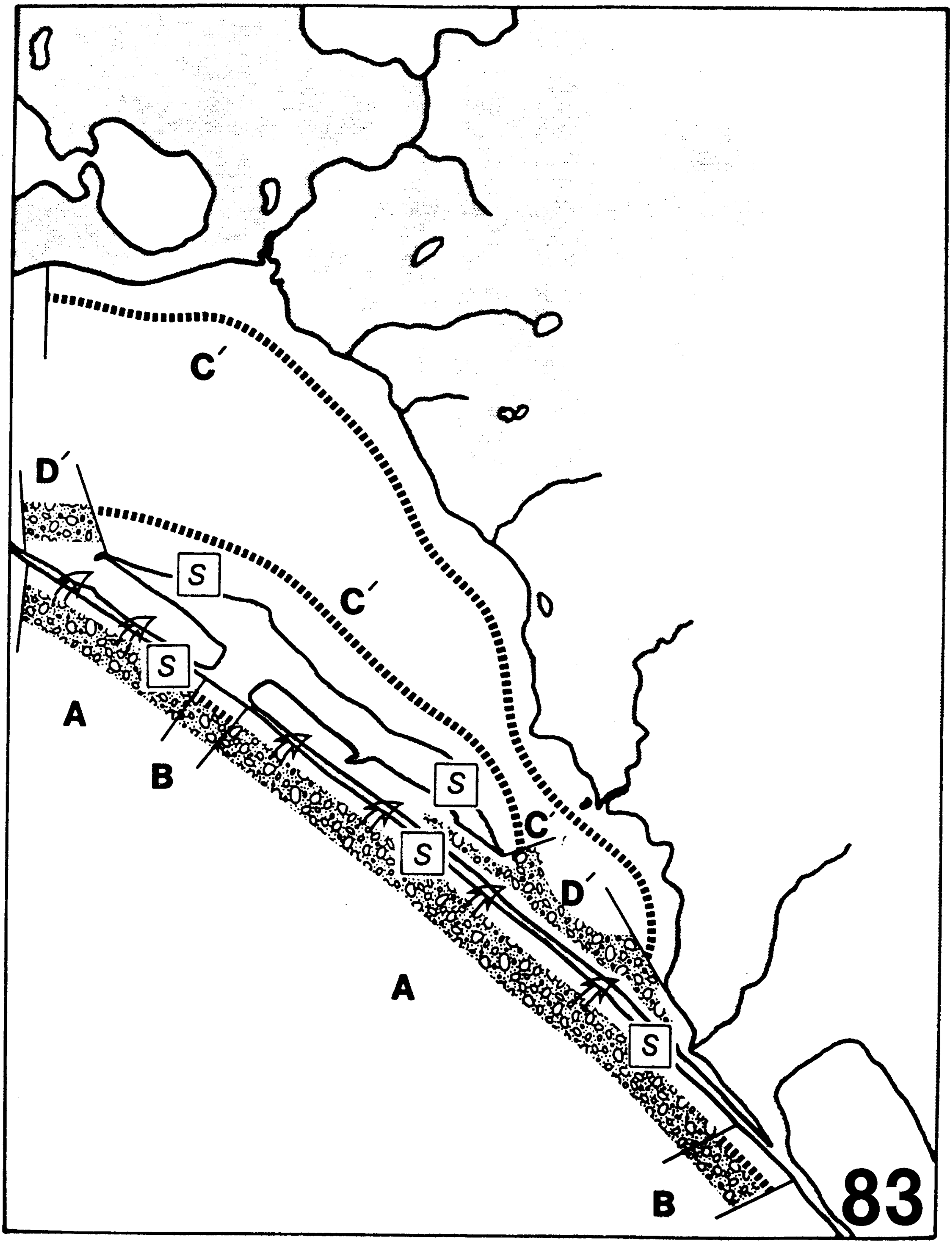


Seasonal Variability of Indices

Identi-fier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Washover channels; Lagoon			■	■	■	■	■	
R2	Low energy beach			■	■	■	■		
R3	Protected tundra cliff			▨	▨	▨	▨		
B1	Shorebirds migration; staging				▨	▨			
	Waterfowl migration; staging			▨	▨	▨	▨		
H1	Waterfowl hunting			■	■				
	Fishing			▨	▨	▨	▨		

82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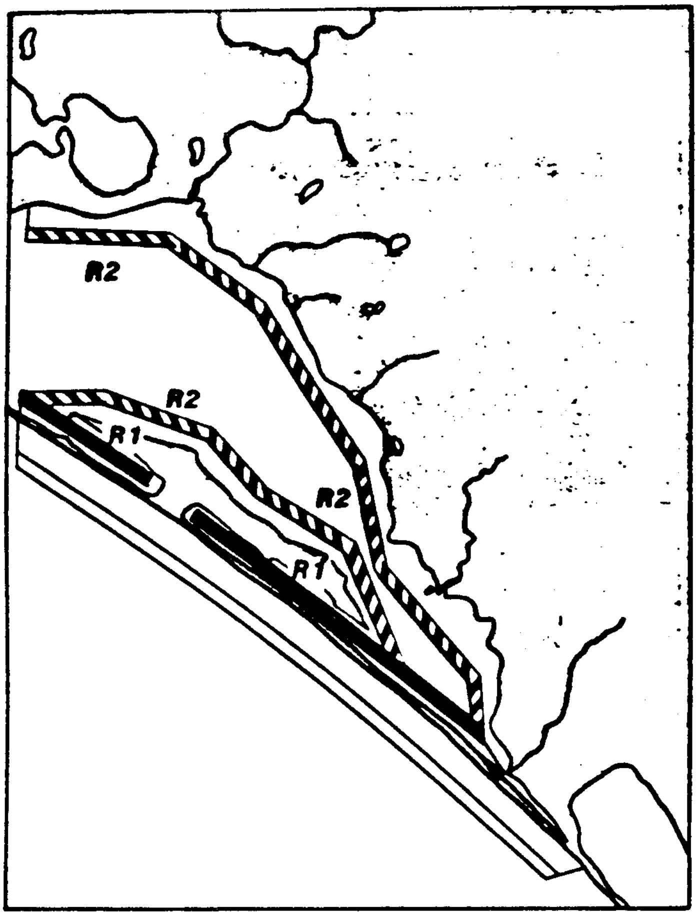
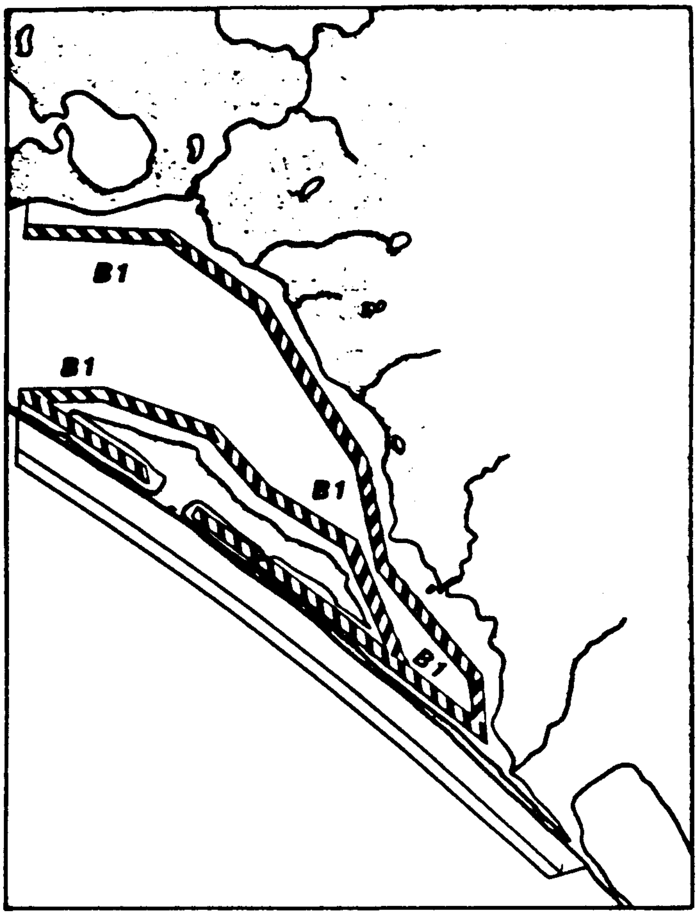
83

OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX



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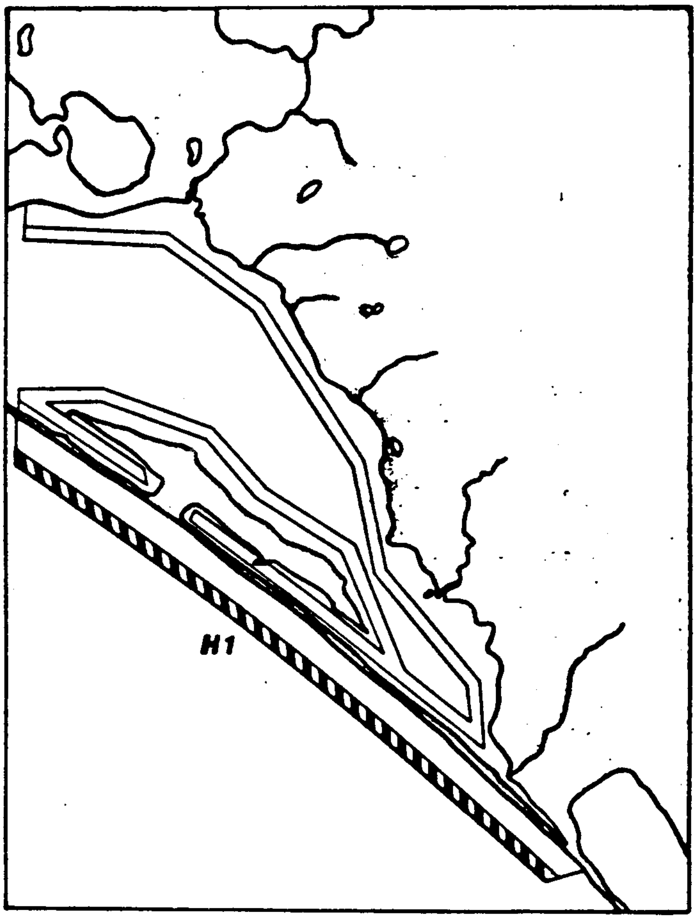
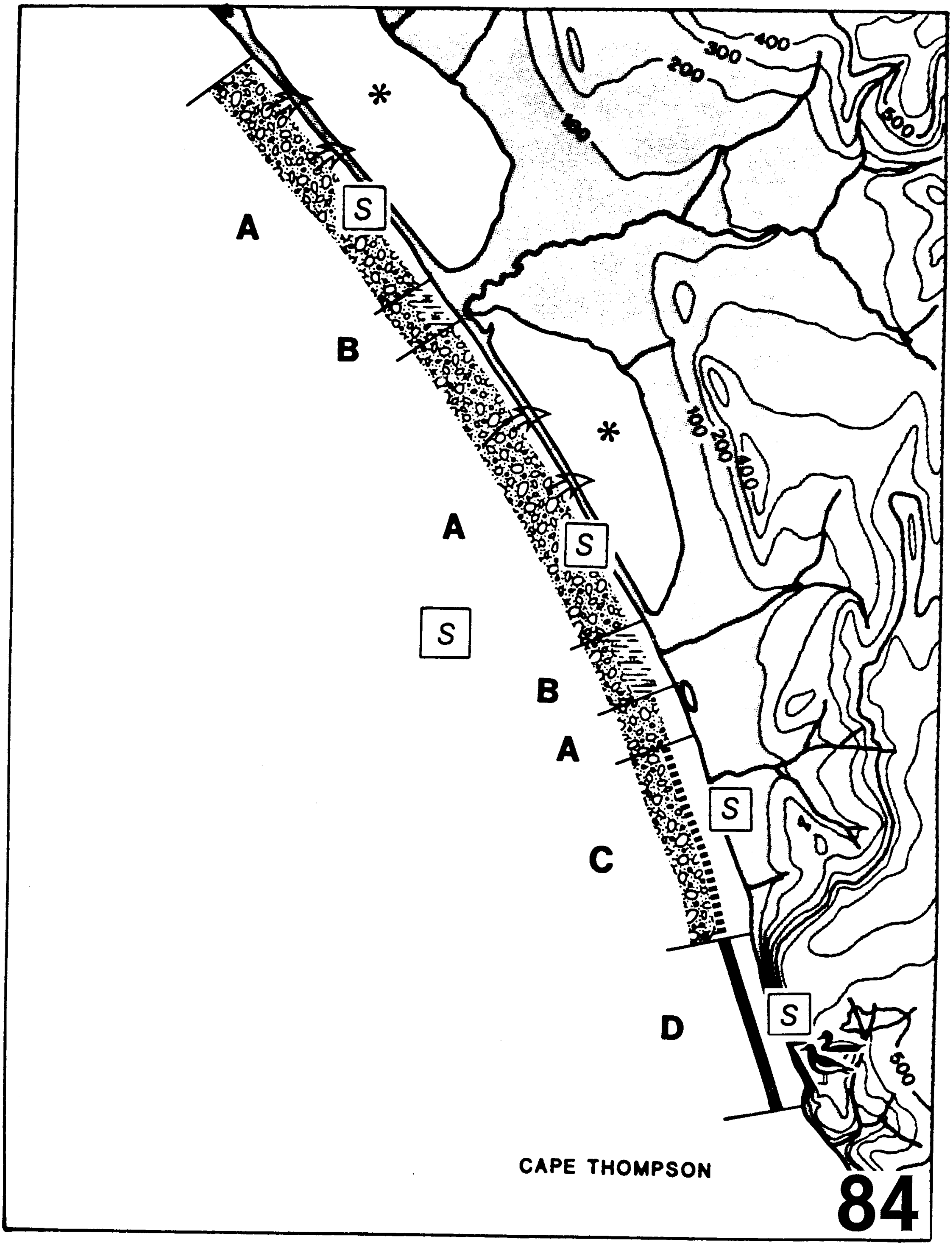


Seasonal Variability of Indices

		SEASON							
Identifier	RESOURCE	Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Low energy beach			■	■	■	■		
R2	Protected tundra cliff			▨	▨	▨	▨		
B1	Shorebirds migration; staging				▨	▨			
	Waterfowl migration; staging			▨	▨	▨	▨		
H1	Waterfowl hunting			▨	▨				
	Fishing			▨	▨	▨	▨		

83



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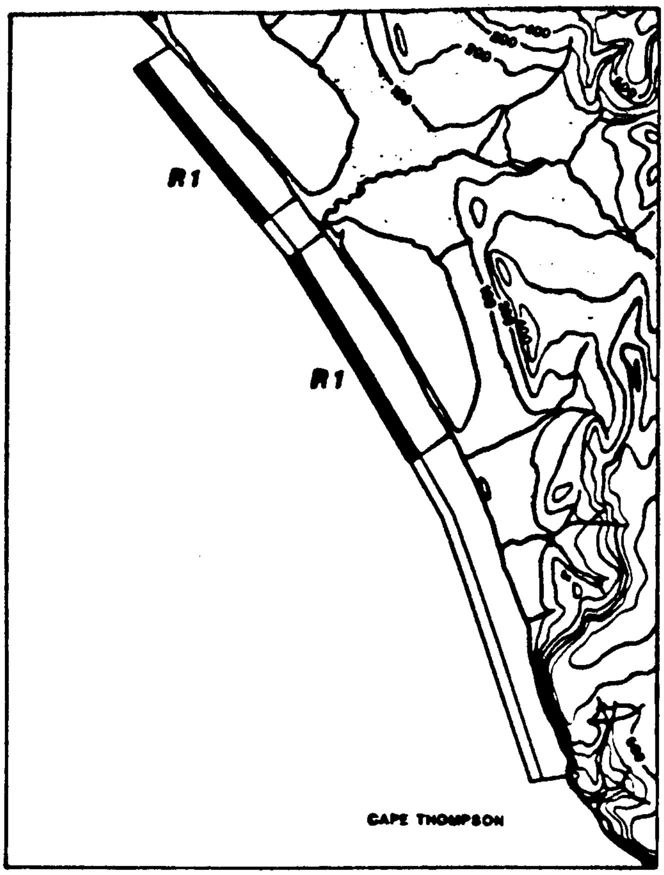
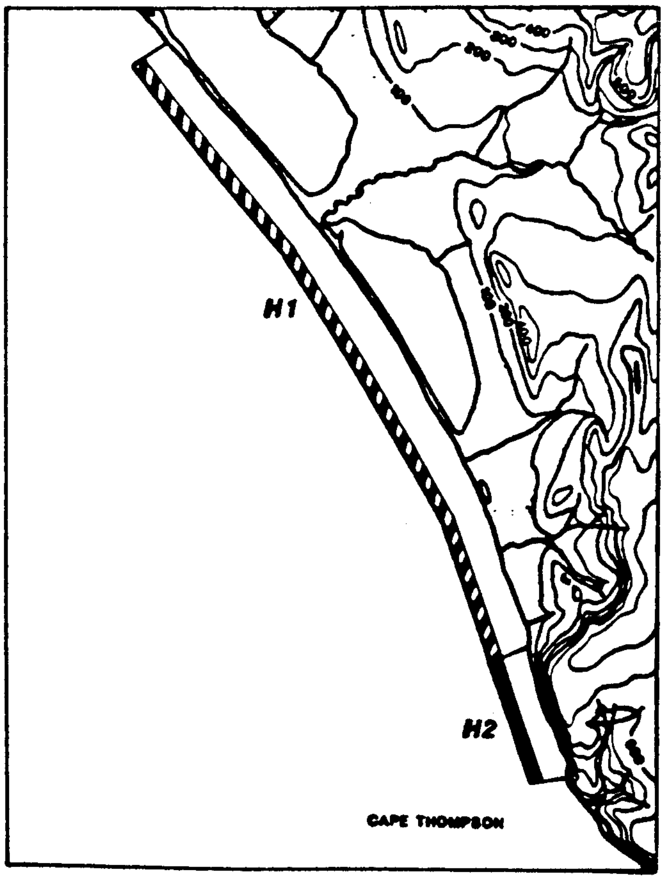
CAPE THOMPSON
84

OIL RESIDENCE INDEX



BIOLOGICAL SENSITIVITY INDEX

HUMAN USE INDEX



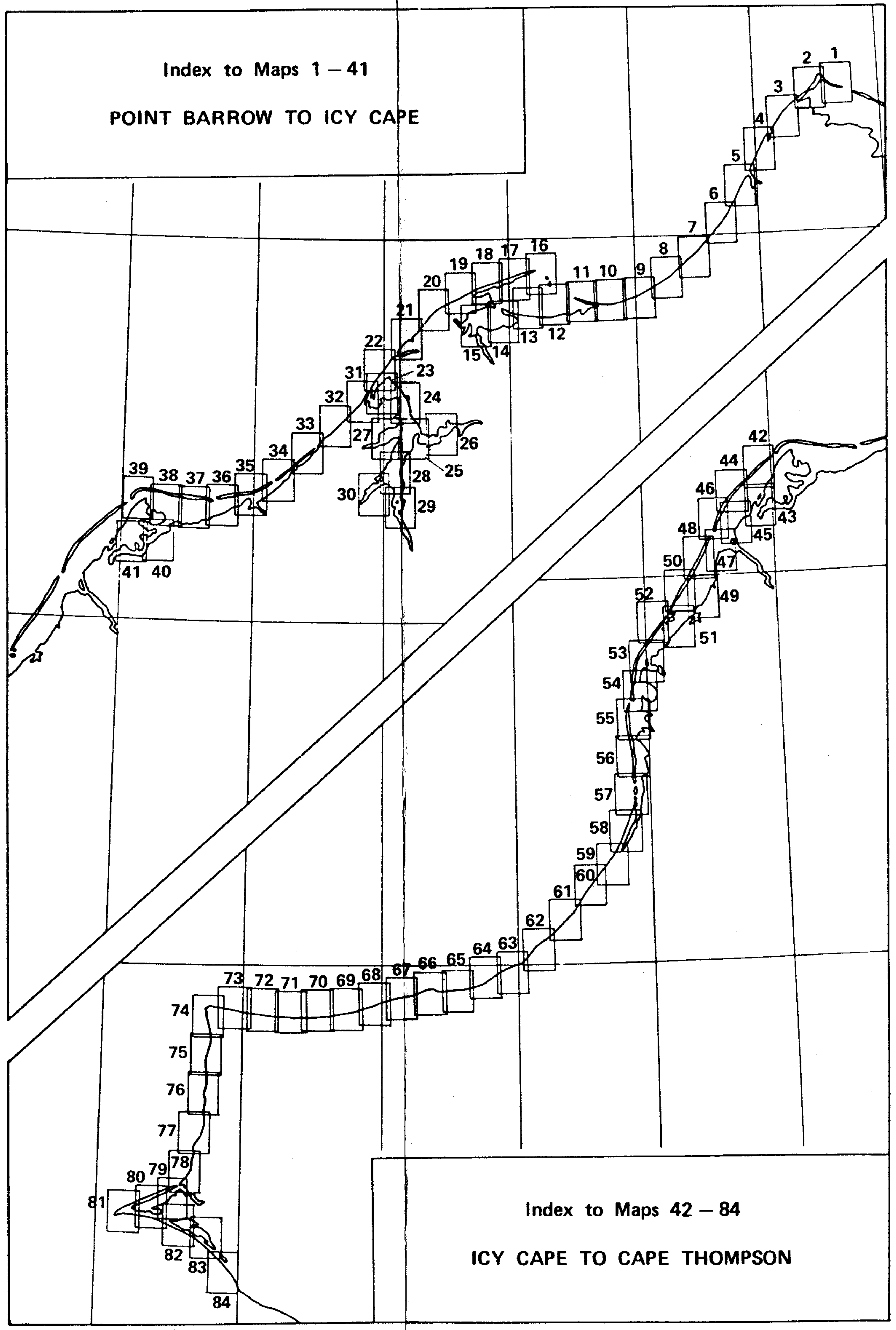
Seasonal Variability of Indices

Identifier	RESOURCE	SEASON							
		Winter	Break-Up/Summer/Freeze-Up						Winter
			May	Jun	Jul	Aug	Sep	Oct	
R1	Washover channels; Lagoon			■	■	■	■		
B1	Seabird colony murres (217,000 pr), kittiwake (10,200 pr), puffins (700 pr), others (100 pr)		■	■	■	■	■		
H1	Waterfowl hunting			▨	▨				
	Fishing			▨	▨	▨	▨		
H2	Egg gathering			■	■				

84

COASTAL SENSITIVITY LEGEND

OIL RESIDENCE INDEX	PRIMARY CONCERN	▬	Lengthy oil-residence time (more than one open-water season); low mechanical wave-energy levels at the shore likely to result in a slow removal rate of stranded oil.
	SECONDARY CONCERN	▨	Variable oil-residence time (weeks to more than one open-water season); residence time may vary substantially due to variations in wave exposure, substrate type, and spill characteristics.
	TERTIARY CONCERN	═	Short oil-residence time (days to weeks of open-water season); high mechanical wave energy levels at the shore and substrate types that prevent oil penetration are likely to result in rapid removal of oil from the shore.
BIOLOGICAL SENSITIVITY INDEX	PRIMARY CONCERN	▬	Major change expected in distribution, size, structure or function of affected biotic resources (population, community or habitat); recovery from these changes likely to require several open-water seasons.
	SECONDARY CONCERN	▨	Moderate change expected in distribution, size, structure or function of affected biotic resources (population, community or habitat); recovery from these changes are expected to require one to several open-water seasons.
	TERTIARY CONCERN	═	Little or no change expected in distribution, size, structure or function of affected biotic resources (population. community or habitat); recovery from these changes are expected to require less than one open-water season.
HUMAN USE INDEX	PRIMARY CONCERN	▬	Important or intensive human-use activities likely to be disrupted for one or more open-water seasons.
	SECONDARY CONCERN	▨	Moderate impact of some human-use activities for some portion of one open-water season.
	TERTIARY CONCERN	═	Non-intensive human-use activities unlikely to be impacted for more than a short period of one open-water season.


Index to Maps 1 – 41
POINT BARROW TO ICY CAPE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
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64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
Index to Maps 42 – 84
ICY CAPE TO CAPE THOMPSON

CHUKCHI SEA COASTAL STUDIES: COASTAL GEOMORPHOLOGY, ENVIRONMENTAL SENSITIVITY, AND PERSISTENCE OF SPILLED OIL

PART III. COASTAL RESOURCE TABLES

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Jon Isaacs,[3] and Carl Foget[4]**

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[4] Deceased

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

1.0

INTRODUCTION

This part contains the 84 Chukchi Sea coastal resource tables that provide additional information on the coastal resource maps in Part II and provide support for the priority levels assigned for the Oil Residence Indices (ORI), Biological Sensitivity Indices (BSI), and Human Use Indices (HUI). These coastal resource tables contain an additional level of detail on the physical, biological, or human uses of each repetitive shore-zone unit of the coastal zone. This detail is beyond that appearing on the maps. It allows a comparatively simple and useable map format to be retained while at the same time providing a high level of detail on shore-zone characteristics for planners and others requiring the detail.

2.0
USE OF COASTAL RESOURCE TABLES

2.1 GENERAL

This section describes how to use the tables and the contents of the tables. Following the table for Map 84 is a foldout which presents the Coastal Resource Table Legend. This legend briefly describes each of the major categories in the table. For additional information, the user is referred to Part I.

The tables only include the shore-zone resources; that is, those from the low water mark to the prominent storm surge line, typically about 2m above normal water level. The exception are the human uses and some of the biological resources in the major passes through the barrier islands and the human uses of the major lagoon systems. The physical, biological and human use characteristics of the nearshore and offshore open water areas were explicitly not included in this study (though they may be affected by an oil spill and be equally or more important than the shore-zone ones).

2.2 CROSS REFERENCE TO MAPS

Each table is identified in the upper right corner with a Map Number from 1 to 84 for immediate cross-reference between the maps and tables. In a few cases, there are 2 pages of information for a map; these are identified as "Page 1 of 2" and "Page 2 of 2".

The information in the tables is related directly to the repetitive shore-zone units presented on the maps. The mapping method is described in detail in Part I but is described briefly in the next section (2.3) to facilitate understanding of how the unit identifiers are obtained and how to use the maps and tables.

The unit identifiers on the Coastal Resource Maps (Part III) correspond to the unit identifiers listed in the left-hand column of the Coastal Resource Tables.

For consistency, the biological and human use resources are described within the physical unit(s) where the resource(s) appear. Where the biological or human use resource extends over 2 or more physical units, the description of the resource, activity, and season-use chart are simply repeated within each physical unit.

2.3 MAPPING METHOD

The mapping method defines a series of shoreline <u>units</u> that are physically homogeneous along a section of coast (Figure 2-1). These units or shore-zone types represent a set of shore-zone components that occur repeatedly in the same combination throughout the study area. The across-shore components are based on geomorphological and/or textural characteristics that are homogeneous both across-shore and alongshore. These physical shore-zone components are described in Table 2-1.

The map format identified the boundaries of units longer than 0.25km in two ways: (a) change in the distinctive graphic pattern used for each shore-zone type (Figure 2-2) and (b) lines perpendicular to the shoreline at each end of the unit (Figure 2-3).

Each shore-zone unit on a map is uniquely identified for that map with a capital letter. Units identified by a letter followed by a superscript "prime" are located on the lagoon shoreline while letters without a "prime" are located on the open Chukchi Sea coast. Water bodies (e.g., lagoons, passes, bays, inlets) are identified by name. Where the same shore-zone type is present on both the lagoon and the

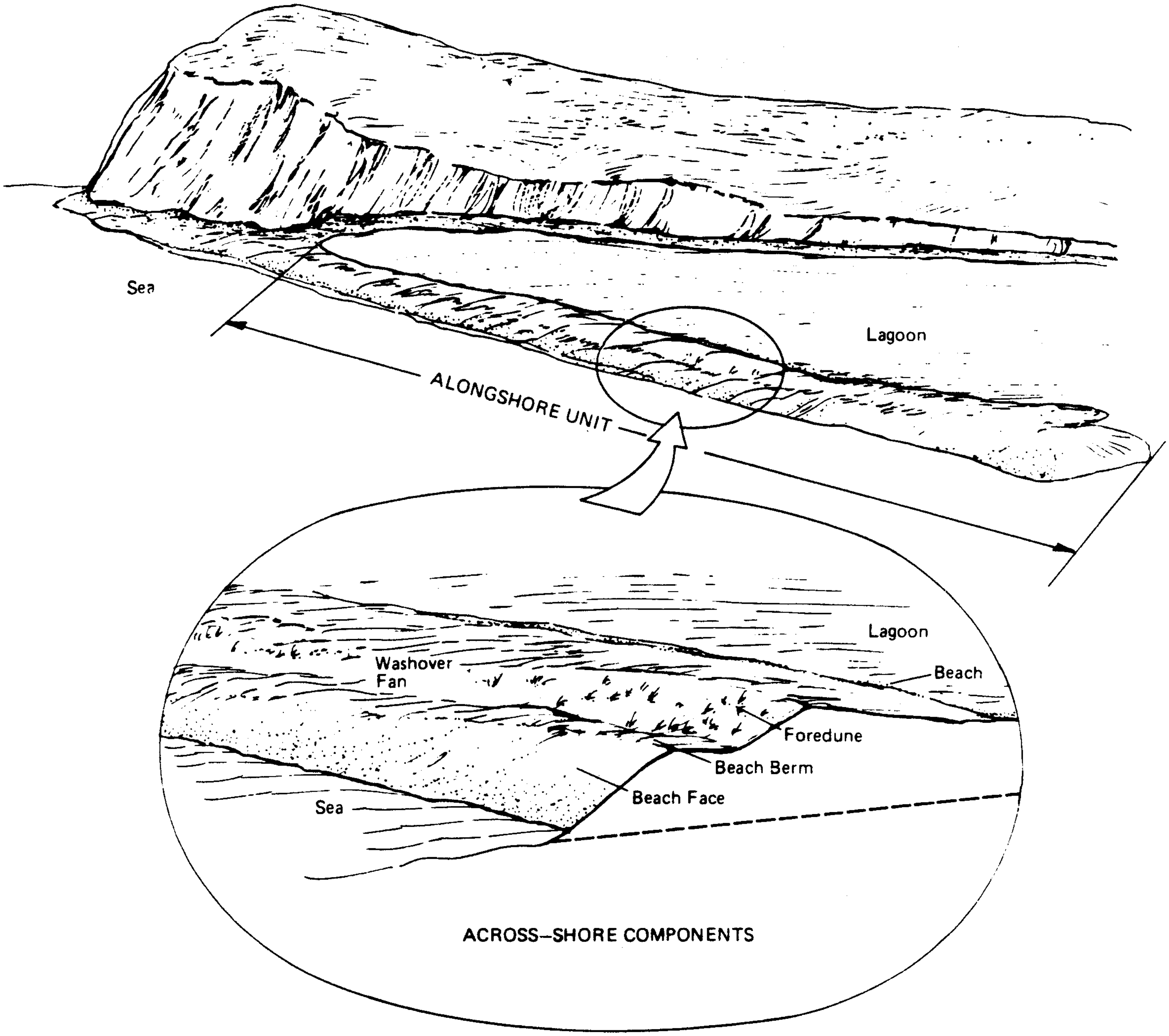

Figure 2-1. ILLUSTRATION OF THE MAPPING APPROACH

Table 2.1. EXPANDED LEGEND OF PHYSICAL SHORE-ZONE COMPONENTS

SHORE-ZONE COMPONENTS

Rock Cliffs - primary morphology is that of a steep cliff cut by waves into the bedrock substrate. Cliff slopes are typically steep (greater than 45°) and fringing beaches are rare. Pocket beaches of gravel sized material may occur in small indentations along the base of the cliffs. Bedrock types include sedimentary sandstones in the northern portion of the study area (Skull Cliff, Peard Bay, Kuk River) to meta sedimentary and igneous in the southern portion of the study area (Cape Sabine, Cape Lisburne, Cape Thompson).

High Tundra Cliffs - wave-cut cliffs formed in unconsolidated Quaternary sediments. Relief from cliff base to cliff edge is greater than 5 m (approximately 15 ft). Cliff sediments are bonded by permafrost and are usually "ice-poor", although massive ice beds do occur locally. Slopes are usually less than 45° and are dominated by surface wash and debris slide mass-wasting processes. Coastal retreat rates, where documented, are less than 1 m/yr. Fringing gravel beaches typically occur at the cliff base.

Low Tundra Cliffs - wave-cut cliffs formed in unconsolidated Quaternary sediments. Relief from cliff base to cliff edge is less than 5 m (approximately 15 ft). Cliff sediments are bonded by permafrost and are usually "ice rich." These cliffs are most common in lagoons and near open-coast river mouths. Coastal retreat con be rapid (> 1m/yr) on some cliffs (usually steep slopes, >45°, indicate rapidly retreating cliffs), although most cliffs appeared retreating only slowly in comparison with those of the Beaufort Sea coast. Narrow fringing sand or gravel beaches are typically associated with these cliff types.

Mixed Sediment Beaches - the vast majority of beaches along the Chukchi Sea coast are comprised of a mixture of sand and gravel-sized sediment. Mixed-sediment beaches are widely distributed and are associated with both/barrier islands and tundra cliffs. Additional detail on size composition of sediment within the unit is provided in the resource tables. (Note: gravel includes sediment greater than 2 mm in diameter; sand includes sediments with diameters of 0.06 to 2.0 mm).

Sand Beaches - sand beaches occur at the distal ends of some barrier spits (the eastern Peard Bay spit, for example). Sand-sized material comprises more than 80 percent of the total sediment mass. Sand beaches may occur locally along the lagoon shores as well.

Table 2.1. EXPANDED LEGEND OF PHYSICAL SHORE-ZONE COMPONENTS (continued)

SHORE-ZONE COMPONENTS

Mud/Sand Flats - wide (>100 m or 300 ft) intertidal flats occur within the lagoon systems of the Chukchi Sea coast. These flats are typically associated with river deltas, flood-tidal deltas on the seaward side of the lagoon, with washover fans on the barrier islands and with other smaller scale coastal features along the mainland coast. Sediment texture on the flats usually grades from sand-sized material in the upper portion of the shore zone to mud-sized material in the lower shore-zone.

Wetlands - low elevation, generally flat areas with standing water for most of the snow or ice-free season. They are subject to occasional storm innundation but are generally not covered by the normal astronomical tides. Vegetation is salt-tolerant and dominated by the grass, Puccinella spp. Wetlands are low energy environments primarily on borders of small estuaries, deltas and the lagoon side of barrier islands.

Lagoons/Estuaries - protected embayments such as small lagoons or estuaries, which are too small to map separately, are delineated by a site symbol. Lagoons and estuaries typically encompass low-energy coastal features such as mudflats or wetlands, which can not be shown on the map due to the small scale of the feature. Lagoons and estuaries are necessarily connected to marine water areas by either a washover channel, or an inlet.

Inlets - inlet provide a critical water exchange link between protected lagoons, estuaries or bays. Inlet widths vary, although most are less than 1.5 km (approximately 0.25 mi) in width (with the exception of the Peard Bay inlets). Inlets which have been permanently open for the past few years are mapped as stable inlets. Inlets which are only open seasonally, such as during spring freshet or during storm-surges or which open and close on a year-to-year basis are mapped as ephemeral inlets.

SHORE-ZONE MODIFIERS

Washover Channels and Fans - washover fans and channels are activated during storm surges and provide an important water exchange conduit during storm surges. Water exchange is in only one direction, landward-directed (return flow occurs through inlets or through ground-water seepage. Washover channel and fans are found on low, usually unvegetated, barrier islands and on small baymouth bars enclosing lagoons and estuaries.

Table 2.1. EXPANDED LEGEND OF PHYSICAL SHORE-ZONE COMPONENTS (concluded)

SHORE-ZONE COMPONENTS

Barrier Island Vegetation - barrier island vegetation is mapped as a shore-zone modifier for open coast barrier islands where significant densities of vegetation occur. Vegetation on the Chukchi Sea side of the barrier islands is primarily dune grass (*Elymus arenarius mollis*). On the lagoon side, the vegetation is typically one for more species of grass, primarily *Puccinella* spp. The presence of vegetation usually indicates a greater barrier island stability (i.e., stable or accretional) and less frequent over-topping during storm surges.

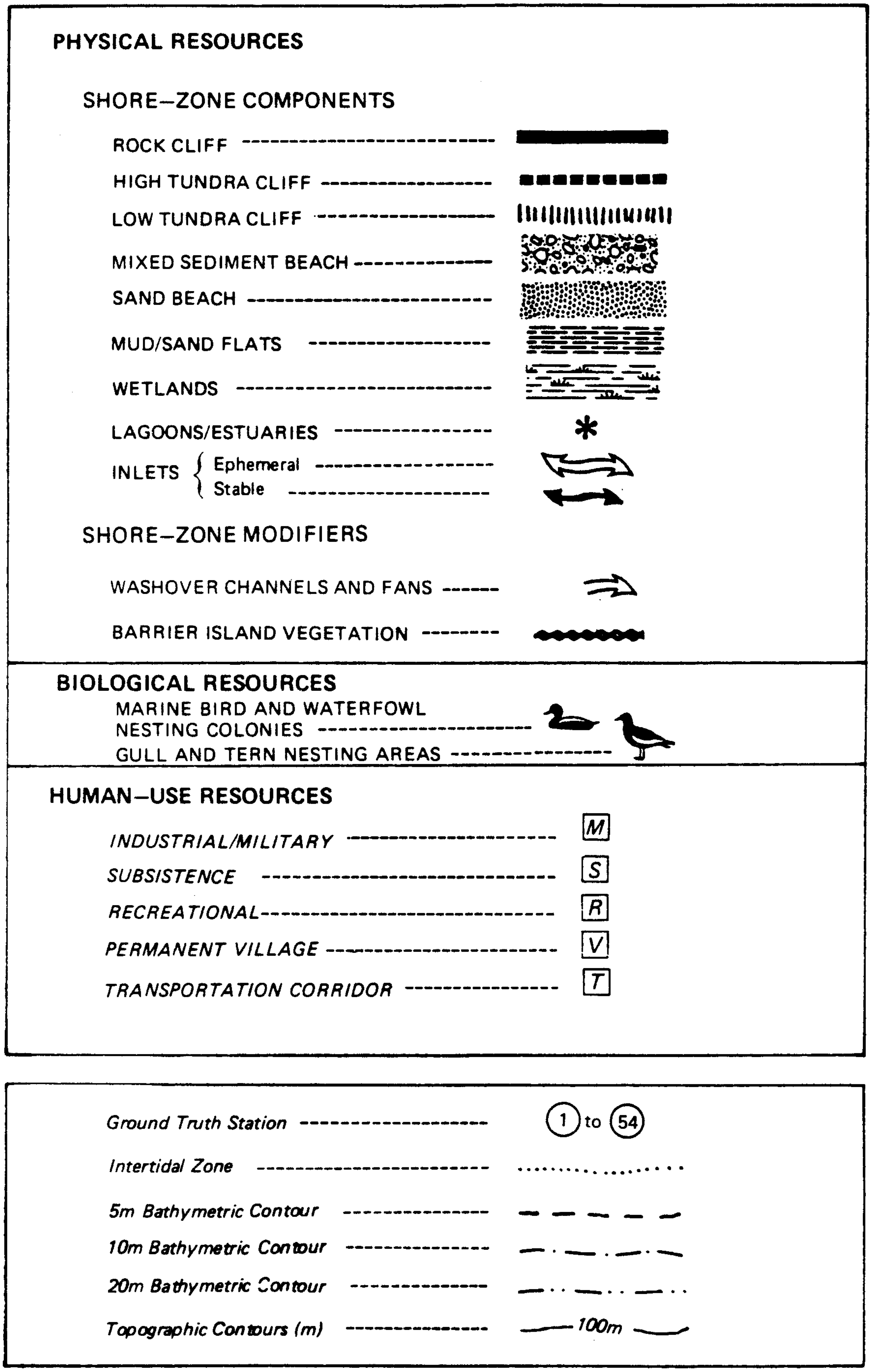

Figure 2-2. MAPPING PATTERNS USED FOR SHORE-ZONE COMPONENTS

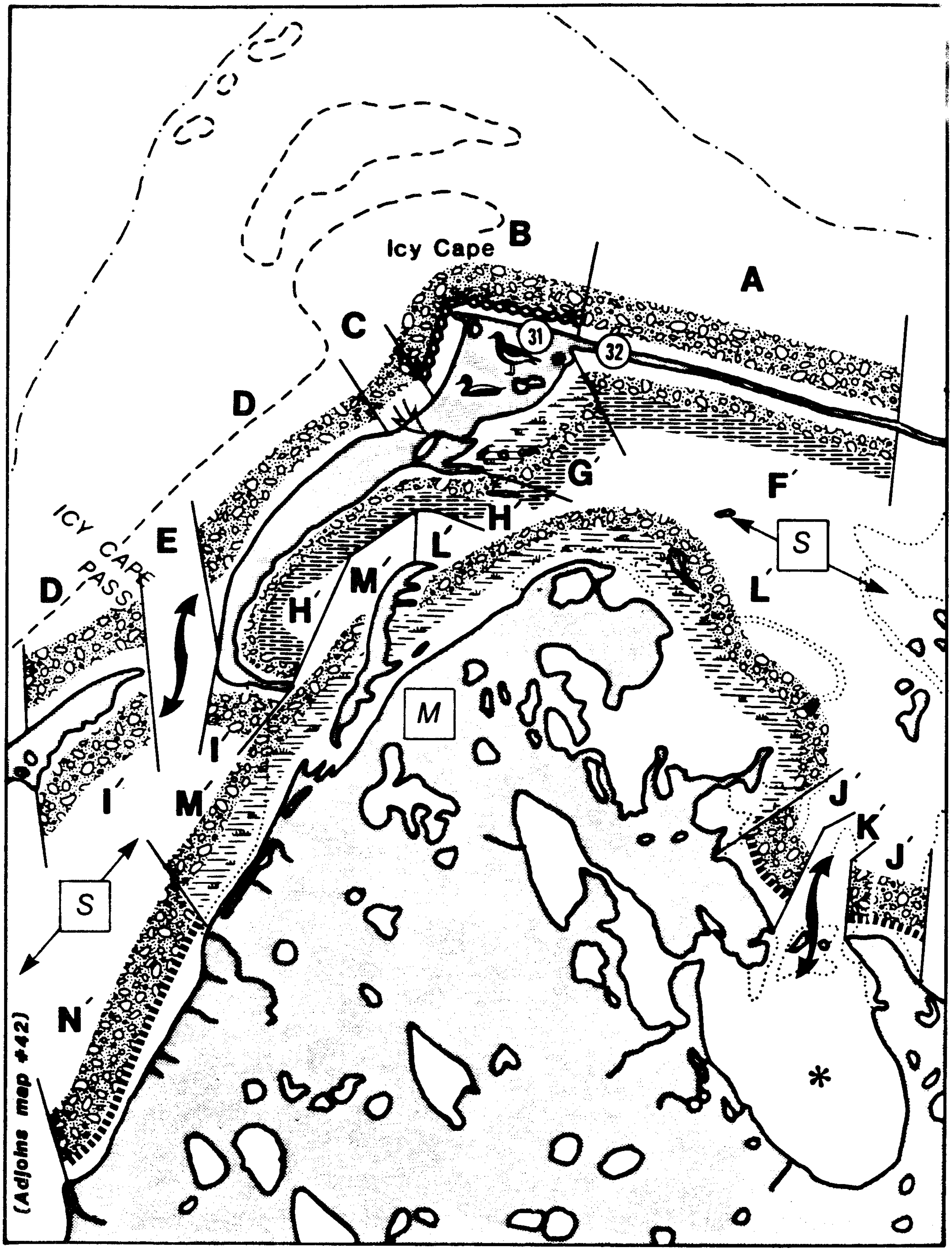

Figure 2-3. EXAMPLE OF COASTAL RESOURCE MAP FROM PART II

Chukchi Sea sides of a barrier island or spit, the shorezone is considered two separate units and each is given a unique unit identifier. The perpendicular line dividing them on the map is arbitrarily placed at the tip of the island or spit where maximum fetch and wave exposure changes.

The unit identifiers (i.e., the capital letters) are applied to the shore-zone unit in a generally north to south direction. Where there are exposed or open as well as lagoon coasts, the unit identifiers are applied: (a) first to the open coast side of the barrier island, (b) next to the lagoon side of the barrier island or spit, and (c) finally to the mainland shore. Only one unit will be identified with a letter (which may be further modified with a "prime" sign) so ideally each letter would appear only once on each map. However, on some maps, it is nessary to label the unit several times reduce confusion. Figure 2.3 illustrates the unit identifier labeling scheme.

Note that the unit identifiers are simply that; they uniquely identify the unit(s) on each map and in the tables. There is <u>no</u> explicit or implied relationship or similarity between units on different maps labelled with the same unit identifier. For example, the unit labelled <u>D</u> on Map 39 (Figure 2-3) is a sandy gravel beach while unit <u>D</u> on Map 40 is a permanent inlet (Figure 2-4).

The location or boundaries for the biological and human use resources may not coincide with the physical shore-zone type boundaries. The wetlands, a biological resource, are also a physical shore-zone type and will have the same bounds. However, bird nesting areas or seabird colonies are typically much smaller than the physical unit. The human use resources which can be mapped as discrete sites, principally villages, military areas and archaeological sites, are typically less areally extensive than the adjacent shore-zone type with which they are associated. These resources are also typically above the storm surge line and thus out of the shore zone as defined in this study.

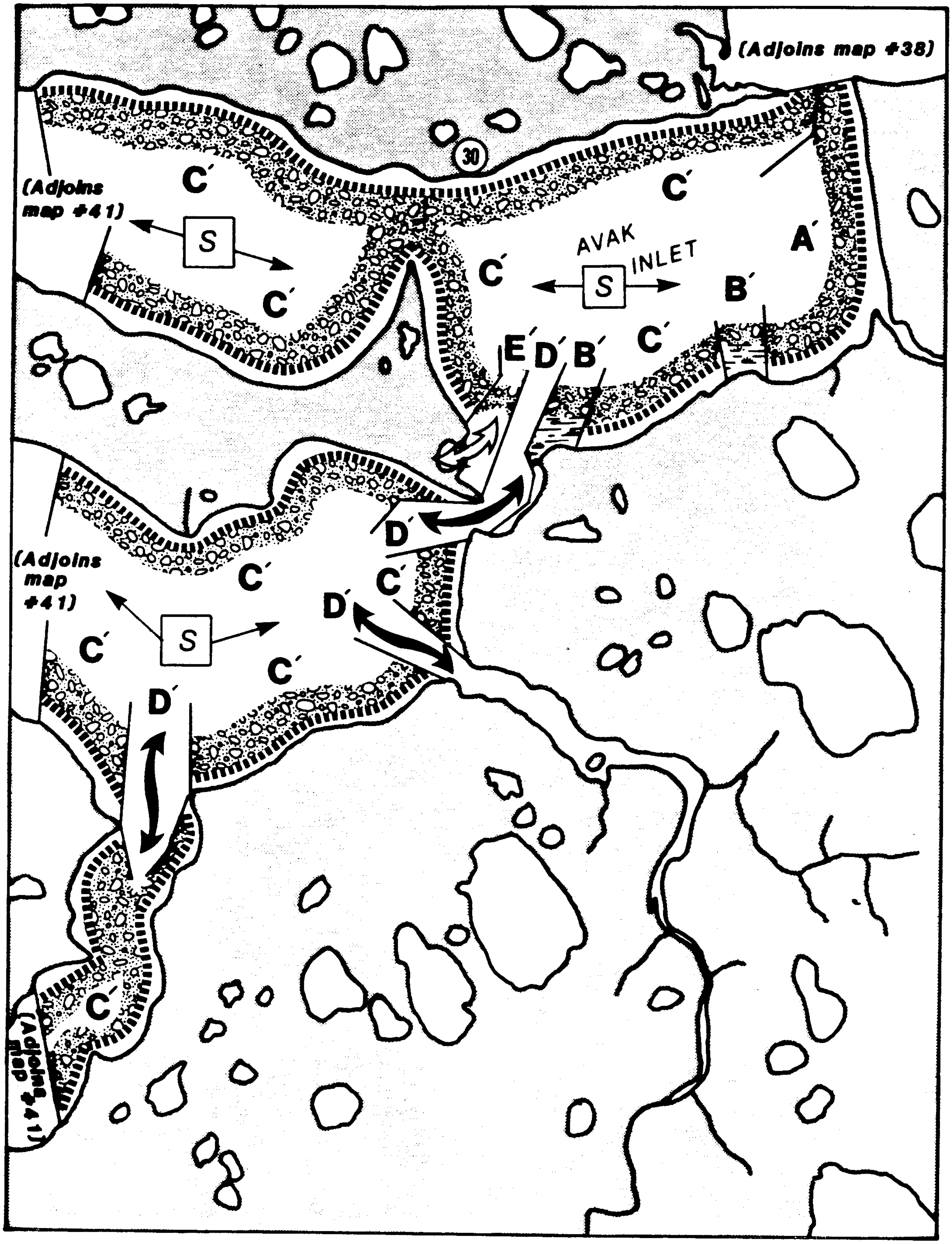

Figure 2-4. EXAMPLE OF COASTAL RESOURCE MAP FROM PART II

Transportation corridors as well as subsistence and recreational areas cannot be as precisely defined. They are shown on the Coastal Resource Maps (Part II) by arrows indicating their approximate extent which typically includes several physical shore-zone units, often over several consecutive maps.

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP I
Page I of I

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	9.5	10-30	<100	Beach	Sandy gravel	Shorebirds	Staging, Migration			●	●								
						Ross's gull	Staging					●	o						
						Oldsquaw	Staging, Molting			●	●	●							
						Common eider	Migration			o	●	o							
						King eider	Migration			o	●	o							
B'	8.0	10-20	10	Beach	Sandy gravel	Shorebirds	Staging, Migration			●	●			Waterfowl hunting	●	●	●	●	
						Ross's gull	Staging					●	o						
						Oldsquaw	Staging, Molting			●	●	●							
						Common eider	Migration			o	●	o							
						King eider	Migration			o	●	o							
Elson Lagoon	--	--	--	Open water area	--									Fishing			●	●	●

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 2
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	7.5	20-30	<100	Small estuary, lagoon	--	Shorebirds	Staging, Migration			●	●			Waterfowl hunting	●	●	●	●	
				Road	Gravel	Ross's gull	Staging					●	o	Subsistence access	●	●	●	●	●
				Beach	Sandy gravel	Oldsquaw	Staging, Molting			●	●	●		Resident recreation	●	●	●	●	●
						Common eider	Migration			o	●	o							
						King eider	Migration			o	●	o							
B	0.8	20-30	<100	Small estuary, lagoon	--									Waterfowl hunting	●	●	●	●	
				Road	Gravel									Subsistence access	●	●	●	●	●
				Beach	Sandy gravel									Resident recreation	●	●	●	●	●
C	3.2	30-50	<100	Small estuary, lagoon	--									Subsistence access	●	●	●	●	●
				Road	Gravel									Resident recreation	●	●	●	●	●
				Beach	Sandy gravel														
D'	4.7	10-50	15	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●	Waterfowl hunting	●	●	●	●	
				Beach	Sandy gravel	Shorebirds	Staging			●	●			Subsistence access	●	●	●	●	●
						Ross's gull	Staging					●	o	Resident recreation	●	●	●	●	●
						Oldsquaw	Staging, Molting			●	●	●							
						Common eider	Migration			o	●	o							
						King eider	Migration			o	●	o							
E'	2.5	20-50	15	Beach	Sandy gravel	Shorebirds	Staging			●	●			Waterfowl hunting	●	●	●	●	
						Ross's gull	Staging					●	o	Subsistence access	●	●	●	●	●
						Oldsquaw	Staging, Molting			●	●	●		Resident recreation	●	●	●	●	●
						Common eider	Migration			o	●	●							
						King eider	Migration			o	●	o							
						Brant	Migration			o	●	●							
F'	1.2	10-20	15	Small estuary, lagoon	--	Shorebirds	Staging			●	●			Waterfowl hunting	●	●	●	●	
				Stable inlet	-	Common eider	Migration			o	●	●		Resident recreation	●	●	●	●	●
				Salt-tolerant wetland	Peat	King eider	Migration			o	●	o							
				Beach	Gravelly sand	Brant	Migration			o	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	1.6	20-30	100-500	Small estuary, lagoon	--	Phalarope	Staging			o	●	o		Subsistence access	●	●	●	●	●
				Ephemeral inlet	--									Resident recreation	●	●	●	●	●
				Road	Sandy gravel														
				Beach	Sandy gravel														
B	2.0	30-50	100-500	Road	Sandy gravel									Subsistence access	●	●	●	●	●
				Beach	Sandy gravel									Resident recreation	●	●	●	●	●
C	3.2	20-30	100-500	Active high tundra cliff	Mud, sand, or gravel									City of Barrow	●	●	●	●	●
														Subsistence access	●	●	●	●	●
				Beach	Sandy gravel									Resident recreation	●	●	●	●	●
D	0.5	5-15	100-500	Road	Mud, sand, or gravel									Community of Barrow	●	●	●	●	●
				Beach	Sandy gravel									Subsistence access	●	●	●	●	●
														Resident recreation	●	●	●	●	●
E	3.8	20-30	100-500	Active high tundra cliff	Mud, sand, or gravel									Subsistence access	●	●	●	●	●
				Beach	Sandy gravel									Resident recreation	●	●	●	●	●
F	0.8	50	100-500	Small estuary, lagoon	--	Phalarope	Staging			o	●	o		Subsistence access	●	●	●	●	●
				Ephemeral inlet	--	Glaucous gull	Staging			●	●	●		Resident recreation	●	●	●	●	
				Road	Gravel	Arctic tern	Staging			●	●	●							
				Beach	Sandy gravel	Waterfowl	Staging			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 4
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	0.6	30	100-500	Small estuary, lagoon	--									Subsistence access	•	•	•	•	•
				Ephemeral inlet	--									Resident recreation	•	•	•	•	•
				Beach	Sandy gravel														
B	12.0	20-50	100-500	Multiple small rivers	--									Subsistence access	•	•	•	•	•
				Active high tundra cliff	Mud, sand, or gravel									Resident recreation	•	•	•	•	•
				Beach	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 5
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	1.6	50-100	100-500			Wetland			●	●	●	●	●	Resident recreation	●	●	●	●	●
				Single channel river	—	Phalarope	Staging			o	●	o							
				Intertidal flat	Mud, Sand	Glaucous gull	Staging			●	●	●							
				Small estuary, lagoon	Mud, Sand	Arctic tern	Staging			●	●	●							
				Salt-tolerant wetland	Peat	Waterfowl	Staging			●	●	●							
				Ephemeral inlet	—														
				Beach	Sandy gravel														
B	9.3	10-30	100-500	Multiple small rivers	—														
				Active high tundra cliff	Mud, sand, or gravel														
				Beach	Logs/Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	3.2	30-50	100-500	Multiple small rivers	--														
				Active high tundra cliff	Mud, sand, or gravel														
				Beach berm	Logs/Gravelly sand														
				Beach face	Sandy gravel														
B	6.2	10-20	100-500	Multiple small rivers	--														
				Active high tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
C	0.7	30	100-500	Single channel river	--														
				Beach	Sandy gravel														
D	1.0	5-10	100-500	Active high tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
E	0.6	50	100-500	Single channel river	--	Phalarope	Staging			○	●	○							
				Small estuary, lagoon	Mud, Sand	Glaucous gull	Staging			●	●	●							
				Ephemeral inlet	--	Arctic tern	Staging			●	●	●							
						Waterfowl	Staging			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES			HUMAN RESOURCES AND USE	
				Across-Shore Character						
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M J J A S O	Activity	J J A S O
A	2.3	10-30	100-500	Single channel river Active high tundra cliff Beach	— Mud, sand, or gravel Sandy gravel					
B	4.4	5-20	100-500	Active high tundra cliff Beach	Mud, sand, or gravel Sandy gravel					
C	3.0	5-20	100-500	Multiple small rivers Active high tundra cliff Beach	— Mud, sand, or gravel Sandy gravel					

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 9
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	6.4	5-10	100-500	Multiple small rivers	—														
B	0.5	10-30	100-500	Single channel river	—														
				Active high tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
C	1.5	5-10	100-500	Active high tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	2.8	10-20	100-500	Multiple small rivers	—														
				Active high tundra cliff	Mud, sand, or gravel/ Sedimentary bedrock														
				Beach	Sandy gravel														
B	0.6	20-50	100-500	Single channel river	—														
				Small estuary, lagoon	—														
				Ephemeral inlet	—														
				Beach	Sandy gravel														
C	1.1	5-10	100-500	Active high tundra cliff	Mud, sand, or gravel/ Sedimentary bedrock														
D	2.1	20-30	100-500	Active low tundra cliff	Sand														
				Beach	Gravelly sand														
E	1.1	20-30		Road	Sandy gravel									DEW Line site and airstrip (abandoned)					
				Small pond(s)	Peat														
				Salt-tolerant wetland	Peat														
				Washover fan	Gravelly sand														
				Beach	Gravelly sand														

MAP 11
Page 1 of 1

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES																
				Across-Shore Character		BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	3.5	50	100-500	Washover fan	Sandy gravel	Phalarope	Staging			o	●	o							
				Beach	Sandy gravel	Glaucous gull	Staging			●	●	●							
						Arctic tern	Staging			●	●	●							
B	5.6	50	100-500	Washover fan	Gravelly sand	Arctic tern	Nesting (25 pr.), Staging		●	●	●	●							
				Beach	Gravelly sand	Phalarope	Staging			o	●	●							
						Glaucous gull	Staging			●	●	●							
						Arctic tern	Staging			●	●	●							
C'	6.5	10-20	15	Washover fan	Gravelly sand														
D'	0.8	5-20	3	Small estuary, lagoon	--	Shorebirds	Staging			●	●								
				Stable inlet	--	Waterfowl	Staging			●	●	●							
				Beach	Logs/Gravelly sand														
				Intertidal flat	Mud, Sand														
E'	0.5	20	3	Single channel river	—														
				Salt-tolerant wetland	Peat														
				Beach	Logs/Gravelly sand														
				Intertidal flat	Sand														
F'	3.3	10-20	3	Active low tundra cliff	Mud, sand, or gravel/ Sedimentary bedrock														
				Beach	Gravelly sand														
G'	1.0	20-50	3	Salt-tolerant wetland		Wetland			●	●	●	●	●						
					Peat	Shorebirds	Staging			●	●								
				Beach	Gravelly sand	Brant	Staging			o	●	●							
H'	0.7	10-20	15	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravelly sand														
I'	0.5	20	15	Single channel river	—														
				Salt-tolerant wetland	Peat														
				Beach berm	Logs/Gravelly sand														
				Beach face	Gravelly sand														
J'	1.7	10-20	15	Multiple small rivers	—														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
Peard Bay	—	--	--	Open water area	--	Waterfowl	Molting, Staging			●	●	●		Beluga whale hunting		●	o		
						Beluga whale	Summering			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	0.7	10-20	10	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
B'	0.6	20-50	10	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravelly sand														
C'	0.5	15	10	Single channel river	--	Wetland			●	●	●	●	●						
				Salt-tolerant wetland	Peat														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach berm	Logs/Gravelly sand														
				Beach face	Gravelly sand														
D'	6.1	15	10	Multiple small rivers	—														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravelly sand														
Peard Bay	--	--	--	Open water area	--	Waterfowl	Molting, Staging			●	●	●		Beluga whale hunting		●	o		
						Beluga whale	Summering			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	7.6	10-20	10	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Peat/Gravelly sand														
Peard Bay	--	--	--	Open water area	--	Waterfowl	Molting, Staging			●	●	●		Beluga whale hunting		●	o		
						Beluga whale	Summering			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 14
Page 1 of 2

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	4.2	10-20	10	Multiple small rivers	--														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravelly sand														
B'	1.8	20-50	10	Small pond(s)	--														
				Salt-tolerant wetland	Peat														
				Ephemeral inlet	—														
				Beach	Mud, Sand														
				Intertidal flat	Mud, Sand														
C'	4.5	10-20	10	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravelly sand														
D'	2.8	20-50	3	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
				Intertidal flat	Mud, Sand														
E'	1.0	20-30	3	Single channel river	—														
				Multiple channel delta	Mud, sand, or gravel														
				Beach	Mud, Sand														
				Intertidal flat	Mud, Sand														
F'	3.5	10-20	3	Multiple small rivers	—														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
G'	1.2	20-50	5	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach	Sandy gravel														
H'	1.8	10-20	5	Active high tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
1'	2.2	10-30	10	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
Peard Bay	--	--	--	Open water area	--	Waterfowl	Molting, Staging			●	●	●		Beluga whale hunting		●	o		
						Beluga whale	Summering			●	o								
						Spotted seal	Summering			●	●	●							
Kugrua Bay	--	--	-	Open water area	--	Spotted seal	Summering		●	●	●	●	●	Spotted seal hunting		●	●		
														Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 15
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	15.2	10-50	10	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
B'	0.5	20	10	Single channel river	—														
				Small estuary, lagoon	—														
				Stable inlet	—														
				Beach	Mud, sand, or gravel														
C'	2.5	10	5	Multiple small rivers	—														
				Active low tundra cliff	Mud, sand, or gravel														
D'	1.6	5-10	3	Active low tundra cliff	Mud, sand, or gravel														
E'	0.4	20-30	3	Small pond(s)	--														
				Washover fan	Sandy gravel														
				Beach	Sandy gravel														
F'	6.5	10-20	5	Multiple small rivers	--														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
Kugrua Bay	--	--	--	Open water area	--	Spotted seal	Summering		●	●	●	●	●	Spotted seal hunting		●	●		
														Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 16
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	3.0	—	100-500	Stable inlet	--	Beluga whale	Summering area		●	●	●	●	●						
						Spotted seal	Summering area			●	●	●							
B	2.8	50-100	100-500	Beach	Sandy gravel	Shorebirds	High conc. staging			●	●								
C	0.4	20	100-500	Foredune	Gravelly sand	Black guillemot	Nesting (20 pr.)		o	●	●								
				Beach	Sandy gravel	Arctic tern	Nesting (20 pr.)		●	●									
						Common eider	Nesting (no. prs. unknown)		●	●									
						Shorebirds	High conc. staging			●	●								
D	3.8	50-100	100-500	Beach	Gravelly sand	Shorebirds	High conc. staging			●	●								
						Spotted seal	Haulout			●	●	●							
						Oldsquaw	Staging			●	●	●							
E	0.6	20-500	100-500	Isolated dune(s)	Gravelly sand	Shorebirds	High conc. staging			●	●								
				Beach storm berm	Gravelly sand	Spotted seal	Haulout			●	●	●							
				Beach face	Gravelly sand	Oldsquaw	Staging			●	●	●							
F	1.0	200-500	100-500	Washover fan	Gravelly sand	Shorebirds	High conc. staging			●	●								
				Beach storm berm	Gravelly sand	Spotted seal	Haulout			●	●	●							
				Beach face	Gravelly sand	Oldsquaw	Staging			●	●	●							
G'	7.2	20-50	13	Beach	Gravelly sand														
				Intertidal flat	Gravelly sand														
Peard Bay	--	--	--	Open water area	--	Waterfowl	Molting, Staging			●	●	●		Beluga whale hunting		●	o		
						Beluga whale	Summering			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 17
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	5.3	100-500	>500	Washover fan	Gravelly sand	Shorebirds	High conc. staging			●	●								
				Beach	Gravelly sand	Spotted seal	Haulouts			●	●	●							
B	2.3	50-100	>500	Foredune	Gravelly sand	Shorebirds	High conc. staging			●	●								
				Beach	Gravelly sand	Spotted seal	Haulouts			●	●	●							
C	1.0	--	>500	Ephemeral inlet	--	Shorebirds	High conc. staging			●	●								
						Spotted seal	Haulouts			●	●	●							
D'	1.4	20-50	10	Salt-tolerant wetland	Peat	Common eider	Nesting (no. prs. unknown)		●	●									
				Beach	Gravelly sand														
				Intertidal flat	Sand														
E'	2.5	20	10	Small pond(s)	--	Wetland			●	●	●	●	●						
				Salt-tolerant wetland	Peat	Common eider	Nesting (no. prs. unknown)		●	●									
				Beach	Gravelly sand	Shorebirds	Staging			●	●								
				Intertidal flat	Sand	Brant	Staging			o	●	●							
F'	3.7	10-20	10	Small pond(s)	--	Wetland			●	●	●	●	●						
				Salt-tolerant wetland	Peat	Common eider	Nesting (no. prs. unknown)		●	●									
				Beach	Gravelly sand	Shorebirds	Staging			●	●								
				Intertidal flat	Sand	Brant	Staging			o	●	●							
G'	1.8	10-20	10	Beach	Gravelly sand														
				Intertidal flat	Sand														
Peard Bay	--	—	--	Open water area	--	Waterfowl	Molting, Staging			●	●	●		Beluga whale hunting		●	o		
						Beluga whale	Summering			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	4.2	20	>500	Foredune	Gravelly sand	Shorebirds	Staging			●	●								
				Beach	Sandy gravel	Brant	Staging			o	●	●							
						Spotted seal	Haulouts			●	●	●							
B	2.3	50-500	>500	Salt-tolerant wetland	Peat	Shorebirds	Staging			●	●								
				Washover fan	Sandy gravel	Brant	Staging			o	●	●							
				Foredune	Gravelly sand	Spotted seal	Haulouts			●	●	●							
				Beach	Sandy gravel														
C	2.8	100-200	>500	Washover fan	Sandy gravel														
				Beach	Sandy gravel														
D'	2.0	10-50	10	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Washover fan	Sandy gravel	Common eider	Nesting (no. prs. unknown)		●	●									
				Foredune	Gravelly sand														
				Beach	Sandy gravel														
E'	6.8	20-50	<5	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●	Waterfowl hunting			●	●	
				Intertidal flat	Mud, Sand	Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
F'	7.8	10	<5	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●	Waterfowl hunting			●	●	
				Beach	Mud, Sand	Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
G'	3.5	10	10	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
H'	2.2	10-20	10	Small estuary, lagoon	—														
				Stable inlet	—														
				Beach	Sandy gravel														
Peard Bay	--	—	--	Open water area	—	Waterfowl	Molting, Staging			●	●	●		Beluga whale hunting		●	o		
						Beluga whale	Summering			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 19
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES							
				Across-Shore Character		BIOLOGICAL RESOURCES			HUMAN RESOURCES AND USE	
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M J J A S O	Activity	J J A S O
A	2.2	50-100	>500	Small estuary, lagoon	—					
				Washover fan	Sandy gravel					
				Beach	Sandy gravel					
B	1.2	50-100	>500	Small pond(s)	—					
				Salt-tolerant wetland	Peat					
				Ephemeral inlet	—					
				Beach	Sandy gravel					
C	5.4	30	>500	Multiple small rivers	—					
				Active low tundra cliff	Mud, sand, or gravel					
				Beach	Sandy gravel					

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 20
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	1.0	50-100	>500	Multiple small rivers	—														
				Salt-tolerant wetland	Peat														
				Beach	Sandy gravel														
B	1.9	50-100	>500	Small estuary, lagoon	—														
				Ephemeral inlet	—														
				Washover fan	Sandy gravel														
				Beach	Sandy gravel														
C	1.2	50-100	>500	Small pond(s)	—														
				Salt-tolerant wetland	Peat														
				Foredune	Gravelly sand														
				Beach	Sandy gravel														
D	3.8	50-200	>500	Small estuary, lagoon	—														
				Ephemeral inlet	—														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
E	3.0	50-100	>500	Active low tundra cliff	Logs/ Mud, sand, or gravel														
				Beach berm	Gravelly sand														
				Beach face	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 21
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	4.2	50	>500	Multiple small rivers	—														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach berm	Gravelly sand														
				Beach face	Gravelly sand														
B	2.9	50	>500	Salt-tolerant wetland	Peat														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach berm	Logs/Gravelly sand														
				Beach face	Gravelly sand														
C	1.5	50	>500	Active low tundra cliff	Mud, sand, or gravel														
				Beach storm berm	Gravelly sand														
				Beach	Gravelly sand														
D	0.5	50-200	>500	Single channel river	--	Shorebirds	Staging			●	●								
				Stable inlet	--	Waterfowl	Staging			●	●	●							
				Isolated dune(s)	Sand														
				Beach	Gravelly sand														
E	1.6	30-50	>500	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravelly sand														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 22
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	1.6	50	>500	Active low tundra cliff	Mud, sand, or gravel									Community of Wainwright	●	●	●	●	●
				Beach	Sand														
B	2.3	30-50	>500	Multiple small rivers	—									Community of Wainwright	●	●	●	●	●
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sand														
C	2.1	30-50	>500	Multiple small rivers	—									Community of Wainwright	●	●	●	●	●
				Road	Mud, sand, or gravel														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sand														
D	2.7	30	>500	Active low tundra cliff	Mud, sand, or gravel									Community of Wainwright	●	●	●	●	●
				Beach	Sand														
E	0.7	200-500	>500	Salt-tolerant wetland	Mud									Community of Wainwright	●	●	●	●	●
				Beach berm	Logs/Gravelly sand														
				Beach face	Gravelly sand														
				Intertidal flat	Sand														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 23
Page 1 of 2

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	0.3	--	<5	Stable inlet	--	Shorebirds	Staging			●	●			Beluga whale hunting		●	o		
						Waterfowl	Staging			●	●	●							
						Beluga whales	Summering			●	o								
B'	1.5	10-30	<2	Active low tundra cliff	Sand														
				Beach	Sandy gravel														
C'	1.6	200-500	<2	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach	Sandy gravel	Shorebirds	Staging			●	●								
				Intertidal flat	Mud														
D'	2.3	20	7	Road	Sandy gravel														
				Beach	Sandy gravel														
E'	3.4	10-20	8	Active high tundra cliff	Sand														
				Beach	Sandy gravel														
F'	0.9	10	5	Boat ramp	Sandy gravel														
				Active low tundra cliff	Sand														
				Beach	Sandy gravel														
G'	0.6	--	5	Small estuary, lagoon	--														
				Ephemeral inlet	--														
				Road	Mud, sand, or gravel														
				Beach	Mud, sand, or gravel														
H'	2.0	10-20	5	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravelly sand														
I'	3.7	10-50	5	Single channel river	--														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravel														
J'	0.7	10-20	3	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
				Intertidal flat	Sand														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 23
Page 2 of 2

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
K'	0.5	20-50	3	Salt-tolerant wetland Small estuary, lagoon Stable inlet Beach	Mud — — Sandy gravel	Wetland			●	●	●	●	●						
L'	0.3	20	3	Active low tundra cliff Small estuary, lagoon Stable inlet Beach	Mud, sand, or gravel — — Sandy gravel														
Wainwright Lagoon	--	--	--	Open water area	—	Beluga whale	Summering			●	o			Beluga whale hunting		●	o		
						Waterfowl	Staging			●	●	●		Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 24
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	3.0	20	5	Single channel river	—														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
B'	1.9	20	2	Small estuary, lagoon	--									DEW Line station and airstrip	●	●	●	●	●
				Beach	Gravel														
				Road	Gravel									Gravel mining operation		●	●	●	
C'	1.3	20-50	6	Small estuary, lagoon	—														
				Ephemeral inlet	—														
				Foredune	Sandy gravel														
				Beach	Sandy gravel														
D'	6.8	10	6	Multiple small rivers	—														
				Active low tundra cliff	Mud, sand, or gravel/ Sedimentary bedrock														
				Beach	Sandy gravel														
E'	2.1	10	5	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
F'	0.8	20-50	5	Active low tundra cliff	Mud, sand, or gravel														
				Small estuary, lagoon	—														
				Stable inlet	—														
				Beach	Gravelly sand														
G'	3.3	20	5	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravel														
H'	2.4	10-20	5	Multiple small rivers	—														
				Active high tundra cliff	Mud, sand, or gravel														
				Beach	Gravel														
Kuk River	--	--	--	Open water area	-									Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	3.8	20	7-10	Active low tundra cliff Beach	Gravelly sand Sandy gravel														
B'	0.3	20	5	Stable inlet	—														
C'	1.0	50-200	7-10	Washover channel Ephemeral inlet Beach	— — Gravel														
D'	8.0	20	10	Active low tundra cliff Beach	Gravelly sand Gravel														
Kuk River	--	—	—	Open water area	—									Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 26
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	1.4	--	<3	Small estuary, lagoon	—														
				Ephemeral inlet	—														
B'	9.1	5-10	<3	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravelly sand														
C'	2.0	20	<3	Beach	Gravel														
D'	11.0	5-10	<3	Multiple small rivers	—														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravelly sand														
Kungok River	—	--	--	Open water area	--									Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 27
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	18.9	10-20	<5	Active low tundra cliff	Gravelly sand														
				Beach	Sandy gravel														
B'	3.8	50-150	3	Active low tundra cliff	Gravelly sand														
				Beach storm berm	Gravel														
				Beach berm	Gravel														
				Beach face	Gravel														
C'	1.0	10-20	5	Small estuary, lagoon	—														
				Ephemeral inlet	—														
				Beach berm	Gravel														
				Beach face	Gravel														
D'	1.3	20	5	Small estuary, lagoon	—														
				Flood-tidal delta	Mud, sand, or gravel														
				Ephemeral inlet	—														
Kuk River	—	—	—	Open water area	—									Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 28
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES																
				Across-Shore Character		BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	2.1	20-50	6	Small estuary, lagoon	—														
				Multiple small rivers	--														
				Beach	Gravelly sand														
B'	17.5	20	5	Multiple small rivers	—														
				Active low tundra cliff	Gravelly sand														
				Beach	Gravel														
C'	1.0	—	7	Small estuary, lagoon	—														
				Stable inlet	—														
D'	1.0	50	5	Salt-tolerant wetland	Peat														
				Beach	Gravel														
E'	1.8	20	5	Multiple small rivers	--														
				Active high tundra cliff	Gravelly sand														
				Beach	Gravelly sand														
Kuk River	--	--	--	Open water area	—									Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 29
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	2.3	20	<3	Multiple small rivers	--														
				Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
B'	0.9	50	<3	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
C'	1.4	20-50	<3	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
				Intertidal flat	Sand														
D'	2.2	200-500	5	Multiple channel delta	--														
				Intertidal flat	Sand														
E'	3.5	10-50	<3	Multiple small rivers	--														
				Active low tundra cliff	Gravelly sand														
				Beach	Gravel														
Kuk River	--	--	--	Open water area	--									Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 30
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	19.0	10-15	<3	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
B'	0.5	—	<3	Small estuary, lagoon	—														
				Stable inlet	—														
Ivisaruk River	--	--	--	Open water area	--									Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 31
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	0.7	200	>500	Beach berm	Sandy gravel														
				Beach face	Sandy gravel														
B	2.4	100-200	>500	Foredune	Sandy gravel									Egg gathering	•	•			
				Beach berm	Sandy gravel									Waterfowl hunting	•	•			
				Beach face	Sandy gravel														
C	4.1	100	>500	Salt-tolerant wetland	Peat	Wetland			•	•	•	•	•						
				Small estuary, lagoon	—														
				Ephemeral inlet	—														
				Beach berm	Sandy gravel														
				Beach face	Sandy gravel														
D	0.9	100	>500	Salt-tolerant wetland	Peat														
				Small estuary, lagoon	—														
				Washover channel	Sandy gravel														
				Beach berm	Sandy gravel														
				Beach face	Sandy gravel														
E	0.9	100	>500	Salt-tolerant wetland	Peat														
				Beach berm	Sandy gravel														
				Beach face	Sandy gravel														
F	0.7	100	>500	Salt-tolerant wetland	Peat	Wetland			•	•	•	•	•						
				Single channel river	—														
				Small estuary, lagoon	—														
				Beach	Sandy gravel														
G'	2.5	100	<2	Foredune	Sandy gravel														
				Beach	Sandy gravel														
H'	0.9	100	<2	Passive low tundra cliff	Sandy gravel														
				Salt-tolerant wetland	Sandy gravel														
				Beach	Sandy gravel														
I'	2.1	20	5	Active high tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
J'	0.4	20	5	Small estuary, lagoon	Sandy gravel														
				Beach	Sandy gravel														
K'	0.6	50	5	Small estuary, lagoon	—														
				Stable inlet	—														
				Beach	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 32
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	5.2	50-100	>500	Passive low tundra cliff	Peat	Wetland			●	●	●	●	●						
				Small estuary, lagoon	--														
				Ephemeral inlet	--														
				Beach berm	Sandy gravel														
				Beach face	Sandy gravel														
B	2.9	50-100	>500	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Small estuary, lagoon	--														
				Ephemeral inlet	--														
				Flood-tidal delta	Sandy gravel														
				Beach	Sandy gravel														
C	0.9	50	>500	Active low tundra cliff	Sandy gravel														
				Beach berm	Sandy gravel														
				Beach face	Sandy gravel														
D	2.5	100-20	>500	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Small estuary, lagoon	--	Shorebirds	Staging			●	●								
				Beach berm	Sandy gravel	Brant	Staging			○	●	●							
				Beach face	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 33
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	9.5	100	>500	Salt-tolerant wetland	Peat														
				Small estuary, lagoon	—														
				Washover fan	Sandy gravel														
				Beach berm	Sandy gravel														
				Beach face	Sandy gravel														
B	0.7	200	>500	Small estuary, lagoon	-	Wetland			●	●	●	●	●						
				Foredune	Sandy gravel														
				Beach berm	Sandy gravel														
				Beach face	Sandy gravel														
Kasegaluk Lagoon	--	--	--	Open water area	-	Waterfowl	High conc. areas, Staging			●	●	●		Beluga whale hunting		●	o		
						Brant	Staging			o	●	●		Spotted seal hunting		●	●		
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

Table ____. CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 34
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	9.0	50	>500	Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B	0.5	50	>500	Small estuary, lagoon	—														
				Stable inlet	—														
C'	9.0	20	5	Beach	Sandy gravel														
D'	3.9	20	5	Multiple small rivers	—														
				Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
E'	1.0	20-50	5	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach	Sandy gravel														
F'	1.4	20-50	5	Active low tundra cliff	Sandy gravel														
				Beach berm	Logs/Sandy gravel														
				Beach face	Gravelly sand														
G'	5.0	15	5	Multiple small rivers	—														
				Active low tundra cliff	Sandy gravel														
				Beach berm	Logs/Sandy gravel														
				Beach face	Gravelly sand														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Beluga whale hunting		●	○		
						Brant	Staging			○	●	●		Spotted seal hunting		●	●		
						Shorebirds	Staging			●	●								
						Phalarope	Staging			○	●	○							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	○								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	8.7	50-100	>500	Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B	0.5	—	>500	Small estuary, lagoon	—														
				Stable inlet	—														
C'	8.7	50	5	Beach	Sandy gravel														
D'	5.6	20	5	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
E'	0.2	--	5	Single channel river	Mud, sand, or gravel									Fishing	●	●	●	●	
				Multiple channel delta	Sand														
				Stable inlet	—														
F'	0.7	20	5	Small estuary, lagoon	—														
				Ephemeral inlet	--														
				Beach	Sandy gravel														
G'	2.5	20-100	7	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach	Gravelly sand														
H'	2.5	30	10	Multiple small rivers	—														
				Active low tundra cliff	Gravelly sand														
				Beach	Gravelly sand														
Kasegaluk Lagoon	--	--	—	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Beluga whale hunting		●	○		
						Brant	Staging			○	●	●		Spotted seal hunting		●	●		
						Shorebirds	Staging			●	●								
						Phalarope	Staging			○	●	○							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	○								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Across-Shore Character Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	5.8	200	>500	Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B	2.3	200	>500	Beach berm	Sandy gravel	Common eider	Nesting (450+ pr.)		●	●									
				Beach storm berm	Sandy gravel	Glaucous gull	Nesting (10 pr.)		●	●									
				Beach face	Sandy gravel	Arctic tern	Nesting (42 pr.)		●	●									
C	1.3	--	>500	Small estuary, lagoon	--														
				Stable inlet	—														
D'	8.3	20	8	Beach	Sandy gravel														
E'	11.1		8	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
F'	0.6	50-100	8	Single channel river	--	Wetland			●	●	●	●	●						
				Multiple channel delta	—														
				Salt-tolerant wetland	Peat														
				Beach	Logs/Sandy gravel														
G'	0.7	20-50	10	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach	Logs/Gravelly sand														
H'	3.0	20-50	10	Single channel river	—														
				Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas,							Beluga whale hunting		●	o		
							Staging			●	●	●		Spotted seal hunting		●	●		
						Brant	Staging			o	●	●		Fishing	●	●	●	●	
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 37
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	7.2	100-300	>500	Washover fan	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B	1.2	200	>500	Foredune	Sandy gravel														
				Beach face	Sandy gravel														
C'	7.1	100	9	Beach	Sandy gravel														
D'	1.2	300	9	Salt-tolerant wetland	Peat	Wetland	Staging		●	●	●	●	●						
				Beach	Sandy gravel	Shorebirds	Staging			●	●								
						Brant				o	●	●							
E'	0.5	20	10	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach	Sandy gravel														
F'	3.0	20-30	12	Single channel river	—														
				Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
G'	2.0	20	10	Small estuary, lagoon	—	Wetland			●	●	●	●	●						
				Ephemeral inlet	—	Waterfowl	Staging			●	●	●							
				Salt-tolerant wetland	Logs	Shorebirds	Staging			●	●								
				Beach	Sandy gravel	Brant	Staging			o	●	●							
H'	4.0	10-20	10	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
Kasegaluk Lagoon	—	—	—	Open water area	- -	Waterfowl	High conc. areas, Staging			●	●	●		Beluga whale hunting		●	o		
						Brant	Staging			o	●	●		Spotted seal hunting		●	●		
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	8.1	100	>500	Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B'	2.7	20	10	Beach	Sandy gravel														
C'	5.3	500	10	Beach	Sandy gravel														
				Intertidal flat	Mud														
D'	2.3	500	15	Salt-tolerant wetland	Logs														
				Beach	Sand														
				Intertidal flat	Mud														
E'	7.6	20-50	15	Active low tundra cliff	Sandy gravel	Backshore			●	●	●	●	●						
				Beach	Sandy gravel	Wetland													
F'	0.9	—	9	Small estuary, lagoon	–									Fishing	●	●	●	●	
				Stable inlet	--														
G'	0.6	20	7	Small estuary, lagoon	--														
				Ephemeral inlet	--														
				Salt-tolerant wetland	Logs														
				Beach	Sandy gravel														
Kasegaluk Lagoon	--	--	—	Open water area	--	Waterfowl	High conc. areas,							Beluga whale hunting		●	o		
							Staging			●	●	●		Spotted seal hunting		●	●		
						Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	3.1	20-50	>500	Washover fan	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B	1.9	500	>500	Foredune	Sand	Common eider	Nesting (62 pr.)		●	●									
				Beach berm	Logs/Sandy gravel	Glaucous gull	Nesting (2 pr.)		●	●									
				Beach face	Sandy gravel	Arctic tern	Nesting (6 pr.)		●	●									
C	0.6	50	>500	Washover fan	Sandy gravel														
				Washover channel	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
D	3.8	200	>500	Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
E	0.6	--	>500	Small estuary, lagoon	--														
				Stable inlet	--														
F'	3.1	500	2	Beach	Mud, sand, or gravel														
				Intertidal flat	Mud														
G'	1.3	500	<2	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach	Sandy gravel	Extensive													
				Intertidal flat	Mud	mud flats			●	●	●	●	●						
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
H'	4.0	200-500	<2	Beach	Sandy gravel														
				Intertidal flat	Mud														
I'	2.2	10-20	10	Beach	Sandy gravel														
J'	3.2	10-30	5	Active low tundra cliff	Sandy gravel														
				Beach	Logs/Sandy gravel														
K'	0.7	--	5	Small estuary, lagoon	--														
				Stable inlet	--														
L'	6.2	50-500	2	Salt-tolerant wetland	Logs	Wetland			●	●	●	●	●						
				Intertidal flat	Mud	Extensive													
						mud flats			●	●	●	●	●						
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
M'	4.1	50-200	2-5	Salt-tolerant wetland	Logs	Wetland			●	●	●	●	●	DEW Line site and airstrip (abandoned)					
				Washover fan	Sandy gravel	Brant	Staging			o	●	●							
				Beach berm	Sandy gravel	Shorebirds	Staging			●	●								
				Beach face	Sandy gravel														
N'	2.9	20-30	10	Multiple small rivers	—														
				Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Beluga whale hunting		●	o		
						Brant	Staging			o	●	●		Spotted seal hunting		●	●		
						Shorebirds	Staging			●	●			Fishing	●	●	●	●	
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 40
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	3.5	10-20	<3	Multiple small rivers	—														
				Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
B'	4.4	10	<3	Salt-tolerant wetland	Logs														
				Beach	Sandy gravel														
C'	25.6	10-20	<3	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Sandy gravel														
D'	1.3	—	<3	Stable inlet	—														
E'	0.8	20	<3	Salt-tolerant wetland	Logs														
				Ephemeral inlet	—														
				Beach	Sandy gravel														
Avak Inlet	--	--	--	Open water area	--	Spotted seal	Summering			●	●			Spotted seal hunting		●	●		
														Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES																
				Across-Shore Character		BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	26.8	10	<3	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
B'	0.2	--	<3	Stable inlet	--														
C'	1.3	10-30	<3	Salt-tolerant wetland	Logs														
Avak Inlet	--	--	--	Open water area	--	Spotted seal	Summering			●	●			Spotted seal hunting		●	●		
														Fishing	●	●	●	●	

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 42
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	7.6	20-30	>500	Washover fan	Sandy gravel														
				Beach storm berm	Mud, sand, or gravel														
				Beach face	Mud, sand, or gravel														
B	0.7	—	>500	Stable inlet	—									Beluga whale hunting		●	○		
C	1.0	20-30	>500	Foredune	Sandy gravel														
				Beach face	Sandy gravel														
D	1.5	10-20	>500	Washover fan	Sandy gravel														
				Beach berm	Sandy gravel														
				Beach face	Sandy gravel														
E'	9.3	10-20	10	Beach	Sandy gravel														
						Common eider	Nesting (350 pr.)		●	●									
						Glaucous gull	Nesting (15 pr.)		●	●									
						Arctic tern	Nesting (20 pr.)		●	●									
F'	1.6	30	10	Multiple small rivers	—														
				Active low tundra cliff	Sandy gravel														
				Beach	Logs/Sandy gravel														
G'	5.2	30-50	10	Multiple small rivers	—														
				Active low tundra cliff	Sandy gravel														
				Beach	Logs/Sandy gravel														
				Intertidal flat	Sand														
H'	0.7	20-30	10	Salt-tolerant wetland	Logs	Wetland			●	●	●	●	●						
				Beach	Logs/Sandy gravel														
Kasegaluk Lagoon	—	—	—	Open water area	—	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			○	●	○							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	○								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	3.5	30	10	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Logs/Sandy gravel														
				Intertidal flat	Sand														
B'	5.0	30-50	10	Active low tundra cliff	Mud, sand, or gravel														
				Intertidal flat	Sand														
C'	2.5	30-50	10	Salt-tolerant wetland	Logs	Wetland			●	●	●	●	●						
				Ephemeral inlet	—														
				Beach	Sandy gravel														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			○	●	○							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	○								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	6.7	50-100	>500	Washover fan	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B	1.7	30-50	>500	Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
C	2.2	30	>500	Washover fan	Sandy gravel														
				Beach face	Sandy gravel														
D	1.3	50-200	>500	Foredune	Sandy gravel														
				Beach storm berm	Mud, sand, or gravel														
				Beach face	Sandy gravel														
E'	1.9	10-30	10	Beach storm berm	Mud, sand, or gravel	Waterfowl	Staging			●	●	o							
F'	0.2	—	10	Small estuary, lagoon	—	Beluga whale	Summering, Calving(?)			●	o								
				Stable inlet	—														
G'	5.5	10-20	10	Beach	Sandy gravel														
H'	1.3	20-30	10	Salt-tolerant wetland	Logs	Wetland			●	●	●	●	●						
				Beach	Mud, sand, or gravel														
				Intertidal flat	Sand														
I'	2.0	20-30	10	Beach	Sandy gravel	Wetland			●	●	●	●	●						
				Intertidal flat	Sand														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	5.6	20-50	10	Multiple small rivers	--														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Organics/Sandy gravel														
				Intertidal flat	Sand														
B'	4.7	500-1000	10	Multiple channel delta	Mud, sand, or gravel	Wetland			●	●	●	●	●						
				Salt-tolerant wetland	Logs	Brant	Staging			○	●	●							
				Intertidal flat	Sand	Shorebirds	Staging			●	●								
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			○	●	○							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	○								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 46
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	8.9	30-50	>500	Washover fan	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B	1.2	50	>500	Foredune	Sand														
				Washover fan	Sandy gravel														
				Washover channel	Sandy gravel														
				Beach face	Sandy gravel														
C	1.8	30-50	>500	Foredune	Sand														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
D	0.5	—	>500	Flood-tidal delta	--									Spotted seal hunting		●	●		
				Stable inlet	—														
E'	5.1	20-50	10	Beach	Sandy gravel														
				Intertidal flat	Sand														
F'	1.3	20-30	10	Salt-tolerant wetland	Logs	Wetland			●	●	●	●	●						
				Beach	Sandy gravel														
G'	5.0	20-50	10	Beach	Sandy gravel														
H'	0.4	200	10	Beach	Sandy gravel														
				Intertidal flat	Sand														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

MAP 47
Page 1 of 1

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	6.0	500-1000	10	Multiple channel delta	Sand	Wetland			●	●	●	●	●						
				Salt-tolerant wetland	Logs	Shorebirds				●	●								
				Intertidal flat	Sand														
B'	4.1	20-30	10	Active low tundra cliff	Sandy gravel														
				Beach	Logs/Sandy gravel														
C'	0.6	20-40	10	Foredune	Sand														
D'	1.9	20	10	Active low tundra cliff	Sandy gravel														
				Beach	Logs/Sandy gravel														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			○	●	○							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	○								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 48
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	2.4	20-30	>500	Beach storm berm	Sandy gravel									Spotted seal hunting		●	●		
				Beach face	Sandy gravel														
B	1.8	20-50	>500	Foredune	Sandy gravel									Spotted seal hunting		●	●		
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
C	1.1	20-30	>500	Beach	Sandy gravel														
D	5.3	20-30	>500	Washover fan	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
E'	2.1	50-300	10	Beach	Sandy gravel														
				Intertidal flat	Sand														
F'	3.0	10-20	10	Beach	Sandy gravel														
G'	5.4	10-30	10	Salt-tolerant wetland	Logs	Wetland			●	●	●	●	●						
				Intertidal flat	Sand	Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	2.4	20-30	10	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Organics/Sandy gravel														
B'	0.7	20-50	10	Single channel river	--	Wetland			●	●	●	●	●						
				Small estuary, lagoon	--														
				Stable inlet	--														
				Beach	Logs/Sandy gravel														
C'	4.5	10-20	10	Active low tundra cliff	Mud, sand, or gravel														
				Beach	Logs/Sandy gravel														
D'	2.2	100-500	10	Active low tundra cliff	Mud, sand, or gravel	Wetland			●	●	●	●	●						
				Intertidal flat	Organics/Sand	Shorebirds	Staging			●	●								
						Waterfowl	Staging			●	●	●							
E'	1.4	5-10	10	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
F'	1.1	20-30	10	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
				Intertidal flat	Sand														
G'	1.0	40-60	10	Single channel river	--	Wetland			●	●	●	●	●						
				Multiple channel delta	--														
				Intertidal flat	Sand														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Spotted seal hunting		●	●		
														Fishing	●	●	●	●	
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			○	●	○							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	○								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 50
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	11.2	20-30	>500	Washover fan	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B	2.3	20-30	>500	Foredune	Sandy gravel														
				Beach face	Sandy gravel														
C'	3.5	20-50	10	Salt-tolerant wetland	Logs	Wetland			●	●	●	●	●						
				Intertidal flat	Sand	Common eider	Nesting (22 pr.)		●	●									
						Arctic tern	Nesting (16 pr.)		●	●									
						Brant	Nesting (4 pr.)		●	●									
D'	10.0	10-20	10	Beach	Sandy gravel														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			○	●	○							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	○								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A'	5.8	20-80	7	Active low tundra cliff	Sandy gravel									Waterfowl hunting	●	●			
				Beach	Organics/Sandy gravel														
B'	1.3	100-200	7	Active low tundra cliff	Sandy gravel									Waterfowl hunting	●	●			
				Beach berm	Sandy gravel														
				Sand	Organics/Sand														
C'	0.6	50-100	7	Active low tundra cliff	Sandy gravel									Waterfowl hunting	●	●			
				Beach	Sandy gravel														
				Intertidal flat	Mud,Sand														
D'	4.2	10	7	Multiple small rivers	-									Waterfowl hunting	●	●			
				Active low tundra cliff	Sandy gravel														
				Beach	Organics/Sandy gravel														
E'	0.8	50-100	7	Single channel river	--									Waterfowl hunting	●	●			
				Multiple channel delta	Sand														
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Organics/Sandy gravel														
				Intertidal flat	Sand														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	0.3	1000	>500	Flood-tidal delta	Sand	Spotted seal	Summering			●	●			Spotted seal hunting		●	●		
				Stable inlet	–	Beluga whale	Summering			●	o			Beluga whale hunting		●	o		
B	2.7	30-100	>500	Washover fan	Sandy gravel									Waterfowl hunting	●	●			
				Beach storm berm	Sandy gravel									Egg gathering	●	●			
				Beach face	Sandy gravel														
C	6.7	50-100	>500	Washover fan	Sandy gravel									Waterfowl hunting	●	●			
				Foredune	Sandy gravel									Egg gathering	●	●			
				Beach berm	Sandy gravel														
				Beach face	Mud, sand, or gravel														
D'	9.0	500	5	Beach	Sandy gravel	Common eider	Nesting (25 pr.)		●	●									
				Intertidal flat	Sand	Glaucous gull	Nesting (4 pr.)		●	●									
						Arctic tern	Nesting (54 pr.)		●	●									
						Brant	Nesting (4 pr.)		●	●									
						Oldsquaw	Nesting (6 pr.)		●	●									
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas,							Spotted seal hunting		●	●		
							Staging			●	●	●		Beluga whale hunting		●	o		
						Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	6.7	200	>500	Small pond(s)	--	Common eider	Nesting (no. prs. unknown)		●	●				Waterfowl hunting	●	●			
														Egg gathering	●	●			
				Salt-tolerant wetland	Peat	Arctic tern	Nesting (no. prs. unknown)		●	●				Seasonally occupied village, Pt. Lay	●	●	●	●	●
				Washover fan	Sandy gravel														
				Foredune	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B	8.0	200	>500	Foredune	Sandy gravel	Common eider	Nesting (no. prs. unknown)		●	●				Waterfowl hunting	●	●			
														Egg gathering	●	●			
				Beach berm	Sandy gravel	Arctic tern	Nesting (no. prs. unknown)		●	●				Seasonally occupied village, Pt. Lay	●	●	●	●	●
				Beach face	Sandy gravel														
C	0.2	--	>500	Stable inlet	--									Beluga whale hunting		●	o		
														Spotted seal hunting		●	●		
D'	6.6	10-20	<7	Beach	Sandy gravel														
E'	1.3	10-20	5	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Ephemeral inlet	--														
				Beach	Sandy gravel														
F'	1.3	20-30	2	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Active high rock cliff	Sedimentary bedrock														
				Ephemeral inlet	--														
				Beach	Sandy gravel														
G'	1.7	10-30	5	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach	Sandy gravel	Shorebirds	Staging			●	●								
H'	9.8	50-1000	5	Multiple channel delta	--	Waterfowl	Migration			●	●	●		Waterfowl hunting	●	●			
				Intertidal flat	Sand									Fishing	●	●	●	●	
I'	3.3	10-50	7	Passive low tundra cliff	Sandy gravel									Waterfowl hunting	●	●			
				Beach	Organics/Sandy gravel									Community of Pt. Lay	●	●	●	●	●
														DEW Line station and airstrip	●	●	●	●	●
Kasegaluk Lagoon	–	--	--	Open water area	-	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 54
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	6.7	20-30	>500	Washover fan	Sandy gravel									Egg gathering	●	●			
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B'	6.7	10-20	5	Beach	Sandy gravel														
C'	7.7	10-30	5	Multiple small rivers	--									Waterfowl hunting	●	●			
				Active low tundra cliff	Sandy gravel														
				Beach	Organics														
D'	3.5	5-10	5	Active low tundra cliff	Sandy gravel									Waterfowl hunting	●	●			
				Beach	Sandy gravel														
E'	2.6	10-40	5	Active low tundra cliff	Sandy gravel									Waterfowl hunting	●	●			
				Beach	Logs/Sandy gravel														
F'	1.0	50-100	5	Active low tundra cliff	Sandy gravel														
				Beach	Organics/Sandy gravel														
				Intertidal flat	Sand														
G'	1.1	20-30	5	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	0.4	—	>500	Flood-tidal delta	-	Spotted seal	Summering			●	●	●		Spotted seal hunting		●	●		
				Stable inlet	-	Beluga whale	Summering			●	o			Beluga whale hunting		●	o		
B	4.7	20-150	>500	Washover fan	Sandy gravel									Egg gathering	●	●			
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
C	2.2	20-30	>500	Washover fan	Sandy gravel									Egg gathering	●	●			
				Washover channel	Sandy gravel														
				Foredune	Sand														
				Beach berm	Sandy gravel														
				Beach face	Sandy gravel														
D	2.3	20-30	>500	Washover fan	Sandy gravel														
				Washover channel	Sandy gravel														
				Foredune	Sand														
				Beach face	Sandy gravel														
E'	7.7	10-20	3	Beach	Sandy gravel														
F'	2.3	10-20	3	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach	Sandy gravel														
G'	6.2	30-500	3	Multiple channel delta	--	Wetland			●	●	●	●	●						
				Intertidal flat	Sand	Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
H'	1.2	100-500	3	Intertidal flat	Sand									Waterfowl hunting	●	●			
				Beach berm	Gravelly sand														
				Intertidal flat	Sand														
I'	0.7	20	3	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	11.3	50-200	>500	Salt-tolerant wetland	Peat														
				Washover fan	Sandy gravel														
				Foredune	Sandy gravel														
				Beach face	Sandy gravel														
B'	5.3	20	8	Beach	Sandy gravel														
C'	6.1	5-20	5	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
						Waterfowl	Nesting (10 pr.)		●	●									
						Arctic tern	Nesting (28 pr.)		●	●									
				Intertidal flat	Mud, Sand	Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
D'	4.0	15-20	8	Active low tundra cliff	Sandy gravel														
				Active high tundra cliff	Logs/Sandy gravel														
				Beach face	Sandy gravel														
E'	0.5	20-50	5	Single channel river	--														
				Salt-tolerant wetland	Logs/Peat														
				Beach storm berm	Logs/Sandy gravel														
				Beach face	Sandy gravel														
F'	1.9	20	3	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
G'	1.3	50-100	5	Single channel river	--														
				Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
H'	5.2	10-20	8	Multiple small rivers	--														
				Active low tundra cliff	Sandy gravel														
				Beach	Logs/Sandy gravel														
				Beach	Sandy gravel														
I'	0.7	30-60	7	Small estuary, lagoon	--														
				Ephemeral inlet	--														
				Ebb-tidal delta	Mud, Sand														
J'	0.7	20-30	7	Passive low tundra cliff	Sandy gravel														
				Foredune	Sand														
				Beach face	Sand														

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●							
						Brant	Staging			o	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			o	●	o							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	o								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 57
Page 1 of 2

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	2.6	200	>500	Salt-tolerant wetland	Peat	Wetland			•	•	•	•	•	Fishing	•	•	•	•	
				Foredune	Sandy gravel	Brant	Staging			o	•	•							
				Beach face	Sandy gravel	Shorebirds	Staging			•	•								
B	0.9	--	>500	Ephemeral inlet	—	Spotted seal	Summering			•	•	•		Spotted seal hunting		•	•		
				Stable inlet	-	Beluga whale	Summering			•	o			Beluga whale hunting		•	o		
														Fishing	•	•	•	•	
C	6.3	50-500	>500	Washover fan	Sandy gravel									Fishing	•	•	•	•	
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
D	1.3	20-50	>500	Salt-tolerant wetland	Peat														
				Washover fan	Mud, sand, or gravel														
				Washover channel	Mud, sand, or gravel														
				Foredune	Sand														
				Beach face	Sandy gravel														
E'	6.5	5-20	3	Salt-tolerant wetland	Peat	Wetland			•	•	•	•	•						
				Intertidal flat	Mud, Sand	Shorebirds	Staging			•	•								
F'	7.0	50-500	3	Beach	Sandy gravel	Common eider	Nesting (6 pr.)		•	•									
				Intertidal flat	Mud, Sand	Arctic tern	Nesting (2 pr.)		•	•									
G'	2.5	30-50	3	Salt-tolerant wetland	Peat														
				Foredune	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
H'	0.3	30-50	3	Small pond(s)	—														
				Active high rock cliff	—														
				Beach	Mud, sand, or gravel														
I'	1.5	30	3	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
J'	1.0	30-50	3	Passive low tundra cliff	Sandy gravel	Wetland			●	●	●	●	●						
				Salt-tolerant wetland	Peat														
				Beach	Sandy gravel														
K'	0.7	20-50	3	Single channel river	--	Shorebirds	Staging			●	●								
				Small estuary, lagoon	--														
				Ephemeral inlet	--														
				Flood-tidal delta	Mud, Sand														
L'	2.6	20-30	3	Active low tundra cliff	Sandy gravel														
				Beach storm berm	Logs/Sandy gravel														
				Beach face	Sandy gravel														
M'	1.1	20-50	3	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Multiple channel delta	Sand	Shorebirds	Staging			●	●								
				Beach	Sand														
N'	1.9	10	3	Multiple small rivers	--														
				Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
Kasegaluk Lagoon	--	--	--	Open water area	--	Waterfowl	High conc. areas,							Spotted seal hunting		●	●		
							Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			○	●	○							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	○								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	11.4	20-50	>500	Salt-tolerant wetland	Peat														
				Washover fan	Sandy gravel														
				Washover channel	Sandy gravel														
				Foredune	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B'	9.6	20-600	2	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Intertidal flat	Mud, Sand	Waterfowl	Staging			●	●	●							
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
C'	1.5	30	2	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach	Sandy gravel	Waterfowl	Staging			●	●	●							
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
D'	1.3	30-50	2	Multiple small rivers	--														
				Active low tundra cliff	Sandy gravel														
				Beach	Logs/Sandy gravel														
				Intertidal flat	Mud, Sand														
E'	1.0	20-30	2	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Small pond(s)	--														
				Ephemeral inlet	--														
F'	4.0	20	2	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
G'	0.3	10-20	2	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Beach	Organics/Sandy gravel														
H'	1.0	20-30	2	Single channel river	--														
				Small estuary, lagoon	--														
				Stable inlet	--														
				Beach	Sandy gravel														
I'	0.9	30-50	2	Small estuary, lagoon	--	Wetland			●	●	●	●	●						
				Ephemeral inlet	--														
				Ebb-tidal delta	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
J'	0.6	10-20	2	Salt-tolerant wetland	Peat														
				Foredune	Sandy gravel														
				Beach	Sandy gravel														
K'	2.9	10-20	2	Multiple small rivers	--														
				Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
Kasegaluk Lagoon	--	—	--	Open water area	--	Waterfowl	High conc. areas, Staging			●	●	●		Fishing	●	●	●	●	
						Brant	Staging			○	●	●							
						Shorebirds	Staging			●	●								
						Phalarope	Staging			○	●	○							
						Arctic tern	Staging			●	●	●							
						Glaucous gull	Staging			●	●	●							
						Beluga whale	Summering, Calving(?)			●	○								
						Spotted seal	Summering			●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	1.0	20-30	>500	Washover fan	Sandy gravel														
				Washover channel	Sandy gravel														
				Foredune	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B	3.1	50	>500	Small estuary, lagoon	-	Wetland			●	●	●	●	●						
				Salt-tolerant wetland	Peat														
				Washover fan	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
C	0.9	30	>500	Salt-tolerant wetland	Peat														
				Foredune	Sandy gravel														
				Beach face	Sandy gravel														
D	1.9	30	>500	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
E	0.7	30-50	>500	Multiple small rivers	--														
				Ephemeral inlet	--														
				Foredune	Sandy gravel														
				Beach face	Sandy gravel														
F'	1.1	20-50	2	Multiple small rivers	--	Wetland			●	●	●	●	●						
				Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
				Intertidal flat	Mud, Sand														
G'	0.6	5-10	2	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
H'	1.0	10-100	2	Salt-tolerant wetland	Peat	Wetland			●	●	●	●	●						
				Intertidal flat	Mud, Sand														

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	8.0	20	>500	Multiple small rivers	--														
				Ephemeral inlet	Logs/Mud, sand, or gravel														
				Beach	Sandy gravel														
B	2.7	20-30	>500	Small estuary, lagoon	-	Wetland			●	●	●	●	●						
				Washover fan	Sandy gravel	Arctic tern	Nesting (10 pr.)		●	●									
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
C	0.9	20-40	>500	Single channel river	--	Wetland			●	●	●	●	●						
				Salt-tolerant wetland	Peat	Shorebirds	Staging			●	●								
				Ephemeral inlet	--														
				Foredune	Sandy gravel														
				Beach face	Sandy gravel														
D	1.2	20-40	>500	Active low tundra cliff	Sandy gravel														
				Beach	Gravelly sand														

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	9.5	20-40	>500	Active low tundra cliff Beach	Sandy gravel Sandy gravel														
B	2.8	20-40	>500	Active high tundra cliff Beach	Sandy gravel Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES																
				Across-Shore Character		BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	4.3	10-20	>500	Multiple small rivers	—														
				Ephemeral inlet	Gravelly sand														
				Beach	Gravelly sand														
B	5.6	15-30	>500	Multiple small rivers	--									DEW Line site and airstrip (abandoned)					
				Active high tundra cliff	Sandy gravel														
				Beach	Gravelly sand														
C	0.4	30	>500	Small estuary, lagoon	—														
				Foredune	Sandy gravel														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 65
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES			HUMAN RESOURCES AND USE	
				Across-Shore Character						
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M J J A S O	Activity	J J A S O
A	8.1	30-50	>500	Multiple small rivers Active low tundra cliff Beach face	— Sandy gravel Gravelly sand					
B	0.5	10-20	>500	Active high tundra cliff Beach face	Sandy gravel Sandy gravel					

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	2.5	30	>500	Small estuary, lagoon	--														
				Ephemeral inlet	--														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
B	0.4	30-50	>500	Single channel river	--														
				Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														
C	1.1	30-50	>500	Small estuary, lagoon	--														
				Beach	Sand														
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
D	5.1	20-30	>500	Active high tundra cliff	Sandy gravel														
				Beach	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 65
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES			HUMAN RESOURCES AND USE	
				Across-Shore Character						
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M J J A S O	Activity	J J A S O
A	2.9	10-50	>500	Single channel river	--					
				Active low tundra cliff	Sandy gravel					
				Beach	Gravelly sand					
B	0.5	0-5	>500	Active high tundra cliff	Sandy gravel					
C	1.0	10-20	>500	Active low tundra cliff	Sandy gravel					
				Beach	Gravelly sand					
D	4.2	50	>500	Small estuary, lagoon	--					
				Washover fan	Gravelly sand					
				Beach storm berm	Gravelly sand					
				Beach face	Sandy gravel					

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	5.3	20-40	>500	Multiple small rivers	--														
				Active low tundra cliff	Sandy gravel														
				Beach	Gravel														
B	0.7	20-50	>500	Single channel river	--	Waterfowl	Staging			●	●	●							
				Multiple channel delta	Mud, sand, or gravel	Shorebirds	Staging			●	●								
				Ephemeral inlet	--														
				Beach	Gravelly sand														
C	0.7	10-20	>500	Active high tundra cliff	Sandy gravel														
				Beach	Gravel														
D	1.6	5-20	>500	Multiple small rivers	--														
				Active high tundra cliff	Sandy gravel														
				Beach	Gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 67
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	1.7	5-20	>500	Single channel river	--														
				Active high rock cliff	Sedimentary bedrock														
				Beach	Gravel														
B	3.2	10-20	>500	Multiple small rivers	--														
				Active low tundra cliff	Sandy gravel														
				Beach	Gravelly sand														
C	0.7	20-30	>500	Single channel river	--	Shorebirds	Staging			●	●								
				Ephemeral inlet	--	Glaucous gull	Staging			●	●	●							
				Beach	Sandy gravel	Arctic tern	Staging			●	●	●							
D	1.1	10-30	>500	Active low tundra cliff	Sandy gravel														
				Beach	Gravelly sand														
E	1.3	0-5	>500	Active high rock cliff	Sedimentary bedrock														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 68
Page I of I

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	7.0	0-5	>500	Multiple small rivers	--	Pelagic cormorant	Nesting (33 pr.)	●	●	●	●	●							
				Active high rock cliff	Sedimentary bedrock														
						Tufted puffin	Nesting (3 pr.)	●	●	●	●	●							
B	1.8	5-20	>500	Multiple small rivers	--														
				Active high rock cliff	Sedimentary bedrock														
				Beach	Gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	7.1	0-5	>500	Active high rock cliff	Sedimentary bedrock	Glaucous gull	Nesting (40 pr.)	●	●	●	●	●							
						Black guillemot	Nesting (9 pr.)	●	●	●	●	●							
B	0.6	30-50	>500	Single channel river	—														
				Active low tundra cliff	Sandy gravel														
				Beach storm berm	Gravel														
				Beach face	Gravel														
C	0.3	20-50	>500	Single channel river	—														
				Beach	Gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 70
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES																
				Across-Shore Character		BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	6.7	0-5	>500	Active high rock cliff	Sedimentary bedrock	Glaucous gull Black guillemot	Nesting (40 pr.) Nesting (9 pr.)	● ●	● ●	● ●	● ●	● ●							
B	0.8	20-40	>500	Active low tundra cliff Beach	Sandy gravel Gravelly sand														

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	7.2	50	>500	Small estuary, lagoon	--	Wetland			●	●	●	●	●						
				Ephemeral inlet	--	Shorebirds	Staging			●	●								
				Beach storm berm	Gravelly sand														
				Beach face	Gravelly sand														
B	1.4	25	>500	Active low tundra cliff	Sandy gravel														
				Beach	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 72
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES			HUMAN RESOURCES AND USE	
				Across-Shore Character						
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M J J A S O	Activity	J J A S O
A	1.3	30-50	>500	Single channel river Salt-tolerant wetland Beach	— Peat Sandy gravel					
B	1.6	40-60	>500	Active low tundra cliff Beach	Sandy gravel Sandy gravel					
C	3.0	30	>500	Small estuary, lagoon Ephemeral inlet Beach storm berm Beach face	-- -- Gravelly sand Gravelly sand					
D	2.3	30	>500	Passive high tundra cliff Foredune Beach storm berm Beach face	Sandy gravel/ Sedimentary bedrock Sand Sandy gravel Sandy gravel					

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	2.6	10-20	>500	Active high rock cliff Beach	Sedimentary bedrock Gravel														
B	4.6	50-70	>500	Multiple small rivers Active low tundra cliff Beach	-- Sandy gravel Gravel									DEW Line station and airstrip	●	●	●	●	●

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 74
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	5.8	20-30	>500	Active high rock cliff Beach	Sedimentary bedrock Gravel									Egg gathering	●	●			
B	5.5	0-50	>500	Active high rock cliff	Sedimentary bedrock	Seabird colony	Nesting	●	●	●	●	●		Egg gathering	●	●			
						Common murre	70,000 pr.												
						Thick-billed murre	30,000 pr.												
						Black-legged kittiwake	25,000 pr.												
						Horned puffin	1,450 pr.												
						Black guillemot	170 pr.												
						Pelagic cormorant	78 pr.												
						Glaucous gull	50 pr.												
						Tufted puffin	20 pr.												
C	0.7	30-50	>500	Single channel river Active low tundra cliff Beach	-- Sandy gravel Gravel									Egg gathering	●	●			

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 75
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	7.7	10-20	>500	Active high rock cliff	Sedimentary bedrock	Seabird Colony at Noyahlik Peak	Nesting	●	●	●	●	●		Egg gathering	●	●			
				Beach	Gravel														
						Horned puffin	35 pr.												
						Murre	20 pr.												
						Tufted puffin	15 pr.												
						Pelagic cormorant	9 pr.												
						Seabird colony at Cape Lewis	Nesting												
						Murres	25,000 pr.												
						Black legged kittiwakes	3,000 pr.												
						Horned puffin	300 pr.												
						Pelagic cormorant	60 pr.												
						Glaucous gull	50 pr.												
						Black guillemot	25 pr.												
						Tufted puffin	4 pr.												
B	1.1	30-60	>500	Single channel river	--									Egg gathering	●	●			
				Active low tundra cliff	Sandy gravel														
				Beach	Gravel														
C	1.2	30-50	>500	Single channel river	--									Egg gathering	●	●			
				Multiple channel delta	--														
				Beach storm berm	Gravel														
				Beach face	Gravel														

MAP 76
Page 1 of 1

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	4.5	20-30	>500	Active high rock cliff	Sedimentary bedrock	Seabird colony	Nesting	●	●	●	●	●		Egg gathering	●	●			
				Beach	Gravel	Murres	20 pr.												
B	4.6	50-70	>500	Passive low tundra cliff	--									Egg gathering	●	●			
				Active low tundra cliff	Mud, sand, or gravel														
				Beach	Gravel														
C	1.1	0-5	>500	Active high rock cliff	Sedimentary bedrock	Seabird Colony at Cape Dyer	Nesting	●	●	●	●	●		Egg gathering	●	●			
						Pelagic cormorant	26 pr.												
						Glaucous gull	48 pr.												
						Horned puffin	24 pr.												
						Tufted puffin	4 pr.												
D	0.5	20-50	>500	Single channel river	—														
				Beach storm berm	Gravel														
				Beach face	Gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 77
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	12	5-30	>500	Active high rock cliff Beach	Sedimentary bedrock Gravel	Seabird colony Pelagic cormorant Glaucous gull	Nesting 100 pr. 40 pr.	●	●	●	●	●							

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 78
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES																
				Across-Shore Character		BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	4.8	20-30	>500	Active high rock cliff Beach	Sedimentary bedrock Gravel									Fishing	●	●	●		
B	0.6	30-50	>500	Single channel river Multiple channel delta Beach	- — Gravel									Fishing	●	●	●		
C	1.1	30-50	>500	Single channel river Active low tundra cliff Beach	- Sandy gravel Gravel									Fishing	●	●	●		

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 79
Page I of I

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	7.5	20-30	>500	Washover fan	Gravelly sand									Fishing	●	●	●		
				Beach storm berm	Gravelly sand														
				Beach face	Gravelly sand														
B	0.2	—	>500	Stable inlet	--	Beluga whale	Summering			●	o			Beluga whale hunting		●	o		
C'	7.6	10-20	1.5	Beach	Gravelly sand	Mudflats		●	●	●	●	●	●	Fishing	●	●	●		
D'	9.5	0-10	1.5	Active low tundra cliff	Peat/ Sandy gravel									Fishing	●	●	●		
E'	0.5	200	1	Active low tundra cliff	Peat/Sandy gravel														
				Intertidal flat	Mud, Sand	Mudflats		●	●	●	●	●	●						
F'	2.3	500	3	Single channel river	—														
				Multiple channel delta	--														
				Intertidal flat	Mud/Sand	Mudflats		●	●	●	●	●	●						
Marryatt Inlet	--	--	--	Open water	--	Beluga whale	Summering			●	o			Fishing	●	●	●		
						Waterfowl	Migration, Staging		●	●	●	●		Beluga whale hunting		●	o		
						Shorebirds	Migration, Staging			●	●								

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 80
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	3.9	30-100	>500	Washover fan	Gravelly sand									Waterfowl hunting	●			●	
				Beach storm berm	Gravelly sand									Fishing	●	●	●		
				Beach face	Gravelly sand														
B	4.2	20-30	>500	Active low tundra cliff	Sandy gravel									Waterfowl hunting	●			●	
				Beach	Gravel									Fishing	●	●	●		
C	0.9	30-50	>500	Foredune	Sandy gravel									Waterfowl hunting	●			●	
				Beach	Gravelly sand									Fishing	●	●	●		
D	3.0	100	300	Foredune	Sandy gravel									Fishing	●	●	●		
				Beach storm berm	Gravelly sand														
				Beach face	Gravelly sand														
E	5.7	50-80	300	Small estuary, lagoon	—														
				Washover fan	Sandy gravel														
				Washover channel	Sandy gravel														
				Foredune	Sandy gravel														
				Beach storm berm	Logs/Gravelly sand														
				Beach face	Gravelly sand														
F'	7.0	10-20	7	Beach	Sandy gravel	Mudflats		●	●	●	●	●	●						
G'	4.8	10-20	7	Active low tundra cliff	Sandy gravel	Mudflats		●	●	●	●	●	●						
				Beach	Sandy gravel														
H'	5.0	20	5	Beach berm	Sand	Mudflats		●	●	●	●	●	●						
				Beach face	Sand														
I'	8.2	5	5	Active low tundra cliff	Mud, sand, or gravel														
Marryatt Inlet	--	--	--	Open water	--	Beluga whale	Summering			●	o			Fishing	●	●	●		
						Waterfowl	Migration, Staging		●	●	●	●		Beluga whale hunting		●	o		
						Shorebirds	Migration, Staging			●	●								

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 81
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	3.7	30-100	>500	Washover fan	Gravelly sand									Fishing	●	●	●		
				Beach storm berm	Gravelly sand														
				Beach face	Gravelly sand														
B	10.0	50-300	300-500	Foredune	Sandy gravel									Fishing	●	●	●		
				Beach storm berm	Sandy gravel									Historical village	●	●	●	●	●
				Beach face	Sandy gravel									Community of Point Hope	●	●	●	●	●
C'	5.5	20-50	10	Beach	Sandy gravel	Mudflats		●	●	●	●	●	●						
				Mudflats	Sand, mud	Shorebirds	Migration, Staging			●	●								
						Waterfowl	Migration, Staging		●	●	●	●							

MAP 82
Page 1 of 1

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	7.6	30-60	300	Small estuary, lagoon	--									Fishing	●	●	●		
				Washover fan	Gravelly sand									Waterfowl hunting	●			●	
				Beach storm berm	Gravelly sand														
				Beach face	Gravelly sand														
B	1.6	20-30	300	Salt-tolerant wetland	Peat									Fishing	●	●	●		
				Foredune	Sandy gravel									Waterfowl hunting	●			●	
				Beach storm berm	Sandy gravel														
				Beach face	Sandy gravel														
C'	12.5	10	5	Active low tundra cliff	Sandy gravel	Mudflats		●	●	●	●	●	●						
						Shorebirds	Migration, Staging			●	●								
						Waterfowl	Migration, Staging		●	●	●	●							
D'	8.2	10	5	Beach	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

MAP 83
Page 1 of 1

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	8.2	50	300	Small estuary, lagoon	–									Fishing	●	●	●		
				Washover fan	Gravelly sand									Waterfowl hunting	●			●	
				Beach storm berm	Gravelly sand														
				Beach face	Gravelly sand														
B	1.3	20-30	300	Active low tundra cliff	Sandy gravel									Fishing	●	●	●		
				Beach	Sandy gravel									Waterfowl hunting	●			●	
C'	14.0	10	9	Active low tundra cliff	Sandy gravel	Mudflats		●	●	●	●	●	●						
						Shorebirds	Migration, Staging			●	●								
						Waterfowl	Migration, Staging		●	●	●	●							
D'	8.2	10	9	Beach	Sandy gravel														

CHUKCHI SEA COASTAL RESOURCES TABLE

UNIT DIMENSIONS			PHYSICAL RESOURCES			BIOLOGICAL RESOURCES								HUMAN RESOURCES AND USE					
				Across-Shore Character															
Unit Identifier	Unit Length (km)	Unit Width (m)	Maximum Wave Fetch (km)	Morphological Components	Substrate Type	Resource	Activity	M	J	J	A	S	O	Activity	J	J	A	S	O
A	7.0	70-100	300	Small estuary, lagoon	--									Waterfowl hunting	●	●			
				Washover fan	Gravelly sand									Fishing	●	●	●		
				Beach storm berm	Gravelly sand														
				Beach face	Gravelly sand														
B	1.2	50	300	Salt-tolerant wetland	Peat									Waterfowl hunting	●	●			
				Beach storm berm	Gravelly sand									Fishing	●	●	●		
				Beach face	Gravel														
C	1.9	20-40	300	Multiple small rivers	-									Waterfowl hunting	●	●			
				Active low tundra cliff	Sandy gravel														
				Beach	Gravelly sand														
D	1.8	0-10	300	Active high rock cliff	Sedimentary bedrock	Seabird colony at Cape Thompson	Nesting	●	●	●	●	●		Egg gathering	●	●			
						Murres	217,000 pr.												
						Black-legged kittiwake	10,200 pr.												
						Horned puffin	700 pr.												
						Glaucous gull	36 pr.												
						Pigeon guillemot	10 pr.												
						Black guillemot	2 pr.												
						Pelagic cormorant	2 pr.												

COASTAL RESOURCE TABLE LEGEND

UNIT DIMENSIONS

Unit Identifier
Letter indicates location of unit on resource maps. A "prime" (e.g., A') indicates that unit is located within a lagoon or embayment.

Unit length (Km)
Alongshore length of unit in kilometers.

Unit Width (m)
Estimated across-shore width of the shore-zone as measured between the low water line and the normal storm high-water line (in meters).

PHYSICAL RESOURCES

Maximum Wave Fetch (Km)
Approximate maximum open-water fetch distance (for average ice years) measured in kilometers.

Across-Shore Character
Description of shore-zone morphology and substrate types. Shore-zone character is described in terms of morphological components; landward-most shore-zone components are listed first, seaward-most components are listed last.

Morphological Components
Shore-zone morphologies which vary in the across-shore direction but which are continuous in the alongshore direction (within the unit).

Substrate Type
The dominant substrate type of each morphological component. Clastic sediment terminology is that of Folk (1968). Last element of substrate description is dominant (e.g., gravelly sand is greater than 50% sand). A "/" indicates one substrate or sediment overlies another substrate (e.g., "organics/sand" indicates an organic layer overlies sand).

BIOLOGICAL RESOURCES

Resources
Descriptive reference to common biological resources within unit. Only shore-based resources are listed, except in lagoons, where key marine resources are identified. Where abundance is well-documented, species numbers are provided (e.g., marine bird colonies).

Activity
Descriptive reference to dominant biological activities which occur within the unit.

Seasonal-Use Chart (MJJASO)
Identifies months (May, June, July, etc.) when major biological activity occurs within the unit. Open circles indicate that only a partial month of activity occurs; filled circles indicate a complete month of activity normally occurs.

HUMAN RESOURCES AND USE

Activity
Identifies important human-uses of the shore-zone or lagoonal waters. Offshore use activities (e.g., bowhead whaling) are not identified).

Seasonal-Use Chart (MJJASO)
Identifies months (May, June, July, etc.) when human use activity occurs within the unit. Open circles indicate that only a partial month of activity occurs; filled circles indicate a complete month of activity normally occurs.

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