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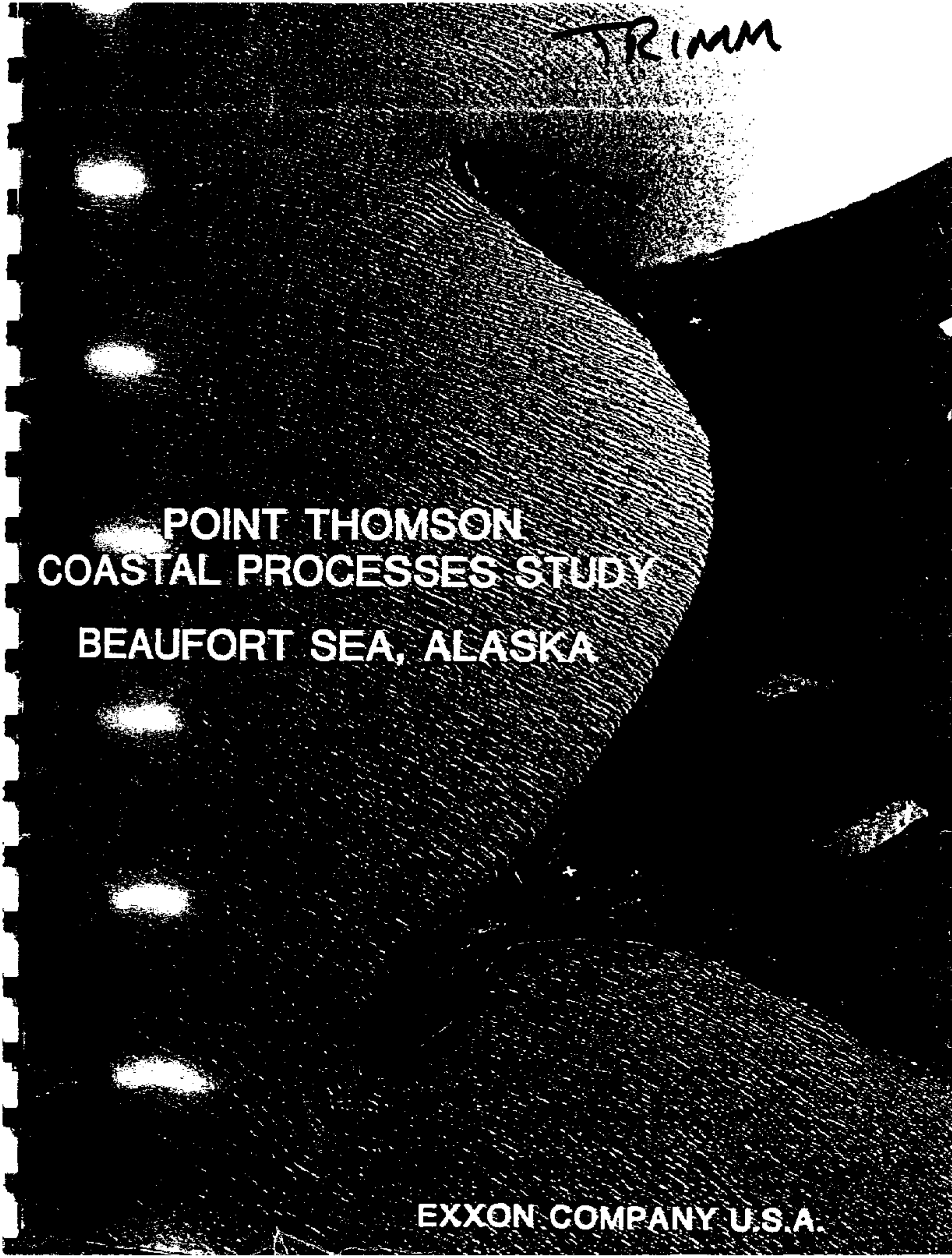

POINT THOMSON COASTAL PROCESSES STUDY

BEAUFORT SEA, ALASKA

EXXON COMPANY U.S.A.

TEKMARINE PROJECT TCN-033

PT. THOMSON COASTAL PROCESSES AND SEDIMENT DYNAMICS STUDY BEAUFORT SEA, ALASKA

PREPARED FOR:
EXXON COMPANY U.S.A.
CONTRACT NO. PTD-8206

TEKMARINE, INC.

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JANUARY 1983

EXECUTIVE SUMMARY

This study describes the coastal processes occurring in the Pt. Thomson region of Northern Alaska. The study area is located on the shores of the Beaufort Sea approximately 45 nautical miles east of Prudhoe Bay.

The objectives of the study program are as follows:

- o Establishment of a monumented coastal survey network to allow repetitive measurements of coastal change;
- o Characterization of the coastal processes on the basis of both quantitative measurements taken during the study and historical information found in the literature;
- o Assessment of the implications of the coastal processes as they related to the planning and design of coastal structures in the Pt. Thomson region.

This report describes the results of the study undertaken during the summer of 1982 in which all of the tasks listed above were accomplished.

Geographically, the study area is divided into two distinct parts. The coastal portion consists of a total of 14 nautical miles of continuous shoreline located on the mainland. A chain of barrier islands consisting of Flaxman, Mary Sachs, North Star, Duchess, and Alaska Islands, and an independent shoal located three nautical miles west of Challenge Island, comprise the offshore portion of the study region.

Two field trips were undertaken during the summer of 1982. During the first field trip, a total of 67 monumented coastal transects were established, and such tasks as detailed surveying of beach profiles, sediment sampling, morphological reconnaissance, and photographic documentation were performed. During the second field trip, each transect was recovered and re-profiled to quantify the changes associated with the intervening period between the surveys.

The survey results show that the shores of the mainland coast are the most stable within the study area. This is due, in part, to the sheltering effect of the offshore islands. In contrast, the offshore islands are quite dynamic. The high northern bluff of Flaxman Island is eroding continuously at a long-term rate of 12 feet/year, based on a survey comparison spanning the 1955-1982 period. This bluff erosion supplies a portion of the beach sediment that nourishes the barrier island complex located to the west.

The barrier islands are constantly undergoing changes in form and location. Typical changes that have been documented include island migration, inlet formation and filling, and fluctuations in shoreline position occasioned by brief, yet extreme, storm events. These islands actively respond to persistent easterly wind and waves resulting in a westward long-term migration that averaged 80 feet/year during the 1908-1982 period. The observed correlation of shoreline configuration with the submerged longshore bars suggests that the underwater topography in the nearshore zone may be just as dynamic.

To utilize the dynamic landforms within the study area as sites for oil development, it is recommended that coastal set-back distances be respected so as to separate the new facility from the active bluff or shore. This strategy of hazard avoidance is deemed to be less expensive than to attempt to control the erosion by artificial means.

The conceptual design of coastal drilling pads has been performed for four distinct zones within the study area. These zones include the high mainland shore, the low mainland shore, the Flaxman Island surface bordered by the eroding bluff, and the low-lying barrier island/lagoon environment.

A conceptual design has been performed for a gravel causeway to connect the mainland shore to Flaxman Island. The perceived environmental impacts associated with such a structure are the localized degradation of water quality within the lagoon and the impoundment of littoral sediments by the causeway structure. Possible mitigative actions include the construction of causeway breaches to allow transfer of water across the structure and the physical transport of impounded sediment at the causeway to adjacent locations where the protective beach cover has been lost.

Based on the results of this study, it is deemed feasible to construct and maintain oil exploration and production facilities within the Pt. Thomson study area. It should be emphasized, however, that coastal structures, once constructed, should be monitored in order to ensure minimum adverse influence on or by the dynamic processes of the Arctic coast, an environment which has just recently been subject to serious scientific scrutiny.

While the long-term coastal changes within this region are predictable, the range of short-term fluctuations are not well defined due to the absence of data collected during consecutive years. Repetitive surveying of the recently established coastal transect network will allow a more definitive view of the short-term variability of Arctic coastal processes and the resultant effects on proposed coastal facilities.

Acknowledgements

The authors are extremely grateful to a number of individuals who allowed this study to be conducted in a timely and efficient manner. We greatly appreciate the overall guidance provided by Mr. Ashley Erwin of Exxon Company U.S.A. for his efforts in directing and monitoring the progress of the study. Drs. Robert Gordon and Martin Miller of Exxon Production Research provided untiring assistance and scientific insight during the Arctic field operations. The staff of the Exxon operations center at Deadhorse, Alaska, deserves special thanks for the service which was provided in support of overall logistics, field communications, and lodging.

Members of the field team who assisted ably and enthusiastically in the Arctic data collection deserve commendation from the authors. These individuals include Mr. Ashley Erwin of Exxon Company U.S.A., Drs. Robert Gordon and Martin Miller of Exxon Production Research, and Dr. Choule Sonu and Messrs. Robert Gould and John D'Auria of Tekmarine, Inc.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF TABLES

LIST OF PHOTOS

LIST OF PHOTOS (Cont'd)

LIST OF PHOTOS (Cont'd)

1. INTRODUCTION

This study characterizes the coastal processes that occur in the Pt. Thomson region of Northern Alaska and derives the engineering implications of these processes as they relate to the planning and design of coastal oil development facilities. More specifically, the objectives of the study program are as follows:

- Establishment of a monumented coastal survey network to allow repetitive measurements of coastal change;
- Characterization of the coastal processes on the basis of both quantitative measurements taken during the study and historical information found in the literature;
- Assessment of the implications of the coastal processes as they relate to the planning and design of coastal structures in the Pt. Thomson region.

This report describes the results of the study undertaken during the summer of 1982 in which all of the tasks listed above were accomplished. It must be cautioned, however, that the results of the data collected during a single summer may not prove to be characteristic of this complex Arctic environment. For this reason, the conclusions drawn in this report should be considered provisional, and subject to refinement as additional data becomes available.

The study area is located approximately 45 nautical miles east of Prudhoe Bay on the shores of the Beaufort Sea. As shown in the Location Map, Figure 1.1, the study area is bounded by longitude 146°45'W (two nautical miles east of Bullen Point) and longitude 146°05'W (4.5 nautical miles west of Brownlow Point).

Geographically, the study area is divided into two distinct parts. The coastal portion consists of a total of 14 nautical miles of continuous crenulated shoreline located on the mainland. A chain of barrier islands consisting of Flaxman, Mary Sachs, North Star, Duchess, and Alaska Islands, and an independent shoal located three nautical miles west of Challenge Island, comprise the offshore portion of the study region.

Two field trips were undertaken for the purposes of data collection during the summer of 1982. During the first field trip (July 19-27), a total of 67 monumented coastal transects were established, and such tasks as detailed surveying of beach profiles, sediment sampling, morphological reconnaissance, and photographic documentation were performed. During the second field trip (August 31 - September 7), each transect was recovered and re-profiled to quantify the changes associated with the intervening period between surveys.

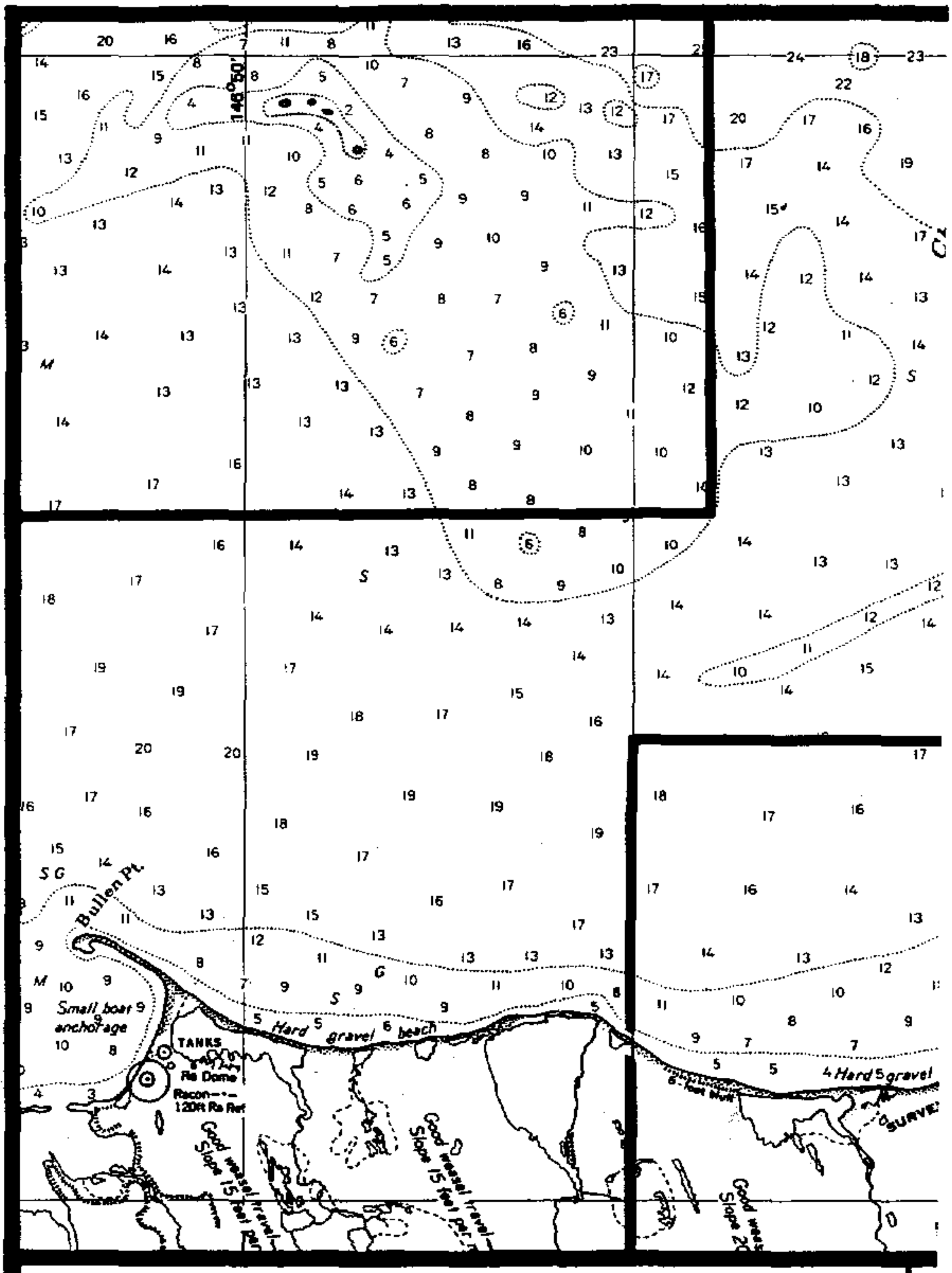


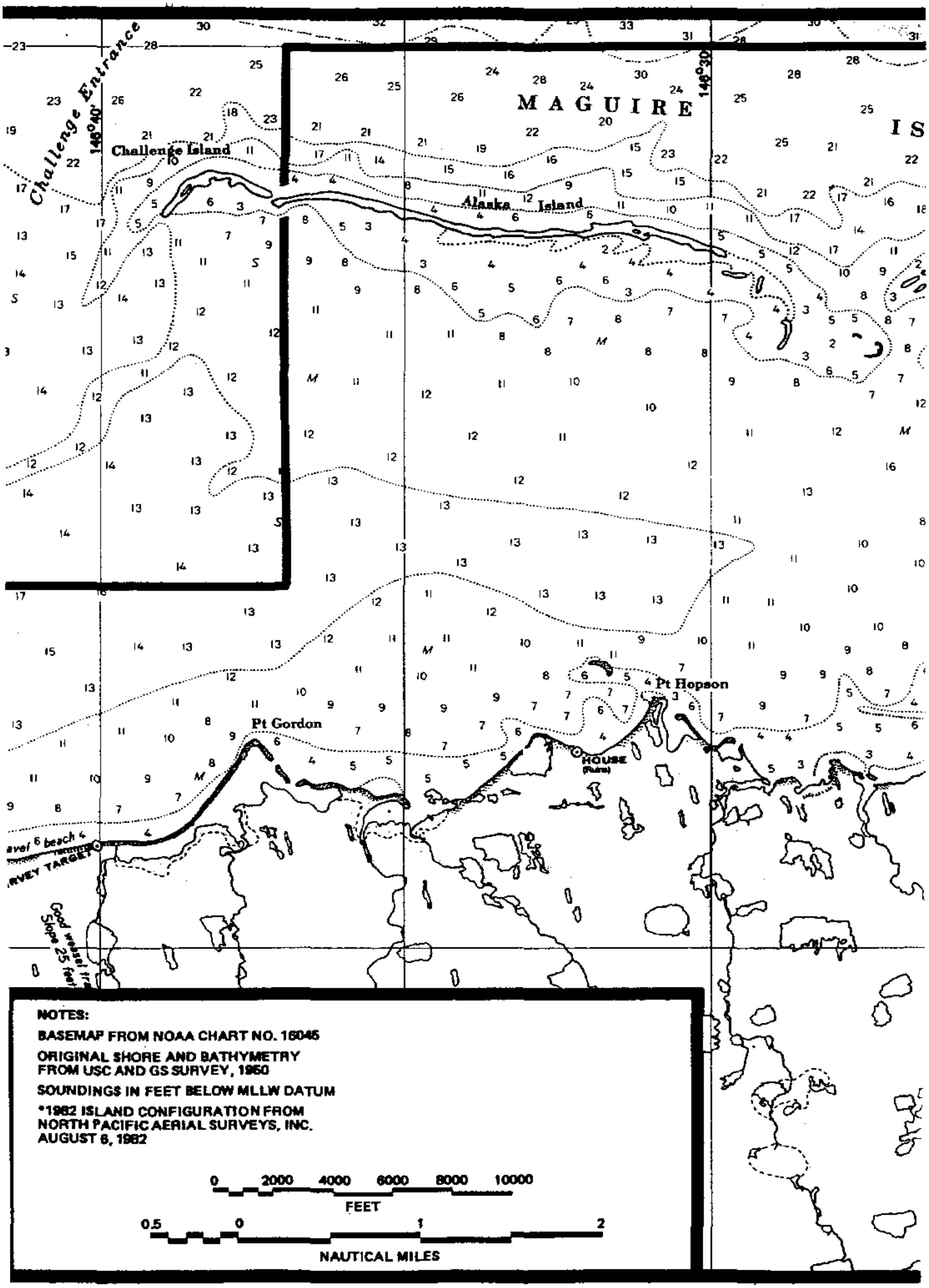
FIGURE 1.1

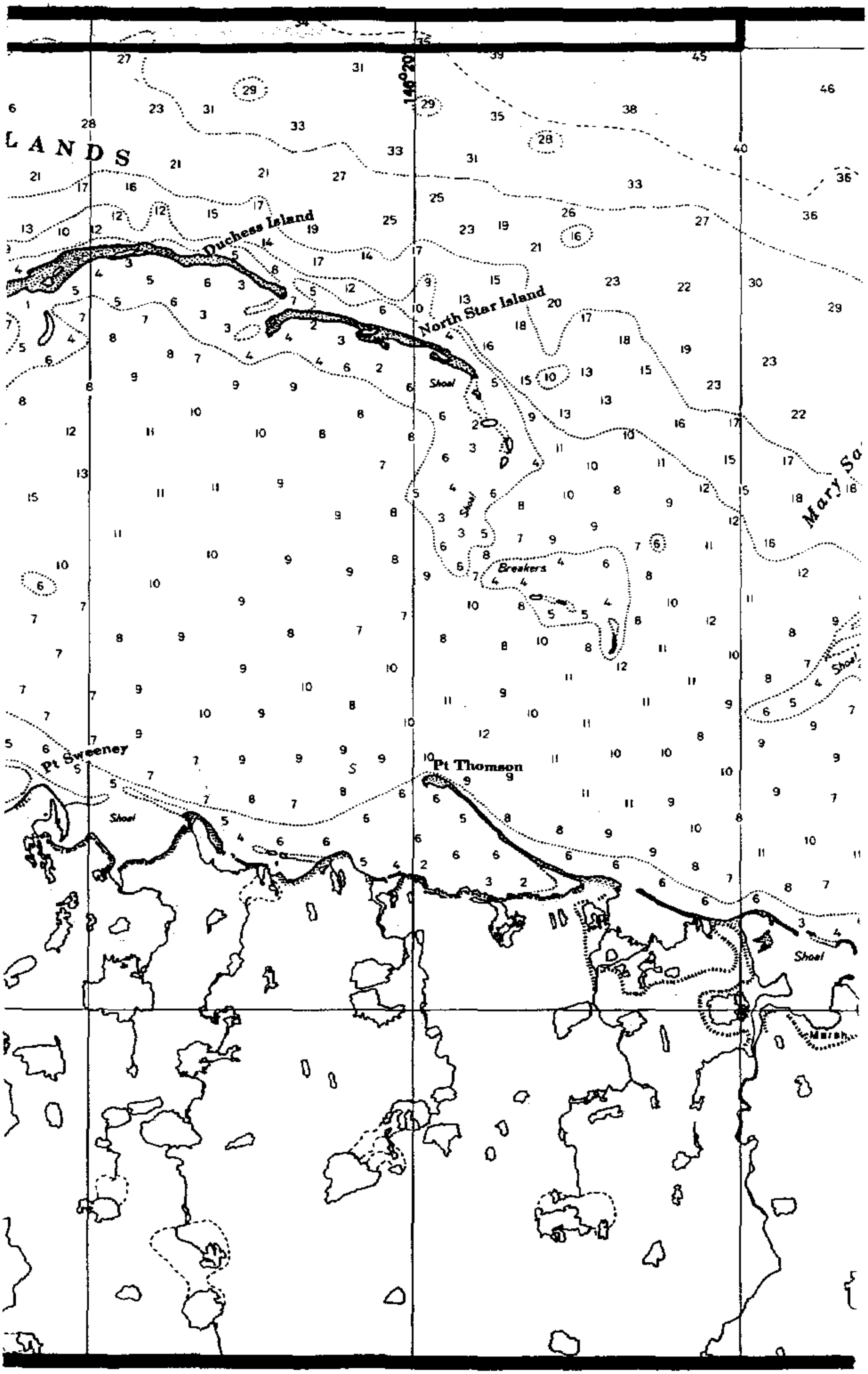
PT. THOMSON STUDY AREA

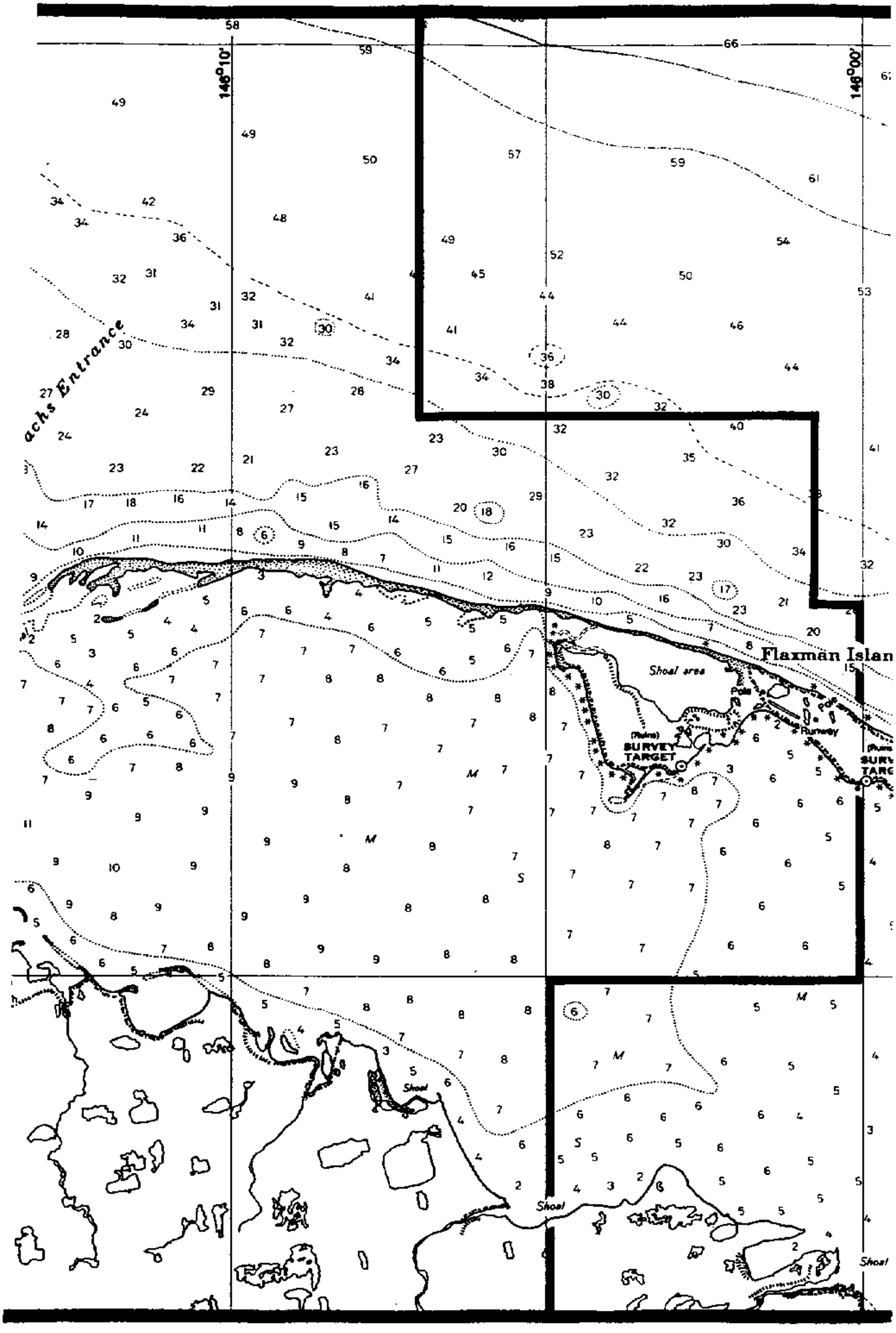
PT. THOMSON DEVELOPMENT PROJECT
COASTAL PROCESSES AND SEDIMENT DYNAMICS
CONTRACT PTD–8206
TEKMARINE, INC.

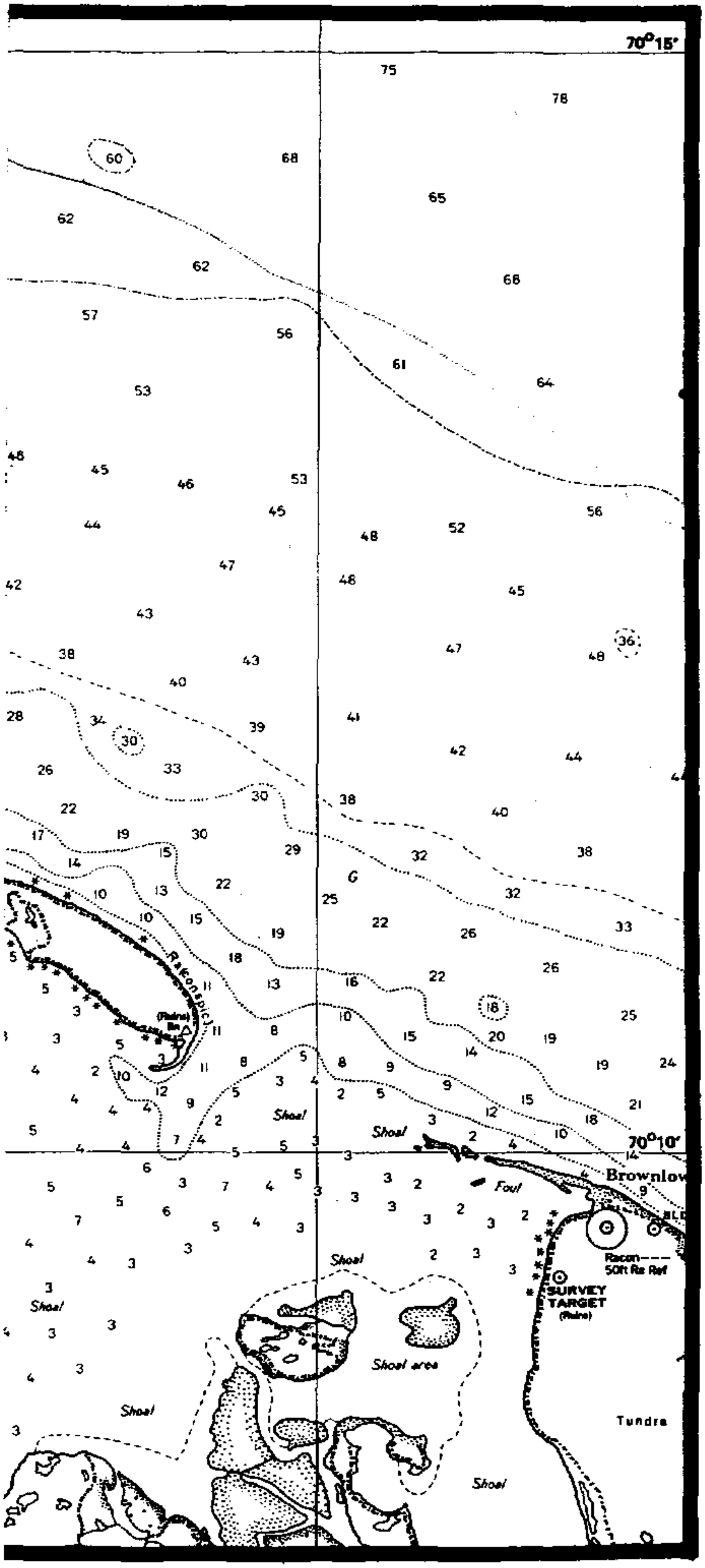
DRAWN

APPROVED


Challenge Entrance
146°40'
Challenge Island
MAGUIRE
Alaska Island
146°30'
Pt Hopson
Pt Gordon
HOUSE
(Ruins)
NOTES:
BASEMAP FROM NOAA CHART NO. 16046
ORIGINAL SHORE AND BATHYMETRY FROM USC AND GS SURVEY, 1950
SOUNDINGS IN FEET BELOW MLLW DATUM
*1982 ISLAND CONFIGURATION FROM NORTH PACIFIC AERIAL SURVEYS, INC. AUGUST 6, 1982
0 2000 4000 6000 8000 10000
FEET
0.5 0 1 2
NAUTICAL MILES


LANDS
Duchess Island
North Star Island
146°20'
Shoal
Breakers
Pt Sweeney
Pt Thomson
Marsh


146°10'
146°00'
achs Entrance
Flaxman Islan
Shoal area
Pole
Runway
(Ruins)
SURVEY TARGET
Shoal



70°15'
70°10'
Shoal
Foul
Brownlow
SURVEY
TARGET
Shoal area
Tundra

2. STUDY AREA OVERVIEW

2.1 Environmental Setting

The Arctic climate has a major influence on the coastal conditions and changes of the Pt. Thomson study area. The Beaufort Sea is ice-covered for most of the year with a brief open-water season occurring usually from mid-July to early October. The astronomical tides of this region are quite small (less than a foot of total tidal range occurs) and are subordinate to sea level changes associated with high wind conditions and barometric pressure effects.

Wave energy impacting the coastline is generally small, limited by the proximity of the Arctic ice pack which remains relatively close to shore during the summer months. Infrequent northeast and northwest storms can create storm waves that can cause erosion of the mainland coast and the offshore islands. Also, high speed westerly winds can cause super-elevation of the ocean surface with the resultant waves and storm surge causing inundation of the low-lying coastal areas and overtopping of certain segments of the offshore barrier islands.

Following the ice break-up of June or July, the coastal beaches and offshore islands are disrupted by moving ice pushing onshore. Furrows and ridges 20 to 30 feet long and three to five feet high may be "bulldozed" on exposed beaches. Government surveyors reported that following the winter of 1949-1950, ridges of gravel five to eight feet high were created by ice push that extended 50 to 70 feet inshore from the water line (notes occurring on USC&GS Hydrographic Survey No. 7851, 1950). Also during early summer, the low coastal bluffs of the region begin to thaw, creating mud flows which escape from the bluff to the beach below. As the thawing continues, "thermal erosion" of the bluff occurs which is a major cause of shore recession in this area.

In late summer, high winds can affect the area creating water level fluctuations and intensified wave impact. During this period, sea ice may again be driven onshore. Most of the major sediment movement and the related coastal changes -- bluff retreat, beach erosion, sand spit elongation or truncation, island movement, and island inlet formation or closing -- occur during the late summer - early autumn period.

In the late fall, the beaches of the study area become sheathed in ice and snow thereby protecting them from the effects of waves and minor ice incursions throughout the winter months.

The Arctic coastal plain is underlain by a series of alluvial and glacial outwash fans extending northward from the Brooks Range. These fans consist mainly of sand and gravel and tend to extend to the coast. In some areas (particularly, Flaxman Island), the coastal veneer consists of a peculiar matrix of marine sandy mud which contains glaciated pebbles, cobbles, and boulders that are quite different in lithology from the gravel of Brooks Range origin that is commonly found in the alluvial fans of the region. This geologic material -- termed the "Flaxman formation" -- contains a suite of pebble types that is completely different from those found in the alluvial and glacial deposits associated with streams draining the Brooks Range (Hopkins and Hartz, 1978).

The Flaxman formation underlies Flaxman Island and large mainland areas east of the Canning River. Components of this formation, owing to the on-going erosion of Flaxman Island, are found in the sediments of the barrier islands to the west.

The mainland coast of the study area is crenulated and deeply embayed. Offshore, Flaxman Island and the Maguire Island chain provide a nearly continuous barrier to northeasterly wave energy. Thus, easterly wave energy striking the mainland coast must be generated within the lagoon located south of the island chain. To the west, no island protection exists in the immediate vicinity to limit the fetch of westerly storms.

The mainland shore is characterized by narrow, low-lying beaches backed by low coastal bluffs (commonly three to twenty feet high). The beaches are typically 25 to 75 feet wide and normally consist of a very thin veneer of clastic sediment overlying the highly organic tundra foundation.

The sand and gravel that form the beaches of the study area are derived from alluvial discharge from the rivers of the region and from the erosion of coastal bluffs. Some investigators believe that rivers of the region do not contribute significantly to the sediment budget, as most of the alluvial bedload is presumed to be deposited inland with only the finer sediment fraction being discharged at the river mouths (Hopkins and Hartz, 1978). Based on a study of the massive sediment discharge of the Colville River (Arnborg, et al., 1966), it is our belief that the sediment contributions of major rivers like the Canning River should not be disregarded in terms of beach sediment contribution to the nearshore zone.

The direction of littoral sediment drift is generally westward under the persistent easterly winds of the region. However, wave refraction and the crenulated coastline induce local reversals both onshore and on the arcuate barrier islands. Due to the generally low wave activity during the brief open-water season, the total volume of alongshore sand transport is quite small relative to beaches of more temperate latitudes.

The bluffed portions of the mainland coast and Flaxman Island are affected by thermal erosion -- a formidable erosive agent in this region. Thermal erosion is most effective and rapid along bluffs that are ice-rich, having high percentages of frozen mud, silt, and fine sand. Thawing and erosion of bluffs containing gravel and sand deliver substantial volumes of beach sediment that subsequently protect the bluff from wave-induced undercutting. The high rate of on-going erosion, particularly on Flaxman Island, provides substantial volumes of beach sediments to nourish the beaches and barrier islands of the downdrift coast.

The barrier islands of the study area extend westward from the tundra-veneered Flaxman Island. These islands, composed of unconsolidated sand and gravel, are low-lying (2 to 4 feet maximum elevations), arcuate, and exhibit major features that may change dramatically with time. The barrier islands are separated by major inlets that may be relatively deep (8 - 12 feet) and wide (1/2 to 2 nautical miles). In addition, a long, seemingly continuous barrier may be segmented by very narrow and shallow inlets, such as the one that formed between Flaxman and Mary Sachs Islands during the 1955 - 1982 period.

As these islands are attacked by the persistant easterlies, the general trend is for growth of the islands' westward extremities. This mechanism of island extension, termed "island migration", has created a long-term westward movement of the islands of the Maguire group that is judged to be on the order of 80 feet/year (Wiseman, et al., 1973). In terms of coastal processes, the rapid changes of island shape and relative location caused by island migration, development of new inlets, and filling of old inlets is the most dynamic aspect of the study area.

Hopkins and Hartz (1978) surmise that the Maguire Islands and possibly the Stockton Islands to the west were originally derived from the bluff erosion of Flaxman Island. This speculation implies that Flaxman Island was, at one time, a much larger source of sedimentary material than it is today. The discontinuous nature of the island chain at this time is due to storm-generated breaching of the narrow barrier islands which, in the case of the largest inlets, is irreversible due to tidal deepening and the diminishing supply of beach sediments generated by Flaxman Island bluff erosion.

Long-term shoreline comparisons indicate that the barrier islands are migrating with little loss of surface area (Hopkins and Hartz, 1978). During storm surge events, waves overwash the island shores thereby driving sediment at the waterline up and onto the main island body. On-shore ice motion can drag or pluck coarse lag material from deeper waters onto the island surface. It is speculated, however, that with time, as Flaxman Island continues to erode, the downdrift coast and Maguire Island chain will slowly diminish in areal extent (Hopkins and Hartz, 1978). The ultimate result will be a loss of the critical mass required to withstand the ambient wave and ice forces leading to subsequent island erosion and submergence.

2.2 Review of Pertinent Literature

The first recorded visit of a western explorer to the shores of the Beaufort Sea was described in the chronicles of the British expedition of 1826, led by Sir John Franklin. The primary focus of this and subsequent early exploration efforts was for mapping purposes and to add to the meager amount of Arctic information that existed at the time. A large number of English, American, and Canadian explorers ventured into the region during the late 1800's. A number of mapped features now bear the names of those early explorers -- Franklin Bluffs, Beechy Point, Simpson Lagoon, Dease Inlet, Maguire Islands, Stockton Islands, Steffanson Sound. Because the early exploration efforts charted land forms and islands at small scale with imprecise survey techniques, few direct comparisons with more modern data are possible. The value of the expeditions that took place prior to 1900 is in the written descriptions of the landscape and navigable passes from which some correlation to the present condition is possible.

In 1906, Ernest Leffingwell, under the auspices of the American Geographical Society, undertook the first comprehensive mapping and geological exploration effort in the Alaskan Arctic. Maps that he created are sufficiently detailed and precise to allow comparison to surveys undertaken in more recent periods. Because Leffingwell's base camp for the entire study period (1906 - 1914) was located on the south shore of Flaxman Island, the region of interest presently was discussed and mapped in detail as a portion of his study.

Leffingwell's contribution to the existing body of Arctic knowledge was formidable. His mapping efforts provided the first precise and comprehensive charts of the entire Arctic coast. His geological reconnaissance proved to be extensive and credits him with discovery of the Sadlerochit formation -- the source of the Prudhoe Bay oil field.

The literature dealing with the Pt. Thomson area becomes sparse following Leffingwell's contribution. In the late 1960's and early 1970's, following the discovery of the large Prudhoe Bay oil field, various investigators undertook significant studies of the Arctic coastal zone. Some of these studies were sponsored by the Department of Defense (Wiseman, et al., 1973) and the U.S. Geological Survey (Barnes, et al., 1977; Hartz, 1978). By the mid-1970's, the U.S. Departments of Commerce and Interior were sponsoring numerous studies to collect and assess environmental information to support oil development planning. These studies, under the program entitled "Environmental Assessment of the Alaskan Continental Shelf", contributed greatly to the oceanographic and coastal zone data base that had been developed previously. Significant contributions documenting the shoreline processes within or near the Pt. Thomson study area include Barnes and Reimnitz, 1974; Barnes, et al., 1977; Hopkins, et al., 1977, Hopkins and Hartz, 1978; Lewellen, 1977; and Reimnitz and Toimil, 1977. In the following section of the report, the results of these previous investigations will be reviewed to establish an understanding of the coastal dynamics within the study area.

In time, this information will be compared to the findings of the current study to determine the extent of conformity to the findings of earlier investigations.

2.3 Historical Data Comparison, 1826 - 1955

The majority of the most recent studies of coastal processes within the study area utilize information gleaned from the following major sources:

- The written descriptions of pre-1900's expeditions;
- The descriptions and charts prepared by Ernest Leffingwell (Leffingwell, 1919);
- The government survey data used for nautical charts and mapping purposes primarily during the 1950 - 1955 period;
- Aerial photos collected since 1950.

Thus, a large proportion of these references develop data comparisons (shoreline and bluff position, island location and form, land form elevations) that reflect the conditions which existed prior to the mid-1950's. The intent of this study is to up-date this information to the summer of 1982 and to place the recent findings in the broader perspective of the historical data.

2.3.1 Mainland Shore

As described previously, the mainland shore of the study area is scalloped with a large number of sinuous sand and gravel spits projecting from the tundra promontories.

In a number of areas, eroding coastal bluffs having heights of 3 to 20 feet are separated from the waterline by a narrow sand and gravel beach.

The erosion rates of the coastal bluffs of this region have been measured by numerous investigators. Hopkins and Hartz (1978) report an average recession rate of the bluffs between Tigvariak Island and Pt. Thomson of seven feet/year. East of Pt. Thomson, Lewellen (1977) has two survey sites which show an average erosion rate of 22 feet/year. Leffingwell calculated a high bluff recession rate of 30 feet/year on Brownlow Point based on observations by the early prospector Arey. While these retreat rates are impressive, it is curious that a number of the prominent coastal features of the mainland appear to have maintained similar shape during the period since the Leffingwell survey, conducted around 1910. Leffingwell's map of the study area, published in 1919, is presented as Figure 2.1. In comparing this chart with the most recent NOAA chart (1950-1955), displayed as Figure 1.1, it is remarkable that certain small mainland features (sand bars, spits, small islets) have exhibited little change during the 1910-1950 period. Additionally, the most recent work has indicates that the 1982 shoreline is extremely similar to that charted by NOAA in the 1950's. Therefore, one must conclude that while localized zones may exhibit high rates of change, the mainland shore generally appears to be highly stable, in part due to the sheltering effect of the offshore islands.

Leffingwell (1919) emphasizes that certain shore areas have remained stable for centuries. He refers to the ancient, decaying timber structures located near Barter Island and Collinson Point. The fact that these man-made

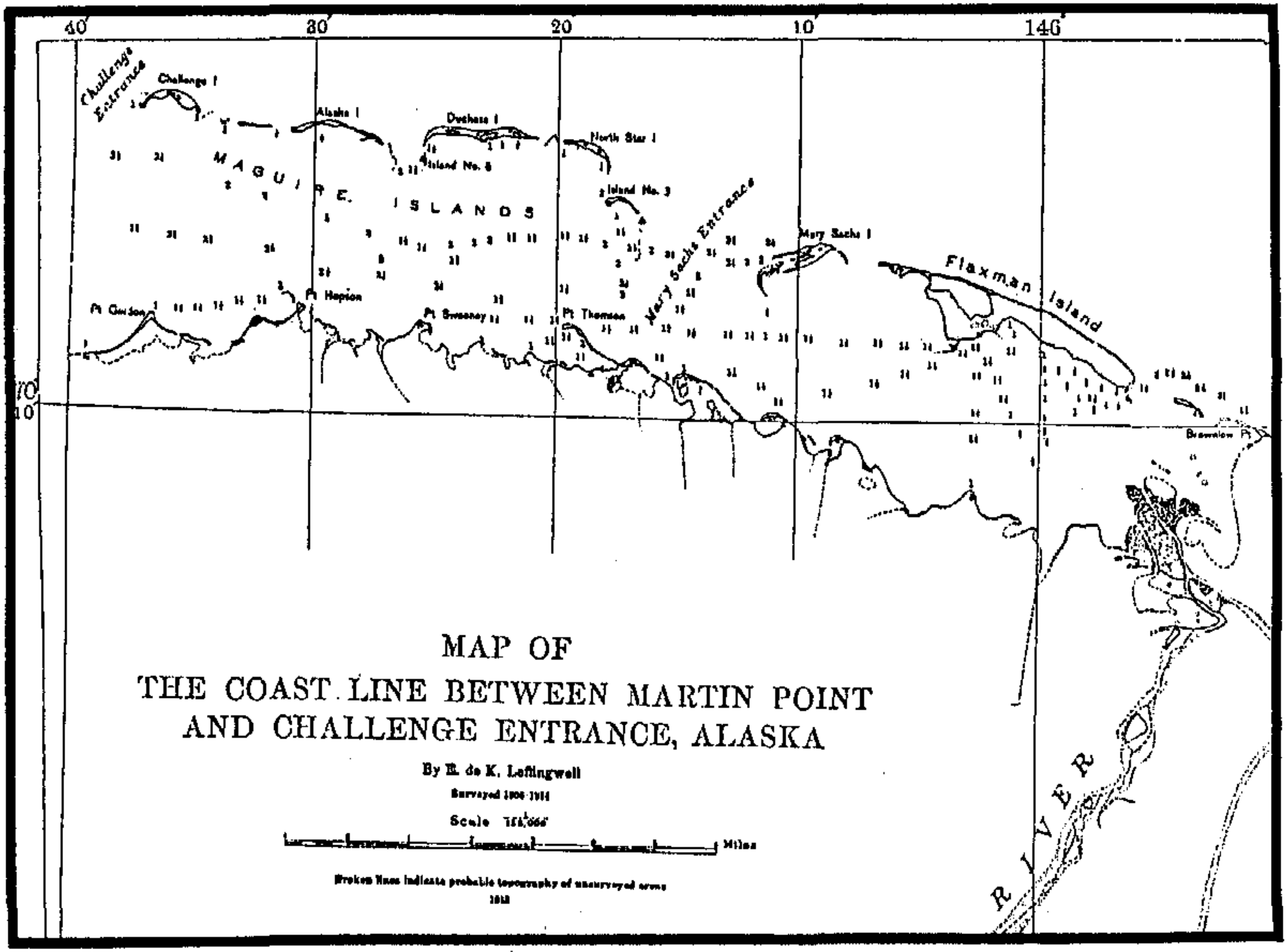


FIGURE 2.1 : EARLY CHART OF STUDY AREA, 1906-1914

features still exist is a tribute to the long-term stability of the shores on which they were constructed.

The relatively high rates of erosion seen on the bluffed portion of the coast are due primarily to thermal erosion of the exposed bluff face. On the low-lying shorelines, thermal erosion is not as dramatic due to the insulating cover of beach sand and gravel which overlies the tundra base.

2.3.2 Flaxman Island

Flaxman Island has undergone continuous change since the first observations were made of the island by Franklin in 1826. In his journal, Franklin documents the extreme difficulty with which his shallow draft vessel passed alongside the island's east end. The depth of water through this channel has continually increased since that early observation. Leffingwell (1919) describes the channel as having a depth of eighteen feet during the 1906-1914 study period. He noted the discrepancy between his findings and those of Franklin's concerning the channel depth. The 1950 bathymetric survey conducted by the U.S. Coast and Geodetic Survey (presently NOAA) reported a channel depth of 23 feet. A recent scuba investigation of the channel (Reimnitz and Toimil, 1977) found the present depth to be 34 feet. This information implies that due to the dynamics of the Flaxman Island coastal environment, this inlet is not in equilibrium with the flow regime which presently exists.

The northern shore of Flaxman Island has been actively eroding, as witnessed by various investigators dating back to the Franklin expedition of 1826. Leffingwell observed the erosion throughout the period of his investigation and noted distinct changes in the island shore when compared to the observations by Franklin. Specifically, the island width decreased by at least one-half mile during the 88-year period between 1826 and 1914. In addition, Franklin noted maximum bluff elevations of 40 feet above sea level in 1826. Leffingwell observed that at no location did the island exceed a 25 foot elevation in 1914. Further, drainage lines leading south were identified by Leffingwell that terminated at the northern bluff. This implies that in earlier times, a far greater area had been drained north of the observed shore.

In the small scale map produced by Franklin, the northern shore of Flaxman Island was convex, bulging towards the north. Leffingwell noted a straight shore, as shown in his map (Figure 2.1). The NOAA chart of 1950-1955 (Figure 1.1) shows that the central shore at that time was beginning to become concave, suggesting a process of continual erosion that is on-going to this day. It shall be shown in Section 4 of this report that the concavity of the northern shore is even more pronounced today. Table 2.1 shows the erosion rates for Flaxman Island that can be determined by the survey data spanning the 1826-1955 period.

2.3.3 Barrier Islands

The barrier islands located directly west of Flaxman Island exhibit the most dynamic nature of all the landforms in the study area. Barrier islands, in general, are regarded for the state of continual change in which they exist. Notable changes include island growth, inlet formation, inlet filling, island emergence, and island truncation. Comparison of Leffingwell's map (Figure 2.1) with the NOAA chart of 1955 (Figure 1.1) gives some indication of the magnitude of the changes of island shape and location that occurred between 1910 and 1955. In 1910, Mary Sachs Island was separated from Flaxman Island by an inlet having a width of 2000 feet. By 1955, the two islands had merged together, thereby eliminating Mary Sachs Island. As will be discussed in Section 4, at the present time a small inlet again exists which separates the Flaxman-Mary Sachs complex into two distinct islands.

TABLE 2.1

FLAXMAN ISLAND BLUFF RECESSION, 1826-1955

Year	Island Width At 146°W Longitude (feet)	Erosion (feet)	Erosion Rate (feet/year)
1826	5280		
		2640	30.0
1914	2640		
		634	15.5
1955	2006		

The changes that have occurred in the configuration of the Maguire Islands (North Star, Duchess, Alaska, and Challenge Islands) are presented in Figure 2.2 for the period 1908-1955 (Wiseman, et al., 1973). The lines of longitude indicate a general westward migration of the island group caused by erosion on the eastern shores and sediment deposition on the western island ends. Also, the distinct island shapes change dramatically with time.

Wiseman, et al. (1973) report that between 1908 and 1950, all four of the Maguire Islands migrated westward an average distance of 3,300 feet, or approximately 80 feet/year. Between 1950 and 1955, the western ends of Duchess, Alaska, and Challenge Islands were extended by 1600, 1000, and 500 feet, respectively, or an average of 600 feet/year. This fluctuation in average annual migration rate is believed to be attributed to an abnormal increase in storm activity during the 1950-1955 period.

Thus, the barrier islands of the study area have been identified as highly dynamic sedimentary structures that fluctuate in location and shape in response to the environmental forces of waves, wind, currents, and ice. These islands are bounded by dynamic inlets and are subject to sporadic, rapid, and generally westward sediment transport driven by the persistent easterly winds of the region.

The identification of changes associated with the most recent period (1955-1982) was a primary goal of the field activities of the recent summer. The following report sections will present the study results in detail.

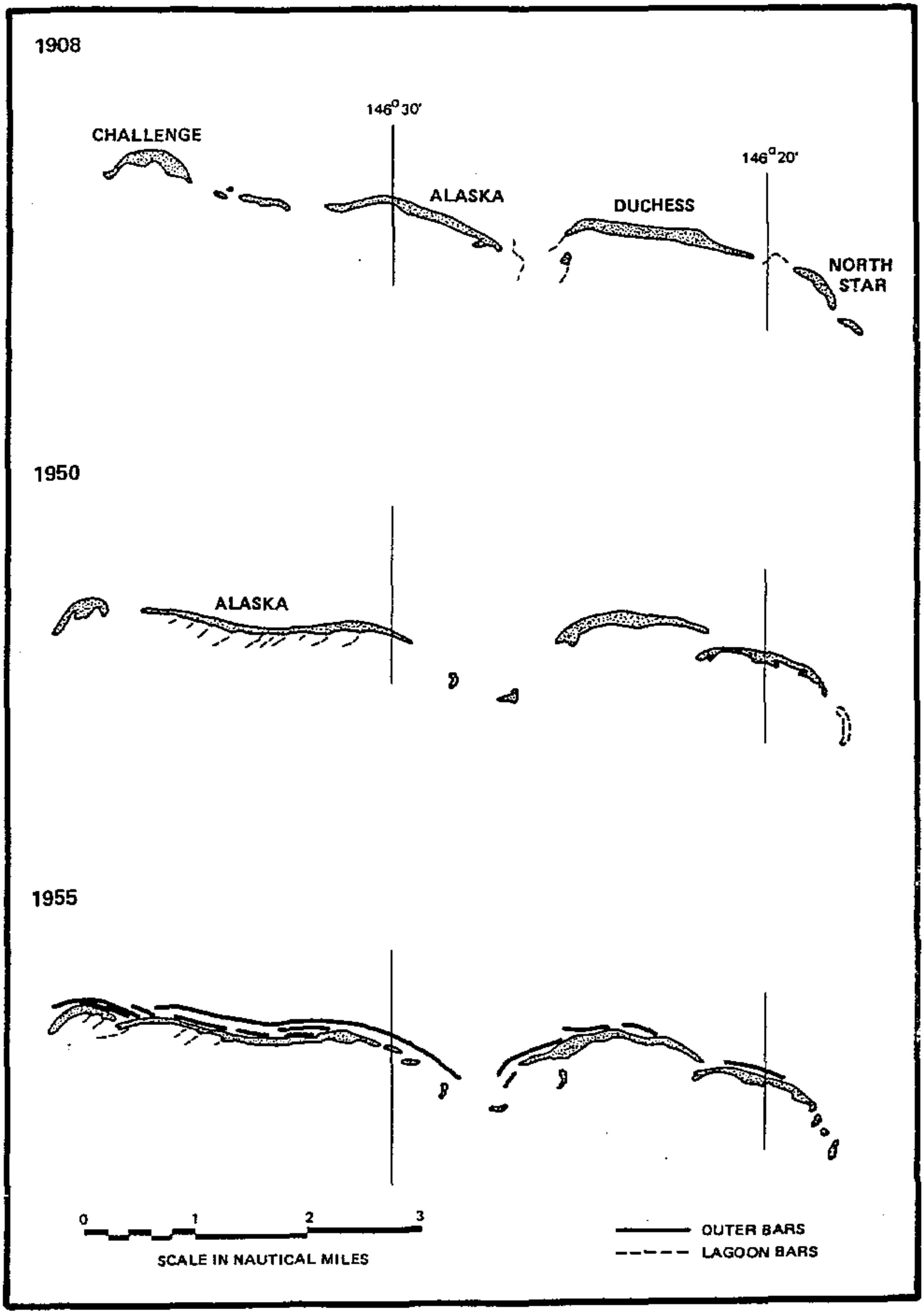


FIGURE 2.2 : MAGUIRE ISLANDS MIGRATION AND CHANGE, 1908–1955

3. SURVEYING METHODOLOGY

The data required to describe the conditions and stability of the shoreline within the study area was collected during an extensive surveying effort performed in July and September, 1982. Coastal transects were selected and profiled at sites that were judged to be representative of the local contiguous shore. In this way, the different coastal environments of the study area were studied to determine the magnitude and character of the shoreline changes which are active within this region.

The surveying tasks consisted of the profiling of beach transects established perpendicular to the shoreline throughout the study area. The initial profiling effort was conducted in late July while a repeat exercise was performed in early September during which all July transects were resurveyed. The profile data collected during the July survey represents a baseline condition of the shoreline in the study area, while the September data reflects the changes which occurred during the brief Arctic open-water season. Comparison of the baseline data with information collected during future surveys will allow multi-season monitoring of the temporal variability of the shoreline profile.

3.1 Survey Network

Prior to the July field trip, a transect location strategy was developed to ensure that all coastal environments of the study area were represented. The strategy resulted in the selection of 67 transect sites spaced at roughly 2000 foot intervals along the mainland and barrier island shorelines. The magnitude of the resultant transect density (3 transects/nautical mile) was considered sufficient to encompass the full spectrum of beach conditions existing in the study area. Beach conditions of interest included direction of exposure to wave attack, expected wave energy, shoreline composition, and coastal features.

At each transect, a permanent reference monument was established as a horizontal and vertical control point. The locations of the 67 monuments and associated transects are presented in Figure 4.6. Inspection of this map indicates that the monuments were sequentially numbered in a counterclockwise fashion starting on the mainland shore at the western end of the study area near Bullen Point. A distribution of the monument locations by geographical area is presented in Table 3.1.

The exact location of each monument (Alaska State Plane Coordinates, Latitude/Longitude) was obtained by electronically measuring the distance to the monument from two survey control stations. A helicopter-borne electronic navigation system (Motorola Mini-Ranger Mark III) was utilized for this purpose. The positioning data developed for the coastal monuments (Mini-Ranger ranges from established triangulation stations, planar coordinates, and latitude/longitude) are presented in Table 3.2.

It should be noted that with one exception, all of the monuments were established by Tekmarine. Monument #65 is an existing NOAA triangulation station designated "Thin, 1949".

TABLE 3.1

MONUMENT PLACEMENT DISTRIBUTION

Region	Sequential Transect Nos.	Length of Coverage* (Nautical Miles)	Number of Monuments	Transect Density (Transect/Nautical Mile)
Mainland	1 - 38	13.2	38	2.9
Flaxman/Mary Sachs Island Comples	39 - 52	4.9	14	2.9
Northstar/ Duchess Island Complex	53 - 60	2.5	8	3.2
Alaska Island	61 - 67	2.3	7	3.4

*Measured along east-west axis.

TABLE 3.2
SURVEY MONUMENT LOCATIONS

PT. THOMPSON STUDY AREA

ESTABLISHED CONTROL MONUMENTS:

MONUMENT	CODE	X-COORD(ft)	Y-COORD(ft)	LATITUDE(dms)	LONGITUDE(dms)
PT THOMP. (EXXON PAD)	1	468591.0	5912628.0	70 10 20.417	146 50 59.391
BULLEN (KLI)	2	394446.0	5915260.0	70 10 39.703	146 15 10.103
FLAXMAN (NOAA)	3	500062.7	5916944.2	70 11 03.512	145 59 58.183
THIN (NOAA)	4	429837.1	5935231.7	70 14 00.178	146 33 59.073

TEKMARINE MONUMENTS - ESTABLISHED JULY 1982:

MONUMENT	X (ft)	Y (ft)	MR CODE/RANGE(m)	MR CODE/RANGE(m)	LATITUDE(dms)	LONGITUDE(dms)
1	406968	5915108	2 3817	4 9285	70 10 39.824	146 44 56.439
2	408712	5914302	2 4358	4 9064	70 10 32.106	146 44 5.614
3	410595	5913888	2 4940	4 8759	70 10 28.256	146 43 10.907
4	413378	5913963	2 5784	4 8197	70 10 29.312	146 41 50.290
5	417117	5914406	2 6915	4 7438	70 10 34.081	146 40 2.084
6	419365	5914285	2 7601	4 7138	70 10 33.130	146 38 56.901
7	422398	5917806	2 8555	4 5775	70 11 8.072	146 37 30.055
8	423304	5916235	2 8801	4 6123	70 10 52.712	146 37 3.326
9	427141	5916004	2 9968	4 5918	70 10 50.813	146 35 12.039
10	429386	5915509	2 10650	4 6013	70 10 46.154	146 34 6.831
11	431515	5917377	2 11317	4 5466	70 11 4.719	146 33 5.613
12	433499	5917559	2 11924	4 5581	70 11 6.683	146 32 8.140

MONUMENT	X (ft)	Y (ft)	MR CODE/RANGE(m)	MR CODE/RANGE(m)	LATITUDE(dms)	LONGITUDE(dms)
13	436114	5919237	2 12758	4 5237	70 11 23.409	146 30 52.735
14	438006	5917582	2 13296	4 5928	70 11 7.286	146 29 57.475
15	439545	5916880	2 13755	4 6328	70 11 .504	146 29 12.692
16	442592	5916744	2 14682	4 6846	70 10 59.400	146 27 44.328
17	444534	5916275	2 15270	4 7311	70 10 54.930	146 26 47.930
18	446890	5917561	3 16208	4 7485	70 11 7.745	146 25 39.895
19	448697	5915968	2 16537	4 8217	70 10 52.199	146 24 47.191
20	451426	5916555	4 8701	2 17372	70 10 58.150	146 23 28.193
21	453491	5915423	2 17997	4 9404	70 10 47.143	146 22 28.127
22	454571	5914638	1 4317	4 9810	70 10 39.849	146 21 56.686
23	458636	5915145	2 19565	4 10702	70 10 44.703	146 19 58.951
24	460295	5914494	4 11231	2 20072	70 10 38.387	146 19 10.767
25	460062	5916909	4 10773	2 20006	70 11 2.129	146 19 17.889
26	463552	5914448	1 1633	4 12072	70 10 38.096	146 17 36.364
27	465559	5914194	3 10550	4 12636	70 10 35.690	146 16 38.163
28	468984	5913467	3 9532	4 13652	70 10 28.685	146 14 58.815
29	470283	5911635	1 598	3 9220	70 10 10.717	146 14 20.964
30	474560	5910467	1 1935	3 8020	70 9 59.382	146 12 16.937
31	475588	5909802	1 2300	3 7771	70 9 52.874	146 11 47.097
32	476637	5908431	1 2766	3 7597	70 9 39.421	146 11 16.590
33	478762	5909871	1 3212	3 6841	70 9 53.647	146 10 15.168
34	479548	5908948	1 3523	3 6711	70 9 44.589	146 9 52.329
35	482951	5908158	1 4584	3 5863	70 9 36.902	146 8 13.720
36	485987	5906332	1 5639	3 5373	70 9 19.003	146 6 45.703
37	485747	5903452	1 5930	3 5996	70 8 50.670	146 6 52.495
38	488342	5902170	1 6812	3 5748	70 8 38.104	146 5 37.336
39					70 10 54.000	145 57 32.000
40	500600	5918124	1 9899	3 395	70 11 15.117	146 59 42.682

MONUMENT	X (ft)	Y (ft)	MR CODE/RANGE(m)		MR CODE/RANGE(m)		LATITUDE(dms)	LONGITUDE(dms)
41	498483	5919266	1	9333	3	856	70 11 26.348	146 0 43.995
42	495792	5920652	1	8644	3	1724	70 11 39.971	146 2 2.061
43	494021	5921338	1	8193	3	2277	70 11 46.707	146 2 53.447
44	490489	5922132	1	7276	3	3319	70 11 54.481	146 4 35.938
45	491262	5919413	1	7213	3	2786	70 11 27.746	146 4 13.420
46	487910	5922300	1	6585	3	4048	70 11 56.097	146 5 50.769
47	486106	5922958	1	6198	3	4632	70 12 2.539	146 6 43.143
48	484359	5923321	1	5807	3	5166	70 12 6.076	146 7 33.886
49	482226	5923848	1	5382	2	26883	70 12 11.213	146 8 35.784
50	478746	5923601	1	4557	2	25820	70 12 8.695	146 10 16.750
51	475804	5923768	1	4045	2	24933	70 12 10.250	146 11 42.136
52	474057	5923305	1	3656	2	24389	70 12 5.639	146 12 32.785
53	459061	5931279	1	6384	2	20291	70 13 23.418	146 19 49.170
54	456300	5932712	1	7177	2	19589	70 13 37.360	146 21 9.609
55	453457	5933633	1	7891	2	18838	70 13 46.252	146 22 32.369
56	451611	5934301	1	8392	2	18365	70 13 52.708	146 23 26.130
57	449363	5934773	1	8939	2	17764	70 13 57.205	146 24 31.544
58	448403	5934614	1	9098	2	17472	70 13 55.577	146 24 59.410
59	445073	5933296	1	9543	2	16381	70 13 42.382	146 26 35.897
60	443897	5932842	1	9727	2	15997	70 13 37.832	146 27 9.966
61	439020	5933521	1	11036	2	14682	70 13 44.138	146 29 31.812
62	436967	5934496	1	11719	2	14225	70 13 53.562	146 30 31.697
63	435540	5934989	1	12163	2	13894	70 13 58.292	146 31 13.285
64	432742	5935086	1	12894	2	13144	70 13 59.006	146 32 34.618
65	429836	5935232	1	13675	2	12386	70 14 .178	146 33 59.073
66	427696	5935622	1	14300	2	11884	70 14 3.818	146 35 1.403
67	425566	5936184	1	14951	2	11430	70 14 9.142	146 36 3.465

3.2 Transect Establishment

During the July field trip, the coastal transects were established and the first survey was performed. The initial task was to distribute the monument and target construction materials at the pre-determined coastal locations. Due to the weight of these supplies and the need to exactly place each transect at the desired location, a helicopter was used for this purpose.

The materials required for each transect consisted of the target and tie-down equipment, monument pipe, and witness post pipe. The target, designed to facilitate transect recognition from both the ground and during aerial overflights, was constructed from two large panels of durable orange or yellow dacron signal cloth.

The field survey crew travelled to each transect site by boat from the base camp located at Pt. Thomson. Upon recovering the transect bundle, a suitable site of relatively flat terrain was selected for target construction. Care was taken to ensure that an adequate set-back distance from the waterline was observed so that future loss of the monument caused by erosion or wave impact would be prevented. Typically, on a tundra plain fronted by a narrow gravel beach, the targeted monument would be placed on the tundra at a distance of 50 to 100 feet from the waterline.

Target construction proceeded systematically with the orientation of one signal cloth section (orange in the case of a mixed color target) on a true north-south alignment. The second signal cloth panel was positioned on an east-west alignment such that the two panels had coincident centers.

Consequently, the brightly colored target resembled a cross when viewed from the air, as shown in Photo 1.

The target material was tied down by a network of stainless steel wires that were secured by aluminum stakes driven into the soil along the edges of the signal cloth. The first season performance of the targets was excellent based on the relative ease with which the transects were recovered and re-surveyed. Remedial maintenance performed on the targets was limited to fewer than 10% of the targets. Based on this experience, it would appear that the target design will exhibit a multi-year life expectancy.

At the southeast interior corner of the target, the two-foot long steel monument pipe was driven into the ground. To aid in recovery, the length of pipe left exposed was spray-painted orange following placement.

The orientation of the profiled transect was established by the placement of the three-foot long steel pipe witness post driven into the ground at a distance of 30 to 80 feet from the monument. Using these two reference pipes to define the transect, the identical profile can be re-surveyed during future field work. The painted witness post was positioned such that the transect was approximately perpendicular to the local shoreline. A bearing of the transect relative to true north was measured using a hand bearing magnetic compass (variation = 33°E) to assist in the resurvey of the transect should the witness post be removed or destroyed. The transect was identified by painting a number on the northern arm of the target (so that it could be identified from a low-flying helicopter) and securing a stamped brass disk to the monument pipe with wire. The characteristic features of the monumented transect are illustrated in Figure 3.1.

PHOTO 1. AERIAL VIEW OF TARGETS THAT IDENTIFY COASTAL TRANSECTS

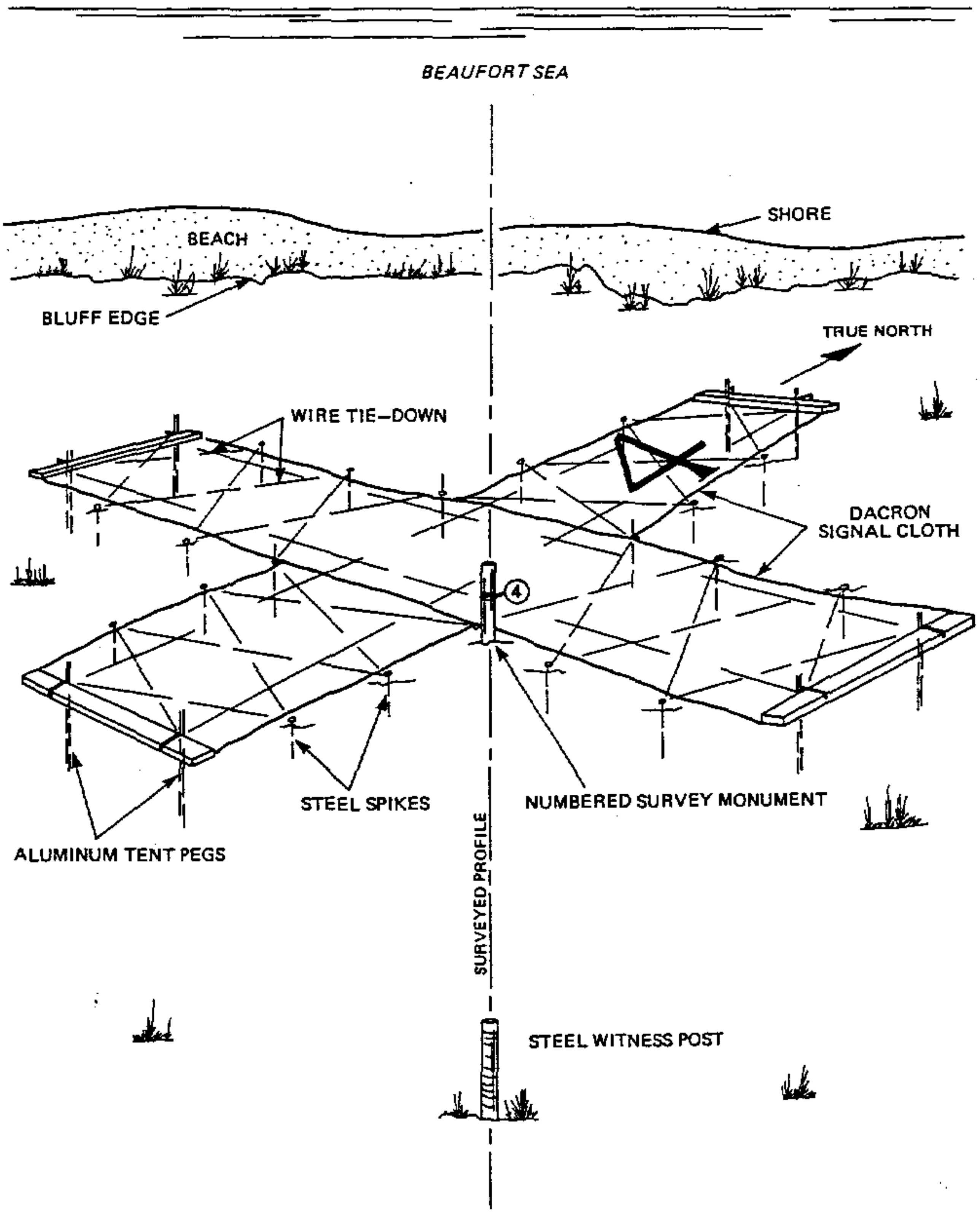


FIGURE 3.1: MONUMENTED TRANSECT LAY-OUT

The actual length of each profiled transect was a function of beach morphology and elevation of the sea level at the time of profiling. Typically, a transect on the tundra shore extended seaward from the monument to a water depth of 3-4 feet. For transects having two shorelines (spits and barrier islands), the transect was profiled from the shallow water near one shoreline to a water depth of comparable magnitude (3-4 feet) near the opposite shore.

A secondary factor affecting transect length was the still water level which prevailed at the time of the survey. Lowered water levels (which often accompanied easterly winds) increased transect lengths by exposing additional beachfront, while increased water levels reduced transect length.

3.3 Surveying

All of the 67 coastal transects that were established in July were re-surveyed during the September field trip. Based on the experience gained during the July survey, fundamental changes were made in the survey operations undertaken in September. The survey methods used for each survey are described below.

- July Survey Methods: The coastal profiling undertaken in July employed standard leveling methods and equipment which included an automatic level, leveling rod, and steel surveying tape. The profile surveyed along each transect measured elevation and distances at all prominent features, signficant changes in beach slope, and at the monument and witness post. Elevation readings were accurate to $\pm$ 0.1 foot while taped horizontal distances were measured to the nearest tenth of a foot. During each transect survey, the elevation and position of the waterline(s) were measured and the time of the measurement was recorded.

Because of the lack of an established vertical control datum in the study area, an absolute vertical datum to which the transect elevations could be referenced was not available. Consequently, a relative elevation datum for each transect was selected to be the still water elevation at the time of each survey. It should be noted that if the two waterline elevations differed for a two shoreline transect, the south waterline elevation was used for the datum by virtue of the lack of wave activity on that shore.

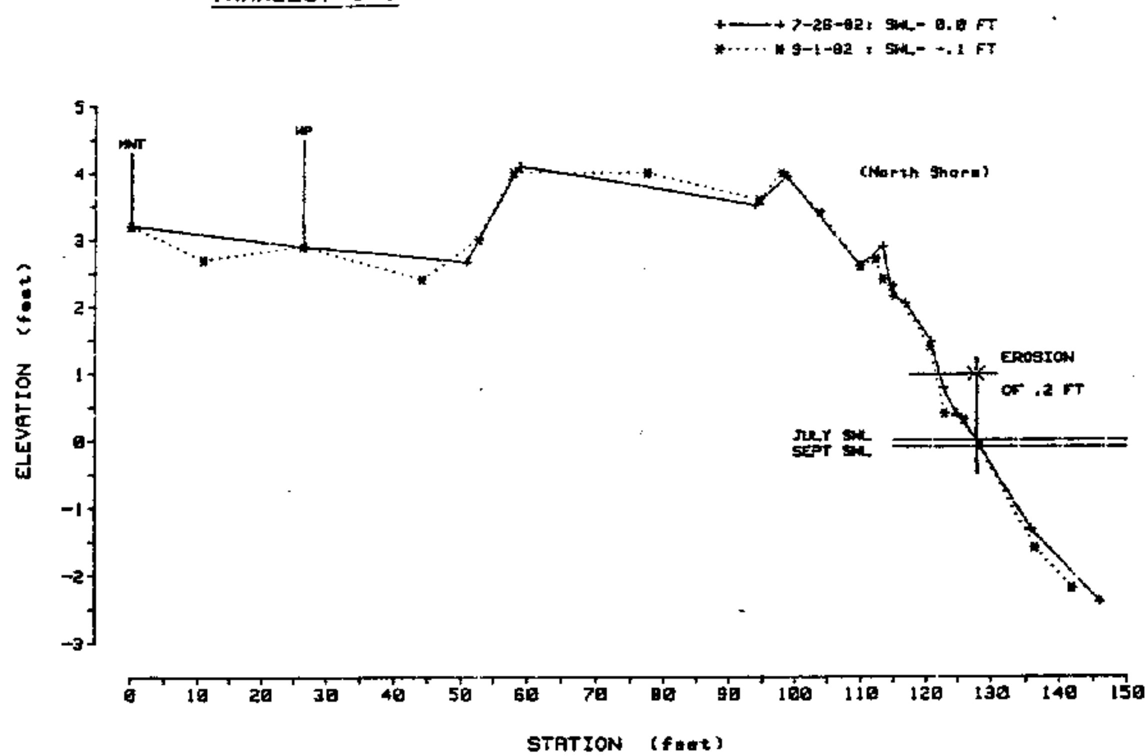
- <u>September Survey Methods:</u> During the July field trip, limitations were identified in the usefulness of the survey methods employed. On many of the longer transects, repetitive movement of the 300 foot long steel tape was inefficient, especially when measuring distances offshore. On the high bluffs, the transect distances were difficult to measure accurately due to the sag in the steel tape. Realizing that these limitations would incorporate errors into the surveying data thereby rendering it less valuable for future transect comparisons, an electronic surveying system was chosen for the September field trip.

  The electronic system that was used, the Hewlett-Packard Model 3810A "Total Station", measures vertical and horizontal distance using an infrared light source. This instrument greatly increased survey speed and minimized the procedural and operator inconsistencies that are common with standard leveling techniques. To verify agreement between the two survey systems, the first transect profiled in September was surveyed by two teams using the July survey techniques and the electronic system proposed for the September field trip. It was determined that both methods gave comparable results over a short, low transect, however, increased speed and efficiency was experienced with the electronic system. With the exception of the survey equipment, the method of profiling was the same for both the July and September field trips.

Because the still water level observed in September differed from that surveyed in July, a vertical datum for the survey had to be chosen. The lack of local tidal information prevented the establishment of a common datum for both surveys, therefore, all elevations were referenced to the still water level measured at each transect in July.

An example plot of the July and September surveys at Transect #1 is displayed in Figure 3.2. The profile data is also presented in tabular form below the figure.

TRANSECT # 1



TRANSECT # 1

LOCATION: MAINLAND-2.5 MILES EAST OF PT. BULLEN

SITE DESCRIPTION: TUNDRA PLAIN W/ SAND & GRAVEL BEACH

TRANSECT BEARING: 035.T EXPOSURE: N-NE

TARGET COLOR: ORANGE

DATE: 7-26-82

STATION (FT)	ELEVATION (FT)	REMARKS
0.0	3.2	@ MONUMENT
26.5	2.9	@ WITNESS PT
51.0	2.7	GRAVEL
59.0	4.1	
94.0	3.5	
99.0	3.9	
110.0	2.6	
113.5	2.9	
115.0	2.2	
117.0	2.1	
121.0	1.5	
123.0	.8	
125.0	.4	
128.0	0.0	No.WL @ 2045
136.0	-1.3	
146.0	-2.4	

DATE: 9-1-82

STATION (FT)	ELEVATION (FT)	REMARKS
0.0	3.2	@ MONUMENT
10.9	2.7	
26.5	2.9	@ WITNESS PT
44.3	2.4	GRAVEL
52.8	3.0	
58.1	4.0	
77.7	4.0	
94.7	3.6	
98.1	4.0	
104.0	3.4	
110.1	2.6	
112.4	2.7	
113.5	2.4	
114.9	2.3	
120.8	1.4	
123.2	.4	
126.0	.3	
128.4	-.1	No.WL @ 1200
136.5	-1.6	
141.9	-2.2	

ELEVATION ON MONUMENT = 4.3 FT

ELEVATION ON WITNESS POST = 4.5 FT

NOTES: 1) STATION DATUM OF 0.0 ASSUMED FOR MONUMENT. NORTHERLY MEASUREMENTS TAKEN AS POSITIVE.
2) ELEVATION DATUM OF 0.0 ASSUMED FOR S.W.L. OF JULY SURVEY.
3) SEPTEMBER S.W.L. = -.1 FT

FIGURE 3.2 : SURVEY TRANSECT #1

3.4 Additional Field Data

To support the findings of the coastal survey, additional field data was collected during the course of the study, as described below.

Transect Photographs: Ground and low elevation aerial photos were taken at many survey transects to provide a visual record of the area during the survey. These photos can be used as a reference to locate monuments during future survey efforts.

Aerial Photographs: To provide a record of the shoreline at the time of each survey, high elevation aerial photos were taken in both July and September. The photos were taken from a helicopter at a sufficient altitude (5,000-7,000 feet) such that at least two targeted monuments appeared on each photo. Knowing the distance between successive monuments, photo scale could be computed.

Soil Samples: To characterize the beach sediment characteristics throughout the study area, soil samples were collected at numerous transect locations. This aspect of the study is described in detail in Section 5.4.

4. SURVEY DATA

As detailed in Section 3, sixty-seven monumented coastal transects were established and surveyed during the course of this study. In the interest of brevity, only representative transects and the summarized results of the survey data will be presented here. A complete compilation of all the survey data is contained in a separate document, the Appendix to this report.

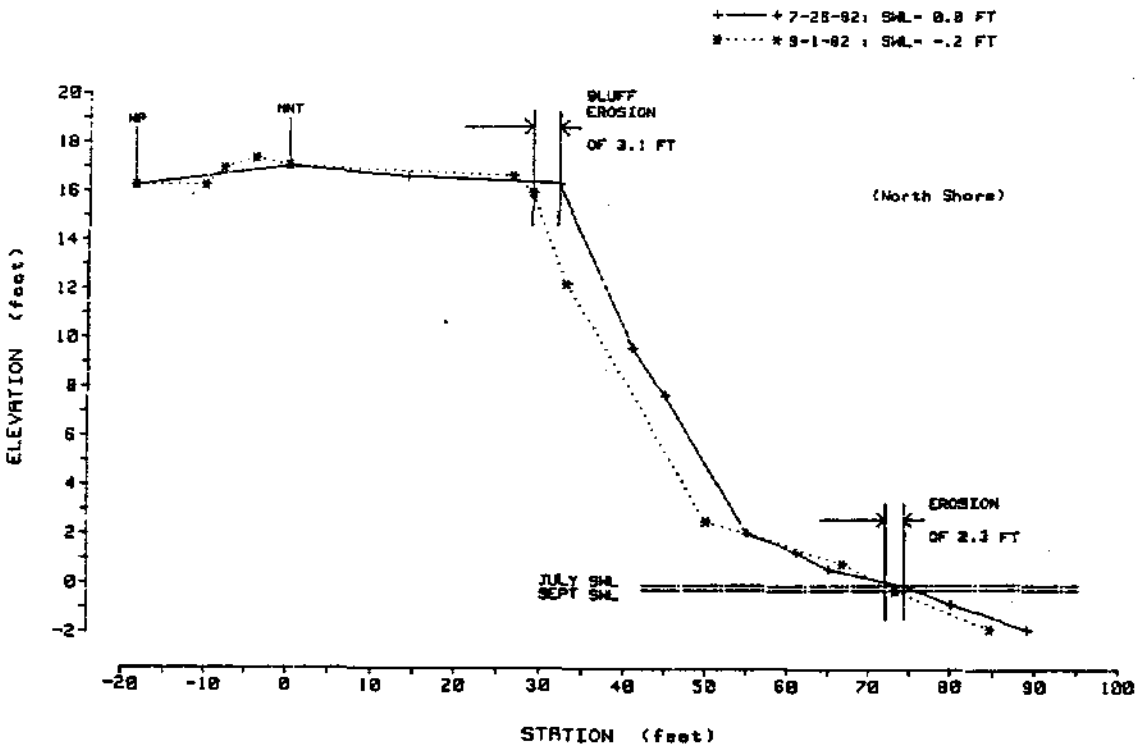
4.1 Profile Data Classification

The various surveyed transects represent the coastal profiles of five general shoreline types: the mainland bluff, the low mainland beach, the mainland gravel spits, the Flaxman Island bluff, and the barrier islands. An example of each of these profile types follows with a brief description and a listing of the applicable monument designations.

- Mainland Bluff: Only three mainland transects occupy bluffs that are higher than 9 feet above mean sea level. These are located at transects #2, #5, and #34 (Ref. Figure 4.6). Figure 4.1 shows the surveyed transect at Transect #5, which indicates bluff erosion of 3.1 feet and beach erosion of 2.3 feet during the July-September, 1982, period. Below the figure, the survey data is presented in tabular form. A narrow gravel beach having a width of 15 feet exists at the toe of the bluff.

- Low Mainland Shore: The majority of the profiles surveyed on the mainland coast attain elevations that average less than four feet. Profiles of this

TRANSECT # 5



TRANSECT # 5

LOCATION: MAINLAND-STATION "GORDON ECC,1978" EST. BY NCI

SITE DESCRIPTION: HIGH ERODING TUNRDA BLUFF W/ NARROW GRAVEL BEACH

TRANSECT BEARING: 000 T   EXPOSURE: NW-N

TARGET COLOR: YELLOW/ORANGE

DATE: 7-26-82

STATION (FT)	ELEVATION (FT)	REMARKS
-18.8	16.3	@ WITNESS PT
0.0	17.1	@ MONUMENT
14.0	16.7	
32.0	16.4	BLUFF EDGE
41.0	9.7	-
45.0	7.8	
55.0	2.1	BLUFF BASE
61.0	1.4	GRAVEL
65.0	.7	
74.3	0.0	No.WL @ 1720
80.0	-.8	
89.0	-1.8	

DATE: 9-1-82

STATION (FT)	ELEVATION (FT)	REMARKS
-18.8	16.3	@ WITNESS PT
-10.3	16.3	
-8.0	17.0	
-4.1	17.4	
0.0	17.1	@ MONUMENT
26.6	16.7	
28.9	16.0	BLUFF TOP
33.0	12.3	
50.0	2.6	BLUFF TOE
66.7	.9	
73.2	-.2	No.WL @ 1437
84.5	-1.8	

ELEVATION ON MONUMENT = 19.0 FT

ELEVATION ON WITNESS POST = 18.6 FT

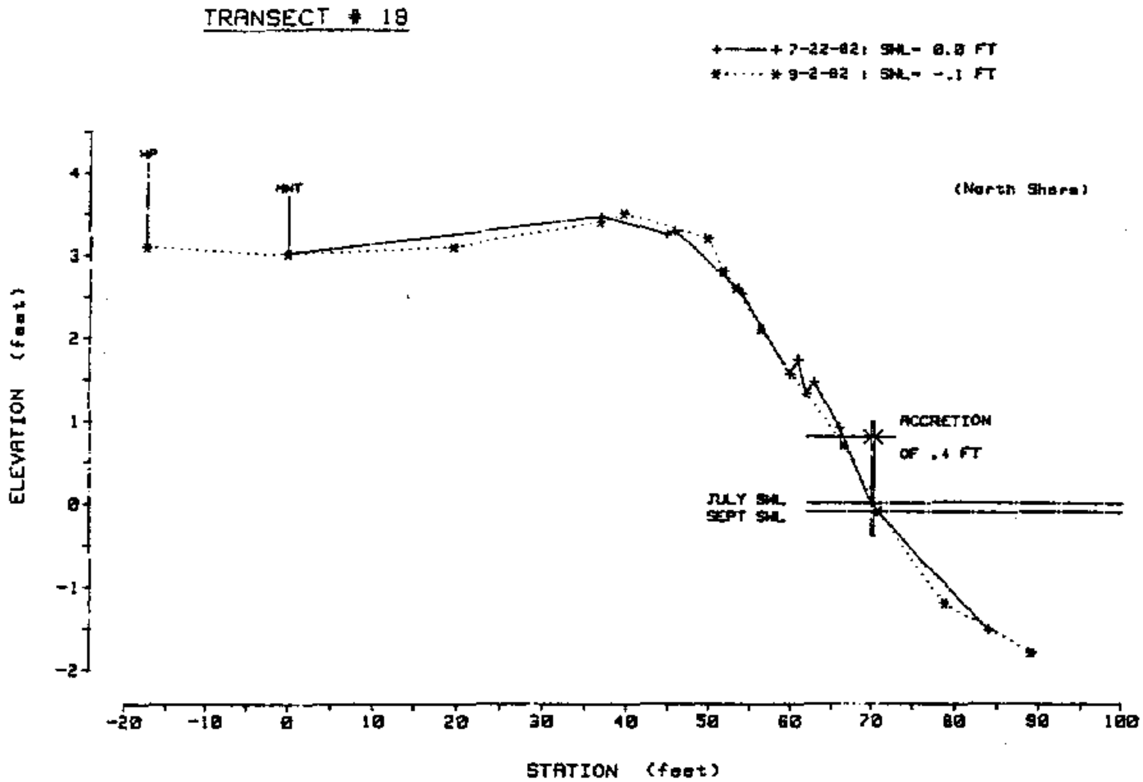
NOTES: 1) STATION DATUM OF 0.0 ASSUMED FOR MONUMENT. NORTHERLY MEASUREMENTS TAKEN AS POSITIVE.
2) ELEVATION DATUM OF 0.0 ASSUMED FOR S.W.L. OF JULY SURVEY.
3) SEPTEMBER S.W.L. = -.2 FT

FIGURE 4.1 : MAINLAND BLUFF AT TRANSECT #5

type are located at 24 transect locations (Transects #1, 8, 10, 12-14, 16-24, 29-33, 35-38, Ref. Figure 4.6). A typical example of this type of profile is Transect #18, shown in Figure 4.2. The highest elevation of this profile is about three feet above mean sea level. The survey comparison shows that virtually no change occurred in the profile during the recent July-September period.

- Mainland Gravel Spits: Gravel spits project from a number of headlands within the study area. A total of 11 spit locations were chosen as sites for surveyed transects (Transects #3, 4, 6, 7, 9, 11, 15, 25-28, Ref. Figure 4.6). Transect #11 is presented in Figure 4.3, which documents the major features of a low spit (maximum elevation = 3.9 feet). As frequently occurred, the exposed northern shore experienced change (in this case, 3 feet of shoreline accretion) while the protected southern shore remained virtually static.

- Flaxman Island Bluff: Four transects were surveyed on the relatively high bluffs of Flaxman Island (Transects #39-41, 45, Ref. Figure 4.6). Three of the transects were placed on the northern shore of the island with Transect #41 serving as a typical example (Figure 4.4). The bluff at this location lies about 13 feet above mean sea level with a very narrow beach at its base. Bluff erosion of 6.5 feet was noted at this transect during the recent survey period.



TRANSECT # 18

LOCATION: MAINLAND-EAST FLANK OF PT SWEENEY

SITE DESCRIPTION: LOW TUNDRA PLAIN W/ SURFICIAL SAND & GRAVEL ON BEACH

TRANSECT BEARING: 040:T EXPOSURE: N-NE

TARGET COLOR: YELLOW/ORANGE

DATE: 7-22-82

STATION (FT)	ELEVATION (FT)	REMARKS
0.0	3.0	@ MONUMENT
37.0	3.5	@ WITNESS PT
45.0	3.3	
46.0	3.3	
54.0	2.5	
60.0	1.6	
61.0	1.7	
62.0	1.3	
63.0	1.5	
66.0	.9	
70.0	0.0	No.WL @ 2005
84.0	-1.5	

DATE: 9-2-82

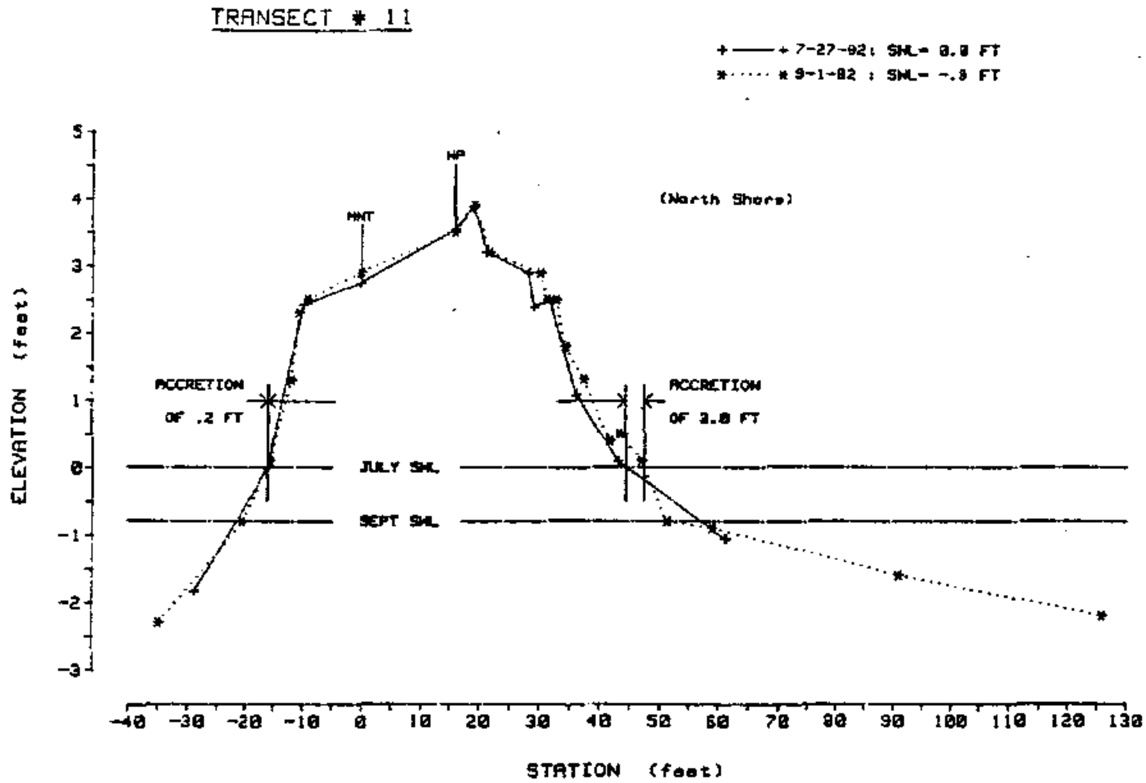
STATION (FT)	ELEVATION (FT)	REMARKS
-17.3	3.1	@ WITNESS PT
0.0	3.0	@ MONUMENT
19.5	3.1	ROLL TRACK
36.9	3.4	
39.8	3.5	DEBRIS LINE
50.0	3.2	
51.8	2.8	
53.3	2.6	
56.4	2.1	
66.5	.7	
71.0	-.1	No.WL @ 1012
78.7	-1.2	
89.1	-1.8	

ELEVATION ON MONUMENT = 3.7 FT

ELEVATION ON WITNESS POST = 4.1 FT

NOTES: 1) STATION DATUM OF 0.0 ASSUMED FOR MONUMENT
NORTHERLY MEASUREMENTS TAKEN AS POSITIVE.
2) ELEVATION DATUM OF 0.0 ASSUMED FOR S.W.L. OF JULY SURVEY.
3) SEPTEMBER S.W.L.= -.1 FT

FIGURE 4.2 : LOW MAINLAND SHORE AT TRANSECT #18



LOCATION: MAINLAND-WEST SPIT FRONTING LAGOON W. OF RUINS

SITE DESCRIPTION: SMALL SAND & GRAVEL SPIT W/ SURFICIAL GRAVEL

TRANSECT BEARING: 300 T EXPOSURE: NW-N

TARGET COLOR: YELLOW/ORANGE

DATE: 7-27-82

STATION (FT)	ELEVATION (FT)	REMARKS
-28.7	-1.8	
-15.7	0.0	So. WL-LAGOON
-9.7	2.4	
0.0	2.7	@ MONUMENT
16.1	3.5	@ WITNESS PT
19.3	3.9	
21.3	3.2	
28.3	2.9	
29.3	2.4	
31.8	2.5	
36.3	1.1	
43.1	1	No. WL @ 1930
61.3	-1.1	

DATE: 9-1-82

STATION (FT)	ELEVATION (FT)	REMARKS
-34.8	-2.3	
-20.3	-.8	So. WL
-15.3	.1	
-11.7	1.3	
-10.5	2.3	
-9.0	2.5	BERM
0.0	2.9	@ MONUMENT
16.1	3.5	@ WITNESS PT
19.4	3.9	
21.8	3.2	
30.3	2.9	
31.4	2.5	
32.9	2.5	
34.4	1.8	
37.5	1.3	
41.7	.4	
43.5	.5	
47.0	.1	
51.3	-.8	No. WL @ 1700
59.1	-.9	
91.1	-1.6	
126.1	-2.2	

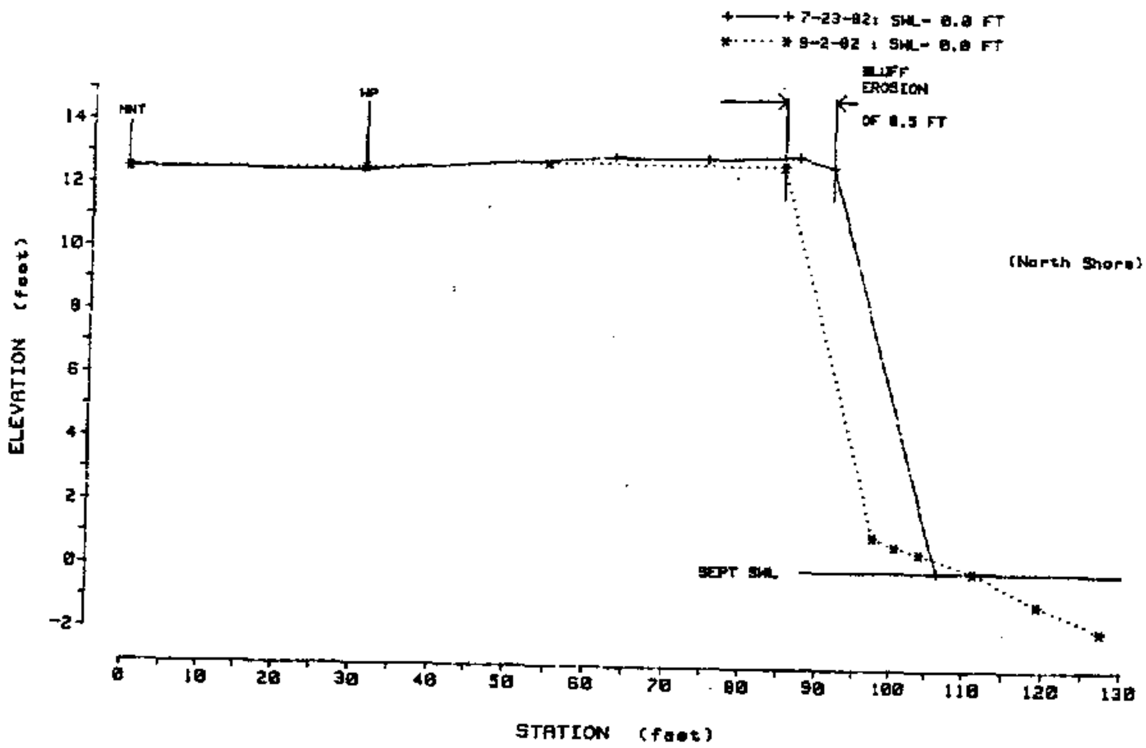
ELEVATION ON MONUMENT = 3.6 FT

ELEVATION ON WITNESS POST = 4.5 FT

NOTES: 1) STATION DATUM OF 0.0 ASSUMED FOR MONUMENT. NORTHERLY MEASUREMENTS TAKEN AS POSITIVE.
2) ELEVATION DATUM OF 0.0 ASSUMED FOR S.W.L. OF JULY SURVEY.
3) SEPTEMBER S.W.L. = -.8 FT

FIGURE 4.3 : MAINLAND SPIT AT TRANSECT #11

TRANSECT # 41



TRANSECT # 41

LOCATION: FLAXMAN ISL.-NORTH SHORE NORTH OF RUNWAY

SITE DESCRIPTION: RECEDING HIGH TUNDRA BLUFF W/ MASSIVE FAILURE @ EDGE

TRANSECT BEARING: 029.T   EXPOSURE: NW-N-NE

TARGET COLOR: YELLOW

DATE: 7-23-82

STATION (FT)	ELEVATION (FT)	REMARKS
0.0	12.5	@ MONUMENT
30.9	12.5	@ WITNESS PT
63.0	13.0	
75.0	13.0	
87.0	13.1	
91.5	12.8	BLUFF EDGE
106.5	0.0	No.WL

DATE: 9-2-82

STATION (FT)	ELEVATION (FT)	REMARKS
0.0	12.5	@ MONUMENT
31.1	12.6	@ WITNESS PT
54.5	12.8	
85.0	12.8	BLUFF EDGE
97.7	1.1	BLUFF TOE
100.7	.8	
104.1	.6	
111.3	0.0	No.WL @ 1120
119.5	-1.0	
127.6	-1.8	

ELEVATION ON MONUMENT = 13.9 FT

ELEVATION ON WITNESS POST = 14.6 FT

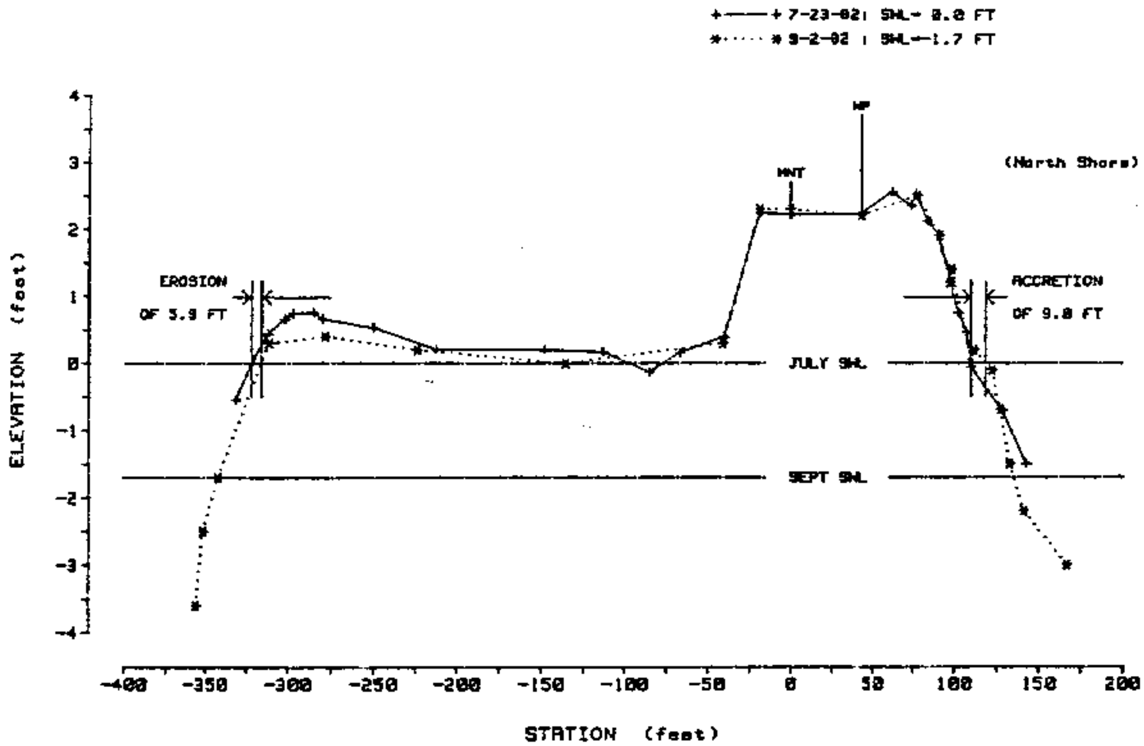
NOTES: 1) STATION DATUM OF 0.0 ASSUMED FOR MONUMENT.
NORTHERLY MEASUREMENTS TAKEN AS POSITIVE.
2) ELEVATION DATUM OF 0.0 ASSUMED FOR S.W.L. OF JULY SURVEY.
3) SEPTEMBER S.W.L.= 0.0 FT

FIGURE 4.4 : FLAXMAN ISLAND BLUFF AT TRANSECT #41

- Barrier Islands: Twenty-five profiles were surveyed on the barrier islands of the study area. These profiles encompass the western sand spit of Flaxman Island, Mary Sachs Island, and North Star, Duchess and Alaska Island of the Maguire group. The transects on these islands are identified by Monuments #42-44, 46-67. Transect #51 is presented in Figure 4.5 as a representative example of an island profile. Unlike the mainland spits, which tend to have a quiescent southern shore, the islands can experience major wave impact (and resulting shoreline change) on both north and south shores. In this instance, the northern shore of Transect #51 experienced accretion of 9 feet and the southern shore eroded 5.9 feet during the July-September period.

The placement strategy for the coastal transects sought to represent all of the shoreline and island types within the study area. In addition, an attempt was made to include locations that yield the full range of exposure to wave and ice conditions. It is probable that profiles with an eastern wave exposure are subject to changes resulting from the most persistant wave conditions, while transects having a western exposure evidence the effects of the less frequent westerly storm events. Table 4.1 summarizes the various coastal classifications and the exposures for the established transects. Wave exposure is listed by direction of wave approach. A number of transects experience wave approach from west clockwise through east (hence, the "W-N-E" designation). Four of the transects are located in well-protected bays resulting in negligible wave exposure during normal conditions.

TRANSECT # 51



LOCATION: MARY SACHS ISL. ~.6 MI. EAST OF WESTERN END

SITE DESCRIPTION: BROAD SAND & GRAVEL PLAIN W/ STORM BERMS

TRANSECT BEARING: 358.T EXPOSURE: W-N-NE/S

TARGET COLOR: YELLOW/ORANGE

DATE: 7-23-82

STATION (FT)	ELEVATION (FT)	REMARKS
-331.0	-.54	
-321.5	0.00	So.WL @ 1525
-312.0	.44	
-302.0	.66	
-297.0	.75	
-285.0	.76	
-280.0	.66	
-250.0	.53	
-212.0	.21	
-148.0	.20	
-113.0	.17	
-85.0	-.13	
-66.0	.16	
-40.0	.40	
-19.0	2.24	
0.0	2.22	@ MONUMENT
43.8	2.23	@ WITNESS PT
62.8	2.55	
74.8	2.35	
77.8	2.53	RIDGE
84.8	2.12	
91.8	1.91	BERM
102.8	.75	
107.8	.47	
110.6	-.05	No.WL @ 1350
128.8	-.70	
142.8	-1.50	

DATE: 9-2-82

STATION (FT)	ELEVATION (FT)	REMARKS
-355.9	-3.60	
-351.5	-2.50	
-341.8	-1.70	So.WL @ 1830
-311.0	.30	
-278.4	.40	
-223.5	.20	
-135.4	0.00	
-40.6	.30	
-18.9	2.30	
0.0	2.30	@ MONUMENT
43.4	2.20	@ WITNESS PT
78.7	2.50	
92.0	1.90	
97.9	1.20	DEBRIS
99.0	1.40	
110.4	0.00	
112.3	.20	
122.8	-.10	
127.8	-.70	
133.0	-1.50	No.WL @ 1840
141.3	-2.20	
167.1	-3.00	

ELEVATION ON MONUMENT = 2.7 FT

ELEVATION ON WITNESS POST = 3.7 FT

NOTES: 1) STATION DATUM OF 0.0 ASSUMED FOR MONUMENT. NORTHERLY MEASUREMENTS TAKEN AS POSITIVE.
2) ELEVATION DATUM OF 0.0 ASSUMED FOR S.W.L. OF JULY SURVEY.
3) SEPTEMBER S.W.L.= -1.7 FT

FIGURE 4.5 : BARRIER ISLAND PROFILE AT TRANSECT #51

TABLE 4.1

SHORELINE CLASSIFICATION AND OCEAN EXPOSURE

Shoreline Type	Total Transects	PREDOMINANT WAVE EXPOSURE NW	NE	W-N-E	SOUTH	PROTECTED
Mainland Bluffs	3		2	1		
Low Mainland Shore	24	7	12	1		4
Mainland Gravel Spits	11	3	3	5		
Flaxman Island Bluff	4		3		1	
Barrier Islands*	25	4	12	9		
	TOTAL:	14	32	16	1	4

* Exposure is for northern shore. Southern shores of all islands are also monitored.

4.2 Long-Term Rates of Shoreline Change 1955-1982

Based on the results of the recent field work, Figure 4.6 has been developed which shows the 1982 coastal transect locations and island features overlying the nautical chart generated from the government (NOAA) survey of the 1950's. On the base map, the bathymetric data was determined in 1950, while the mainland shore and island configurations were based on 1955 aerial photography.

The major coastal changes that have occurred during the 1955-1982 comparison period may be summarized as follows:

- The mainland shore has remained relatively stable. The most significant change is the breach that has formed in the Pt. Thomson spit. This is due to the northeast wave energy that can proceed unimpeded to the spit through Mary Sachs Entrance. Other obvious changes include the migration of several coastal inlets (the arrows in Figure 4.6 show the present inlet locations).

- The northern bluffed coastline of Flaxman Island has retreated substantially. The concave nature of that shore is even more pronounced today than in 1955. In contrast, the southern island shore has not changed markedly. The bluff in the vicinity of Transect #45 on the southwest shore has retreated during the comparison period.

- A small inlet has formed which now separates Flaxman Island from Mary Sachs Island to the west. This inlet is located between Transects #44 and 46.

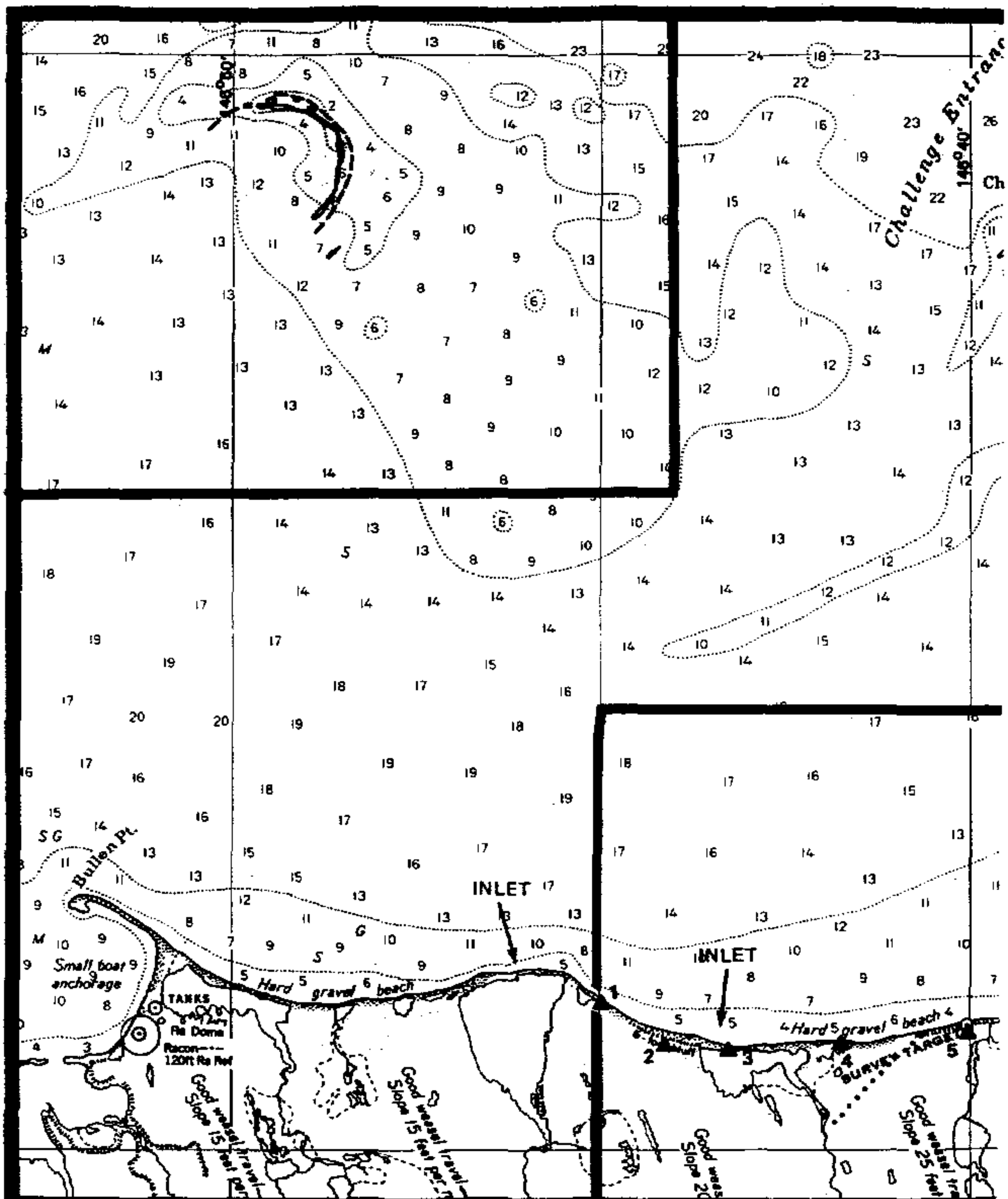


FIGURE 4.6

TRANSECT LOCATIONS AND 1982 SHORELINE

PT. THOMSON DEVELOPMENT PROJECT
COASTAL PROCESSES AND SEDIMENT DYNAMICS
CONTRACT PTD-8206
TEKMARINE, INC.

DRAWN

APPROVED

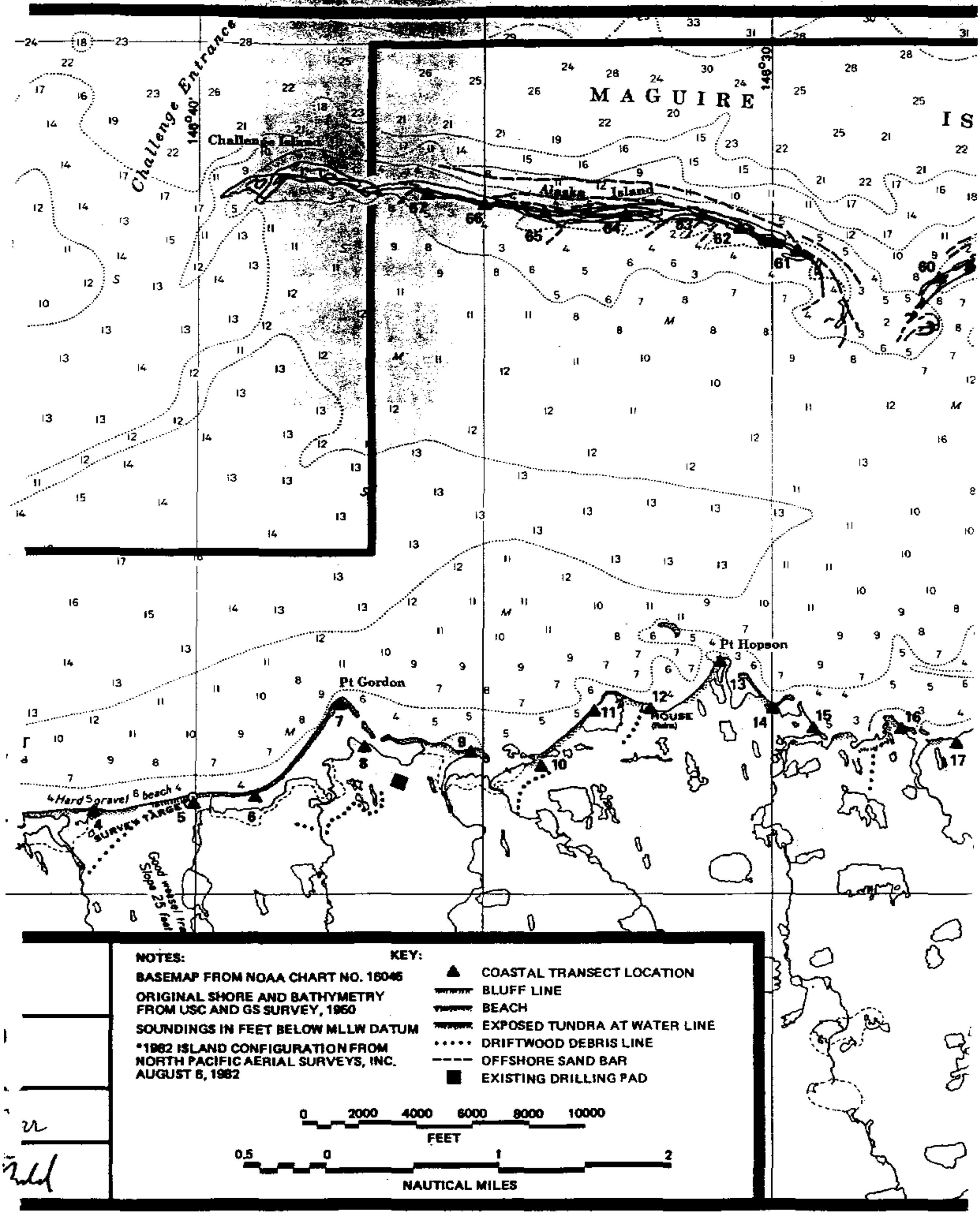
NOTES:

BASEMAP FI

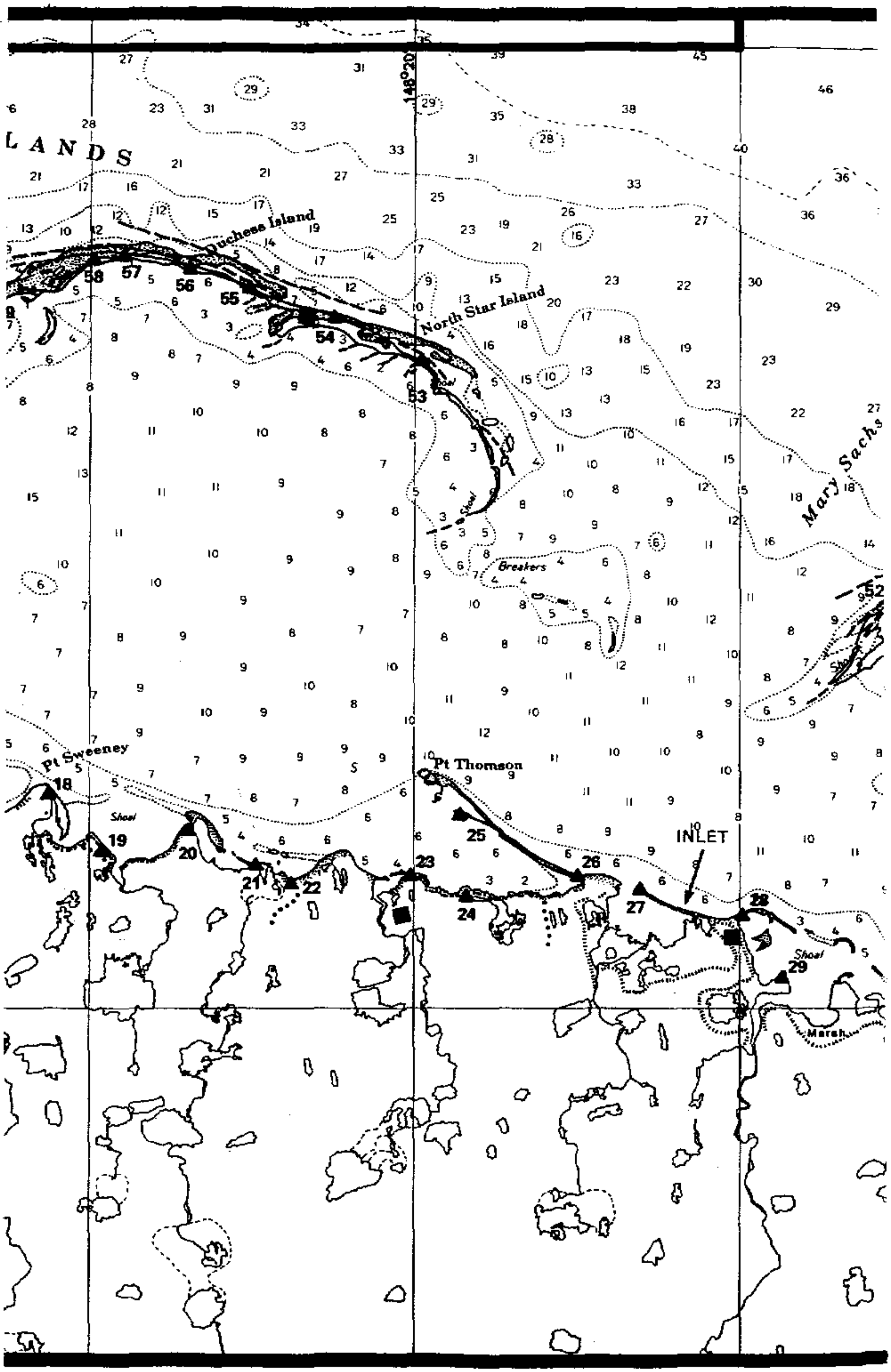
ORIGINAL S
FROM USC A

SOUNDINGS

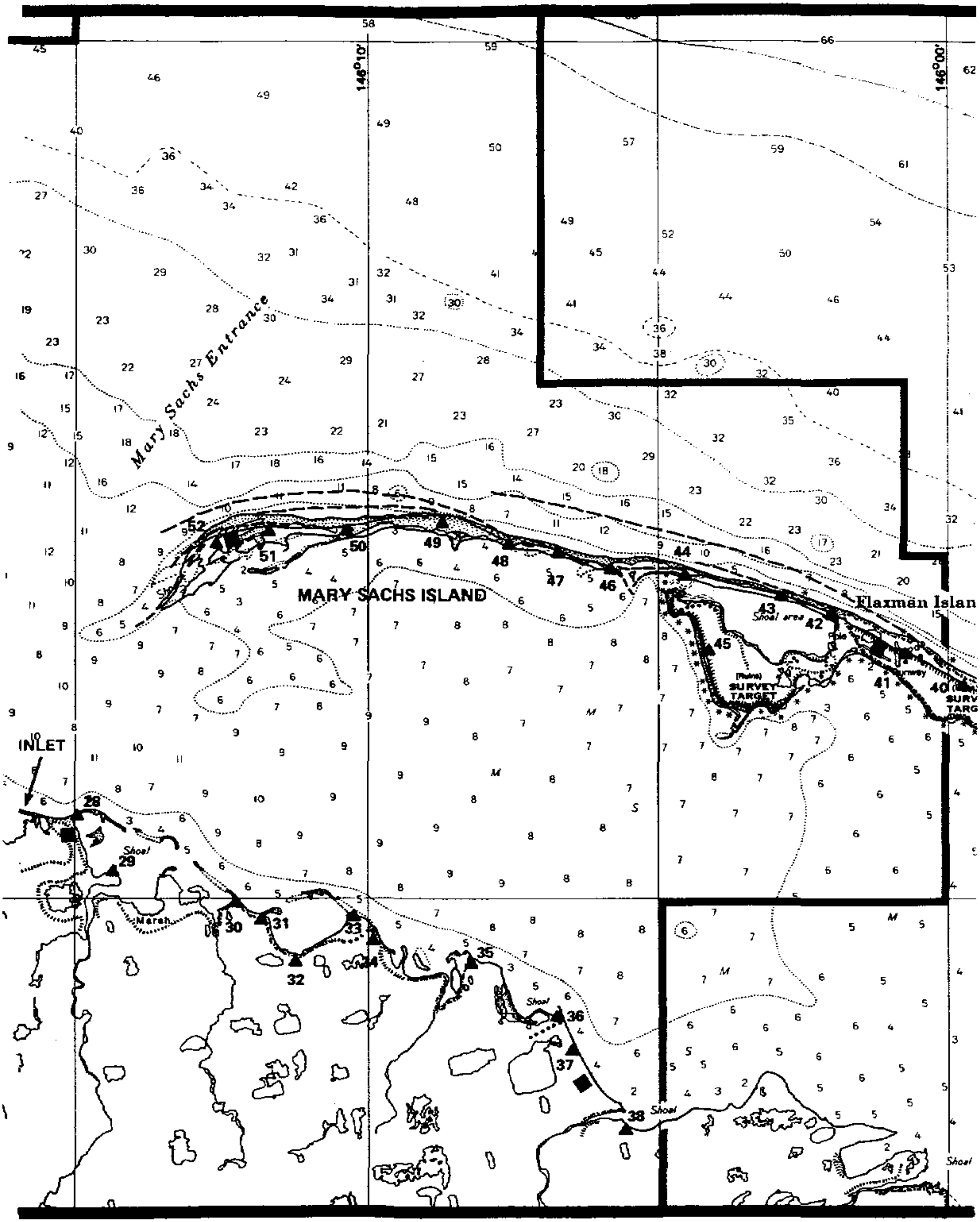
*1982 ISLAN
NORTH PAC
AUGUST 6, 1



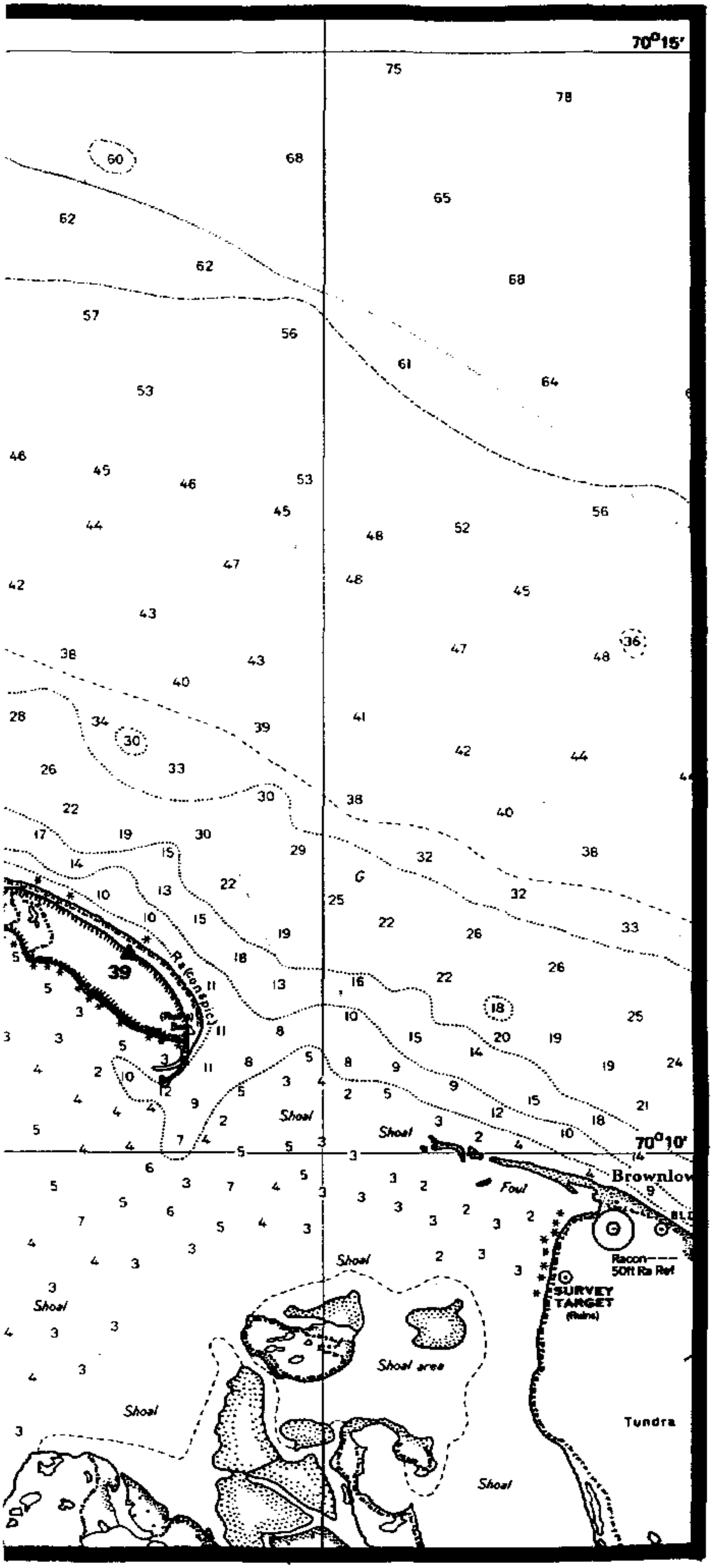
MAGUIRE
IS
Challenge Entrance
Challenge Island
Alaska Island
Pt Gordon
Pt Hopson
HOUSE (Ruin)
Hard gravel beach
SURVEY TARGET
NOTES:
BASEMAP FROM NOAA CHART NO. 16046
ORIGINAL SHORE AND BATHYMETRY FROM USC AND GS SURVEY, 1950
SOUNDINGS IN FEET BELOW MLLW DATUM
*1982 ISLAND CONFIGURATION FROM NORTH PACIFIC AERIAL SURVEYS, INC. AUGUST 6, 1982
KEY:
COASTAL TRANSECT LOCATION
BLUFF LINE
BEACH
EXPOSED TUNDRA AT WATER LINE
DRIFTWOOD DEBRIS LINE
OFFSHORE SAND BAR
EXISTING DRILLING PAD
0 2000 4000 6000 8000 10000
FEET
0.5 0 1 2
NAUTICAL MILES



LANDS
Duchess Island
North Star Island
Mary Sachs
Breakers
Shoal
Pt Sweeney
Pt Thomson
INLET
Marsh
148°20



146°10'
146°00'
Mary Sachs Entrance
MARY SACHS ISLAND
Flaxman Islan
INLET
Shoal area
SURVEY TARGET
Marsh
Shoal
52
51
50
49
48
47
46
44
43
42
45
41
40
28
29
30
31
32
33
34
35
36
37
38


70°15'
70°10'
Brownlow
Foul
Shoal
Shoal area
Racon
50ft Ra Ref
SURVEY TARGET
(Ruins)
Tundra
Ra (conspic)

- The western ends of Mary Sachs and Duchess Islands have migrated towards the west.

- The eastern ends of North Star and Alaska Islands have migrated towards the east.

- The inlet separating North Star and Duchess Island no longer exists. These two islands have merged together.

- The inlet separating Challenge and Alaska Islands has migrated to the east a distance of approximately 1200 feet.

The results of the survey comparison between 1955 and 1982 underscore the general belief that while the mainland shore remains quite stable, the offshore islands show a high degree of change in both shape and location. The reasons for these changes and quantification of the general observations will be presented in detail in Section 5.

4.3 Short-Term Rates of Shoreline Change, July-September, 1982

As mentioned previously, a complete tabulation of all survey data collected during the recent field work is contained in the Appendix. For purposes of brevity, only the summarized results of the survey operations are contained in this report.

Table 4.2, "Summary of Transect Characteristics", lists the general location, wave exposure, target color, and survey dates for each transect. The geographic coordinates of each monument were presented previously in Section 3.

The specific findings at each transect are listed in Table 4.3, "Summary of Survey Data". For each monumented transect, the following information is presented:

- <u>Bearing:</u> The bearing (in degrees) of the transect relative to true north.

- <u>Transect Length:</u> The total horizontal length of the surveyed transect for both the July and September surveys. As discussed in Section 3.2, lower water levels and improved survey equipment and methods resulted in longer transect lengths during the second survey.

- <u>South WL to MNT:</u> This quantity represents the distance between the south water line and the monument for the two surveys. Note that only the mainland spits and the offshore barrier islands have south shores.

- <u>MNT to North WL:</u> This quantity shows the distance between the monument and the north waterline for all transects except Transect #45, located on the south shore of Flaxman Island.

- <u>Elevations:</u> Elevations are given for both the top of each monument ("MNT") and the still water level of the September survey ("Sept SWL"). The datum has been chosen to be the water level during the July

TABLE 4.2

SUMMARY OF TRANSECT CHARACTERISTICS

TRANSECT	LOCATION	EXPOSURE	TARGET COLOR	SURVEY DATES
1	MAINLAND	N-NE	ORANGE	7-26-82 / 9-1-82
2	MAINLAND-BLUFF	N-NE	YELLOW/ORANGE	7-26-82 / 9-1-82
3	MAINLAND-SPIT	NW-N-NE	YELLOW	7-26-82 / 9-1-82
4	MAINLAND-SPIT	NW-N-NE	ORANGE	7-26-82 / 9-1-82
5	MAINLAND-BLUFF	NW-N	YELLOW/ORANGE	7-26-82 / 9-1-82
6	MAINLAND-SPIT	NW-N	YELLOW	7-26-82 / 9-1-82
7	MAINLAND-SPIT	W-N-E	ORANGE	7-26-82 / 9-1-82
8	MAINLAND	PROTECTED	YELLOW/ORANGE	7-27-82 / 9-1-82
9	MAINLAND-SPIT	NW-N-NE	YELLOW	7-27-82 / 9-1-82
10	MAINLAND	NW-N	ORANGE	7-27-82 / 9-1-82
11	MAINLAND-SPIT	NW-N	YELLOW/ORANGE	7-27-82 / 9-1-82
12	MAINLAND	N-NW	YELLOW	7-27-82 / 9-1-82
13	MAINLAND	W-N-NE	ORANGE	7-27-82 / 9-1-82
14	MAINLAND	N-NE	YELLOW/ORANGE	7-27-82 / 9-1-82
15	MAINLAND-SPIT	N-NE	YELLOW	7-27-82 / 9-1-82
16	MAINLAND	N-NW	YELLOW/ORANGE	7-22-82 / 9-2-82
17	MAINLAND	NW	YELLOW	7-22-82 / 9-2-82
18	MAINLAND	N-NE	YELLOW/ORANGE	7-22-82 / 9-2-82
19	MAINLAND	N-NE	YELLOW	7-22-82 / 9-2-82
20	MAINLAND	NW	YELLOW/ORANGE	7-22-82 / 9-2-82
21	MAINLAND	N-NE	YELLOW/ORANGE	7-27-82 / 9-2-82
22	MAINLAND	N-NE	YELLOW/ORANGE	7-22-82 / 9-2-82
23	MAINLAND	NW-N	YELLOW	7-22-82 / 9-2-82
24	MAINLAND	NW	YELLOW/ORANGE	7-22-82 / 9-2-82
25	MAINLAND-SPIT	W-N-NE	YELLOW	7-22-82 / 9-2-82
26	MAINLAND-SPIT	N-NE	ORANGE	7-22-82 / 9-2-82

TRANSECT	LOCATION	EXPOSURE	TARGET COLOR	SURVEY DATES
27	MAINLAND-SPIT	N-NE	YELLOW/ORANGE	7-22-82 / 9-2-82
28	MAINLAND-SPIT	NW-N	YELLOW	7-27-82 / 9-2-82
29	MAINLAND	PROTECTED	ORANGE	7-24-82 / 9-2-82
30	MAINLAND	N-NE	YELLOW	7-24-82 / 9-1-82
31	MAINLAND	N	YELLOW/ORANGE	7-24-82 / 9-1-82
32	MAINLAND	PROTECTED	YELLOW	7-24-82 / 9-1-82
33	MAINLAND	N-NE-E	YELLOW/ORANGE	7-24-82 / 9-1-82
34	MAINLAND-BLUFF	N-NE	YELLOW	7-24-82 / 9-1-82
35	MAINLAND	N-NE	ORANGE	7-24-82 / 9-1-82
36	MAINLAND	N-NE-E	ORANGE	7-24-82 / 9-1-82
37	MAINLAND	NE-E	YELLOW	7-24-82 / 9-1-82
38	MAINLAND	N	ORANGE	7-24-82 / 9-1-82
39	FLAXMAN IS-BLUFF	N-NE	YELLOW	7-23-82 / 9-2-82
40	FLAXMAN IS-BLUFF	N-NE	ORANGE	7-23-82 / 9-2-82
41	FLAXMAN IS-BLUFF	N-NE	YELLOW	7-23-82 / 9-2-82
42	FLAXMAN IS	N-NE	YELLOW	7-23-82 / 9-2-82
43	FLAXMAN IS	N-E	YELLOW	7-43-82 / 9-2-82
44	FLAXMAN IS	N-E	ORANGE	7-23-82 / 9-2-82
45	FLAXMAN IS-BLUFF	SW-W-NW	YELLOW/ORANGE	7-23-82 / 9-2-82
46	MARY SACHS	NE/S	YELLOW	7-23-82 / 9-2-82
47	MARY SACHS	NE/S	ORANGE	7-23-82 / 9-2-82
48	MARY SACHS	NE/S	ORANGE	7-23-82 / 9-2-82
49	MARY SACHS	NW-NE/S	YELLOW/ORANGE	7-23-82 / 9-2-82
50	MARY SACHS	NW-NE/S	ORANGE	7-23-82 / 9-2-82
51	MARY SACHS	W-N-NE/S	YELLOW/ORANGE	7-23-82 / 9-2-82
52	MARY SACHS	W-NW-N/S	ORANGE	7-23-82 / 9-7-82
53	NS/DUCH IS	N-NE/S	YELLOW/ORANGE	7-25-82 / 9-7-82
54	NS/DUCH IS	N-NE/S	YELLOW/ORANGE	7-25-82 / 9-7-82

TRANSECT	LOCATION	EXPOSURE	TARGET COLOR	SURVEY DATES
55	NS/DUCH IS	N-NE/S	ORANGE	7-25-82 / 9-7-82
56	NS/DUCH IS	NW-N-NE/S	ORANGE	7-25-82 / 9-7-82
57	NS/DUCH IS	NW-N-NE/S	ORANGE	7-25-82 / 9-7-82
58	NS/DUCH IS	NW-N-NE/S	YELLOW	7-25-82 / 9-7-82
59	NS/DUCH IS	W-N/S-SE	YELLOW/ORANGE	7-25-82 / 9-2-82
60	NS/DUCH IS	W-N/S-SE	ORANGE	7-25-82 / 9-7-82
61	ALASKA IS	N-NE/S	YELLOW/ORANGE	7-25-82 / 9-7-82
62	ALASKA IS	N-NE/S	YELLOW/ORANGE	7-25-82 / 9-7-82
63	ALASKA IS	N-NE/S	YELLOW	7-25-82 / 9-7-82
64	ALASKA IS	NW-N-NE/S	YELLOW,ORANGE	7-25-82 / 9-7-82
65	ALASKA IS	NW-N-NE/S	YELLOW	7-25-82 / 9-7-82
66	ALASKA IS	NW-N-NE/S	ORANGE	7-25-82 / 9-7-82
67	ALASKA IS	NW-N-NE/S	YELLOW	7-25-82 / 9-7-82

TABLE 4.3
SUMMARY OF SURVEY DATA

(ALL MEASUREMENTS EXPRESSED IN FEET)

TRANSECT	BEARING (Deg)	TRANSECT LENGTH		SOUTH WL TO MNT		MNT TO NORTH WL		ELEVATIONS		SHORELINE CHANGE AT JULY SWL DATUM	
		JULY	SEPT	JULY	SEPT	JULY	SEPT	ON MNT	SEPT SWL	SOUTH SHORELINE	NORTH SHORELINE
1	035.T	146	142			128	128	4.3	-.1		.2 EROSION
2	024.T	142	142			131	132	10.2	-.3		.8 EROSION
											.7 EROSION (BLUFF)
3	000.T	111	133	35	42	38	49	3.5	-.2	4.4 ACCRETION	9.3 ACCRETION
4	000.T	152	153	45	48	76	79	4.5	-.5	1.0 EROSION	.7 EROSION
5	000.T	108	103			74	73	19.0	-.2		2.3 EROSION
											3.1 EROSION (BLUFF)
6	355.T	112	115	32	35	56	58	3.4	-.3	.1 EROSION	.1 ACCRETION
7	000.T	127	143	51	54	55	67	4.2	-.5	.0 ACCRETION	10.7 ACCRETION
8	010.T	57	80			47	54	3.3	-.7		2.7 EROSION
9	350.T	82	322	21	27	31	87	3.6	-1.0	.3 ACCRETION	3.3 ACCRETION
10	334.T	160	195			144	151	4.7	-1.1		.1 ACCRETION
11	300.T	90	161	16	20	45	51	3.6	-.8	.2 ACCRETION	3.0 ACCRETION
12	000.T	125	159			113	119	7.4	-1.1		6.2 EROSION
13	000.T	115	180			100	114	5.0	-.8		4.0 ACCRETION
14	020.T	73	82			63	64	3.4	-.5		2.0 EROSION
15	030.T	72	111	19		35	36	4.3	-.7	.1 EROSION	2.0 EROSION
16	040.T	93	135			81	88	3.1	-.6		.4 EROSION
17	343.T	79	262			51	56	3.6	-.5		1.2 EROSION
18	040.T	84	106			70	71	3.7	-.1		.4 ACCRETION
19	036.T	106	139			78	79	4.1	-.3		3.0 EROSION
20	352.T	197	243			172	177	3.9	-.2		6.8 EROSION
21	300.T	92	134			53	54	3.2	-.2		0.0 ACCRETION
[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]		[illegible] EROSION

TRANSECT	BEARING (Deg)	TRANSECT LENGTH		SOUTH WL TO MNT		MNT TO NORTH WL		ELEVATIONS		SHORELINE CHANGE AT JULY SWL DATUM	
		JULY	SEPT	JULY	SEPT	JULY	SEPT	ON MNT	SEPT SWL	SOUTH SHORELINE	NORTH SHORELINE
23	000.T	126	195			103	118	4.2	-.3		2.0 ACCRETION
24	000.T	172	224			108	145	2.1	-.7		.4 EROSION
25	003.T	176	211	46	47	119	128	2.8	-.6	2.2 EROSION	6.0 ACCRETION
26	000.T	130	161	50	61	65	72	1.6	-.7	1.0 EROSION	.6 EROSION
27	000.T	68	81	22	25	34	34	3.0	-.7	1.1 EROSION	5.8 EROSION
28	344.T	100	102	27	29	55	57	3.4	-.7	.2 EROSION	1.3 EROSION
29	019.T	115	120			82	87	3.1	-.6		.4 EROSION
30	045.T	91	93			78	80	5.8	-.6		1.7 EROSION
31	000.T	101	105			87	92	7.8	-.6		1.5 ACCRETION
32	000.T	130	141			109	115	7.8	-.5		.4 ACCRETION
33	008.T	160	168			141	145	3.0	-.5		1.0 EROSION
34	056.T	104	107			98	101	10.0	-.6		.3 EROSION
											0.0 EROSION (BLUFF)
35	002.T	145	170			114	116	6.7	-.6		1.9 EROSION
36	062.T	150	162			142	145	3.2	-.5		.5 EROSION
37	066.T	122	126			105	112	7.5	-.5		1.6 ACCRETION
38	028.T	195	243			129	161	7.0	-.7		2.2 EROSION
39	034.T	144	161			108	108	20.3	0.0		5.2 EROSION (BLUFF)
40	023.T	177	186			120	102	16.4	0.0		20.5 EROSION (BLUFF)
41	029.T	107	128			107	111	13.9	0.0		6.5 EROSION (BLUFF)
42	018.T	207	223	78	80	101	106	4.0	-.2	1.2 ACCRETION	3.4 ACCRETION
43	014.T	171	172	63	68	71	72	3.7	-.3	3.0 ACCRETION	.9 EROSION
44	033.T	261	296	59	60	85	85	2.8	-.2	.5 EROSION	1.6 EROSION
45	080.T	115	134			69	68	8.0	-.3		2.2 EROSION
											0.0 EROSION (BLUFF)
46	000.T	214	250	41	58	146	159	1.1	-.7	8.7 ACCRETION	4.8 ACCRETION
47	020.T	151	193	42	53	61	77	2.0	-.9	5.5 EROSION	8.3 ACCRETION

TRANSECT	BEARING (Deg)	TRANSECT LENGTH		SOUTH WL TO MNT		MNT TO NORTH WL		ELEVATIONS		SHORELINE CHANGE AT JULY SWL DATUM	
		JULY	SEPT	JULY	SEPT	JULY	SEPT	ON MNT	SEPT SWL	SOUTH SHORELINE	NORTH SHORELINE
48	026.T	177	272	64	89	64	76	2.8	-1.0	3.5 EROSION	7.6 ACCRETION
49	000.T	687	723	375	384	281	292	3.9	-1.5	3.6 EROSION	9.6 EROSION
50	356.T	442	678	196	443	178	195	2.2	-1.3	4.2 EROSION	16.6 EROSION
51	350.T	474	523	322	342	110	135	2.7	-1.7	5.9 EROSION	9.0 ACCRETION
52	340.T	523	1409	225	1011	263	294	1.0	-1.9	.0 ACCRETION	5.1 EROSION
53	026.T	129	509	44	296	49	51	2.3	-.5	5.6 EROSION	2.6 EROSION
54	006.T	476	514	360	372	79	94	4.1	-1.7	1.2 EROSION	2.4 ACCRETION
55	020.T	191	334	96	179	55	69	2.7	-1.5	.4 ACCRETION	.1 EROSION
56	015.T	214	248	76	89	103	116	2.7	-1.5	.2 EROSION	.2 EROSION
57	000.T	171	194	68	78	69	86	5.7	-1.3	.3 ACCRETION	7.4 ACCRETION
58	000.T	317	336	137	147	138	150	5.2	-1.7	1.5 EROSION	.3 ACCRETION
59	340.T	388	424	205	217	127	150	2.4	-1.7	2.8 EROSION	8.8 EROSION
60	332.T	445	485	310	320	92	120	2.3	-1.7	2.8 EROSION	22.0 EROSION
61	040.T	92	236	21	97	32	55	1.7	-1.6	8.9 EROSION	5.5 EROSION
62	012.T	145	213	29	63	66	77	3.3	-1.7	1.4 ACCRETION	3.3 ACCRETION
63	015.T	141	289	61	90	52	68	3.3	-1.5	6.0 ACCRETION	4.7 ACCRETION
64	008.T	435	497	48	65	352	369	2.5	-1.5	4.5 ACCRETION	24.7 EROSION
65	012.T	273	455	132	162	92	186	4.2	-1.7	4.9 EROSION	5.0 EROSION
66	000.T	190	207	80	96	69	81	3.4	-1.5	4.3 ACCRETION	1.0 ACCRETION
67	008.T	252	477	42	245	152	171	2.7	-1.7	.2 EROSION	10.2 EROSION

survey at each profile. Due to persistent easterly winds throughout the September survey period, the water levels were lower than those during the July survey by as much as two feet.

- Shoreline Change at July SWL Datum: For each transect, the change in shoreline position at the survey datum (the July still water level) was computed. In the case of mainland spits and barrier islands, the changes at both the north and south shorelines are given. For the Flaxman Island and mainland bluffs, the change in bluff and shoreline positions are listed.

The shoreline changes associated with the July-September, 1982, survey period are summarized in Figure 4.7. Transects are designated by small numbers, while the large red numerals show the values of the beach or bluff changes. Shoreline changes are given in feet, with positive numbers representing accretion of the beach, and negative numbers representing erosion. In the case of barrier islands with north and south shorelines, the measured values of erosion and/or accretion are presented adjacent to both shorelines.

A detailed interpretation of the shoreline change data summarized in Figure 4.7 is presented in Section 5.

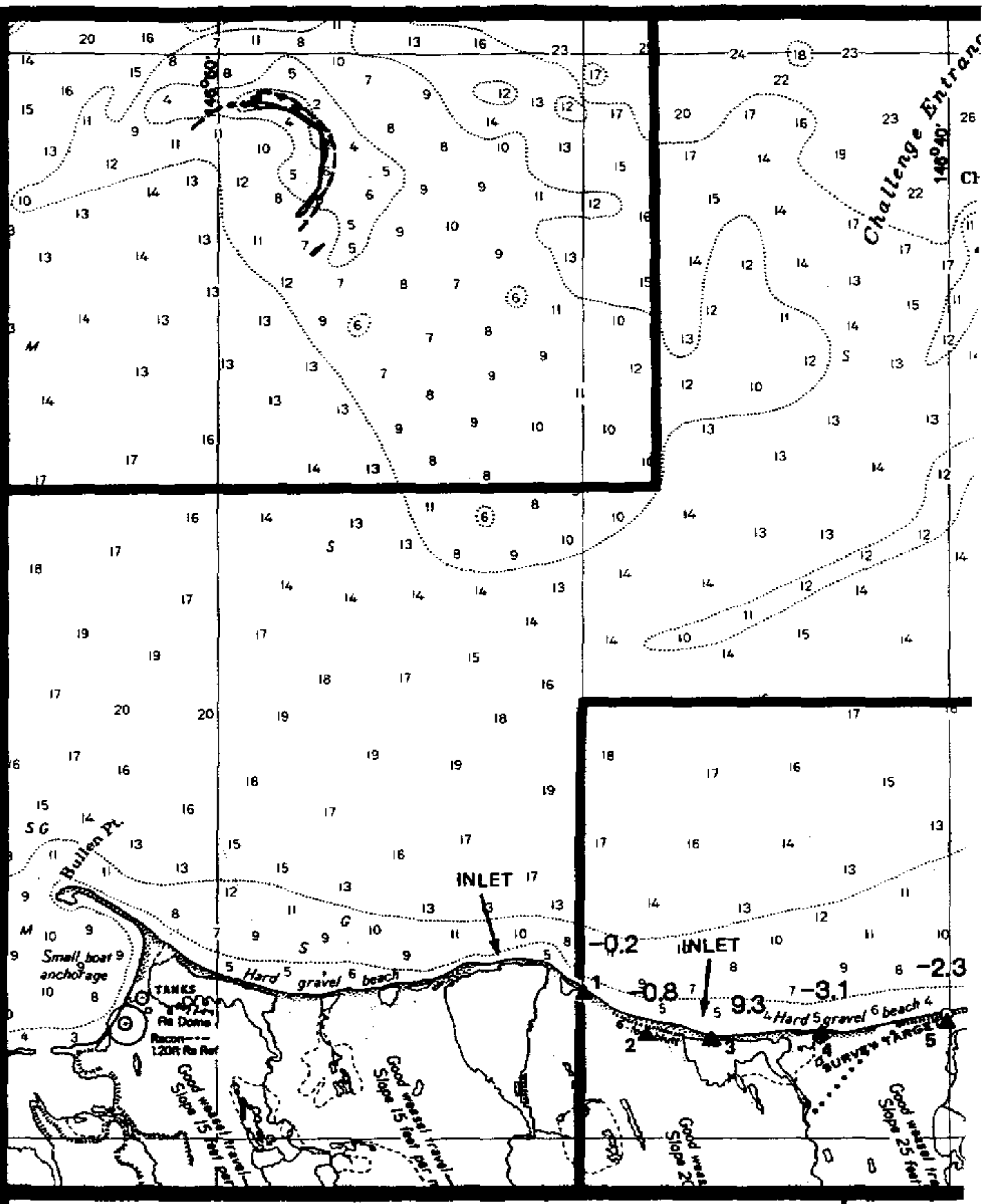


FIGURE 4.7

COASTAL CHANGES, JULY - SEPTEMBER, 1982

PT. THOMSON DEVELOPMENT PROJECT
COASTAL PROCESSES AND SEDIMENT DYNAMICS
CONTRACT PTD–8206
TEKMARINE, INC.

DRAWN

APPROVED

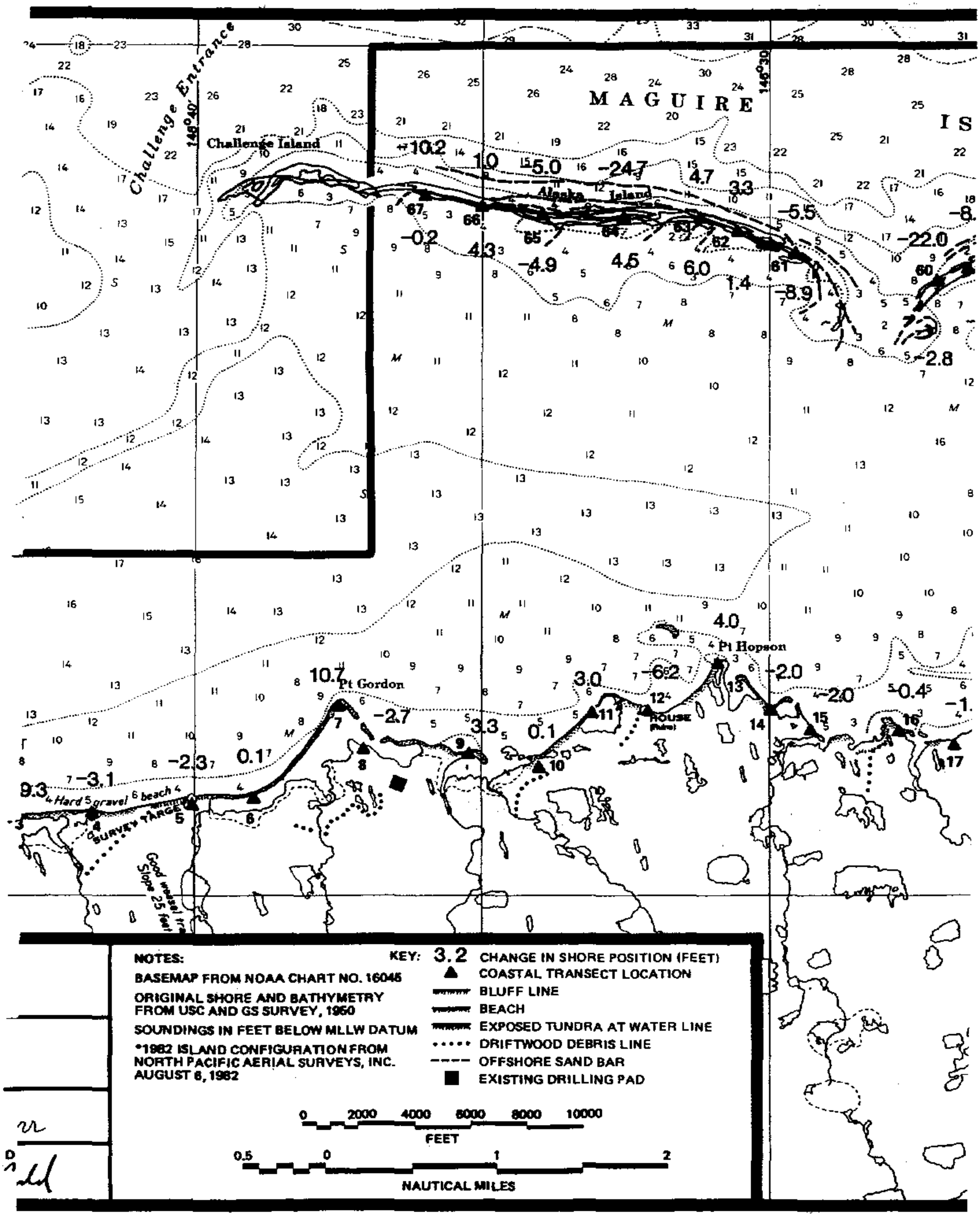
NOTES:

BASEMAP

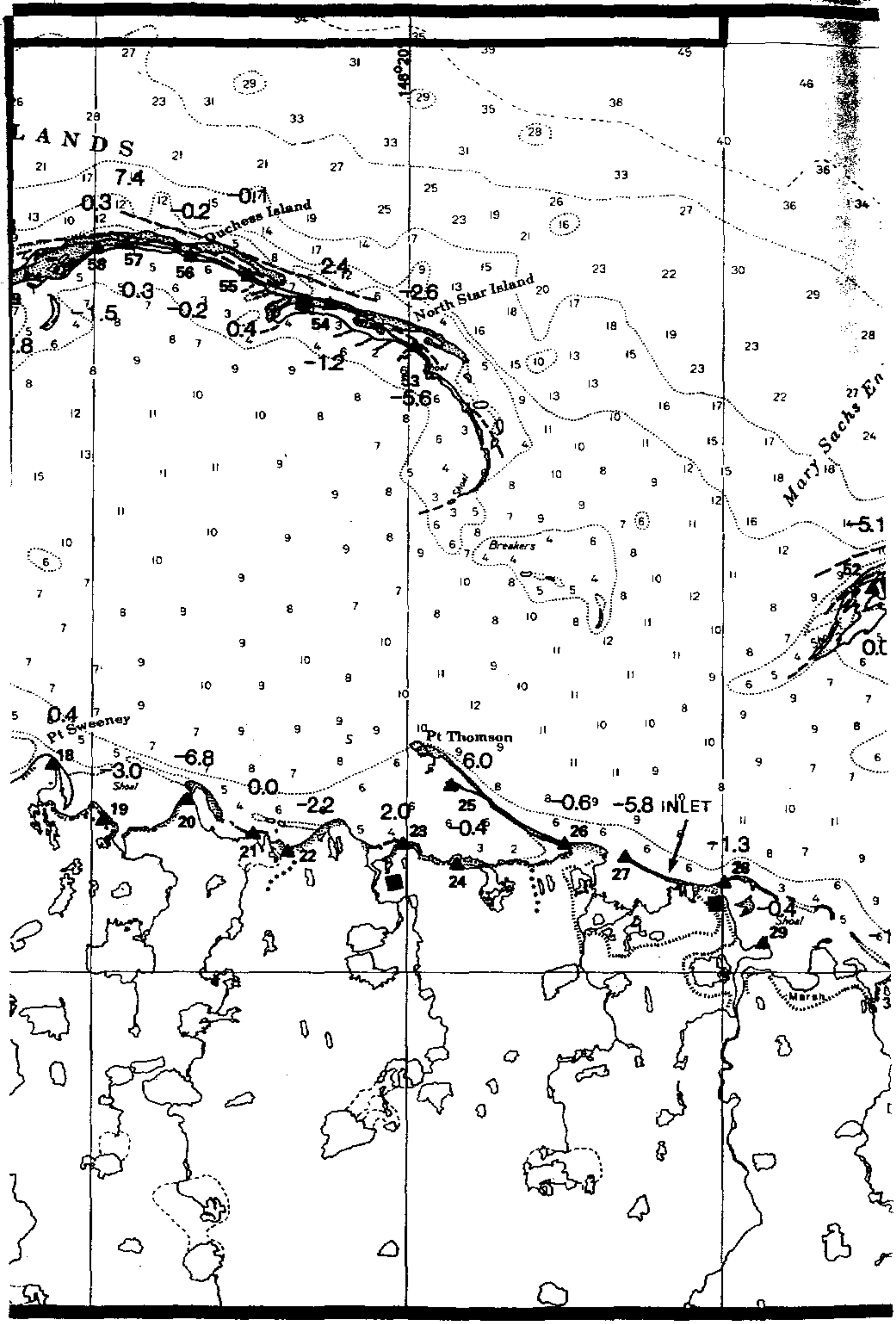
ORIGINAL
FROM USC

SOUNDING

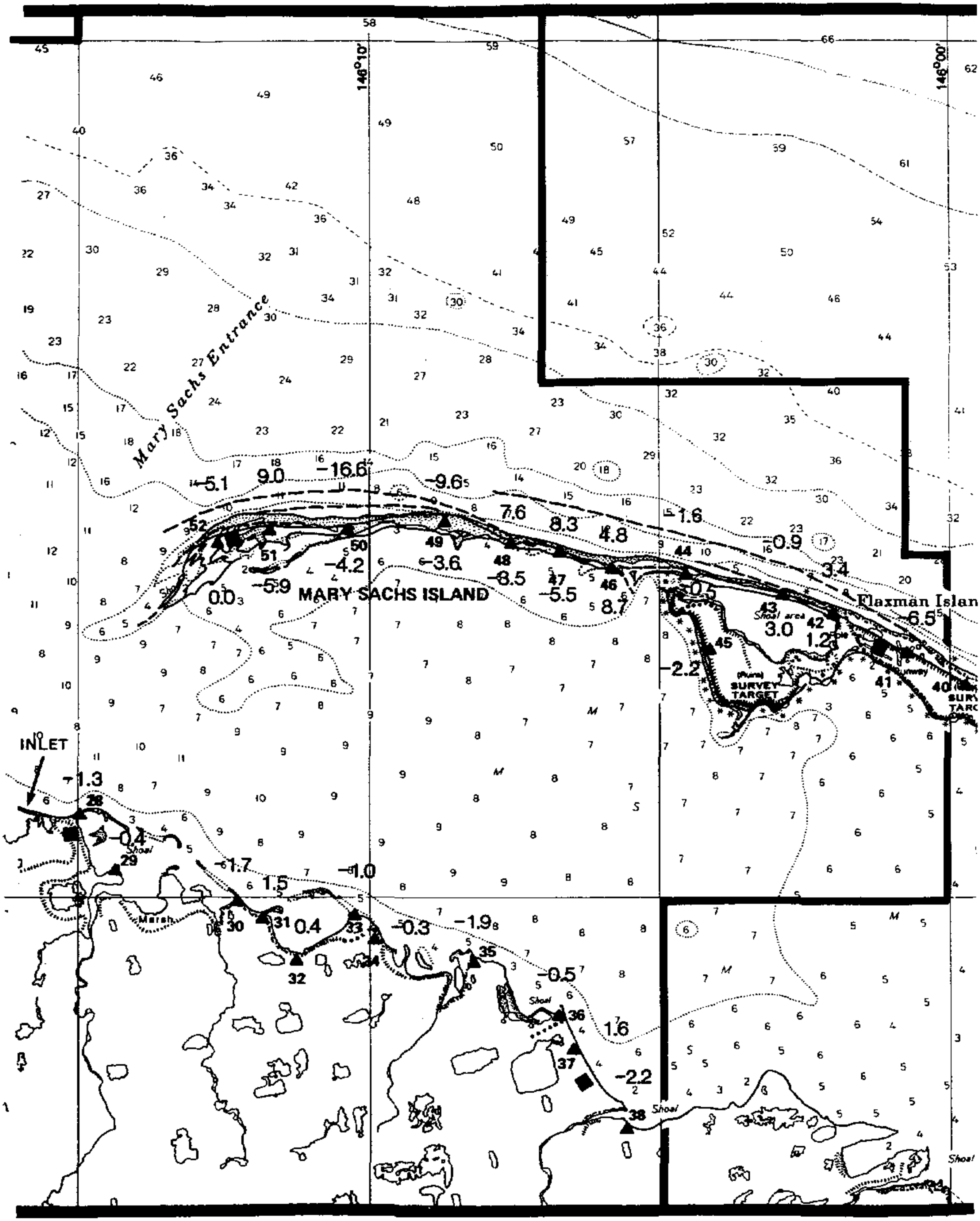
*1982 ISLA
NORTH PA
AUGUST 6

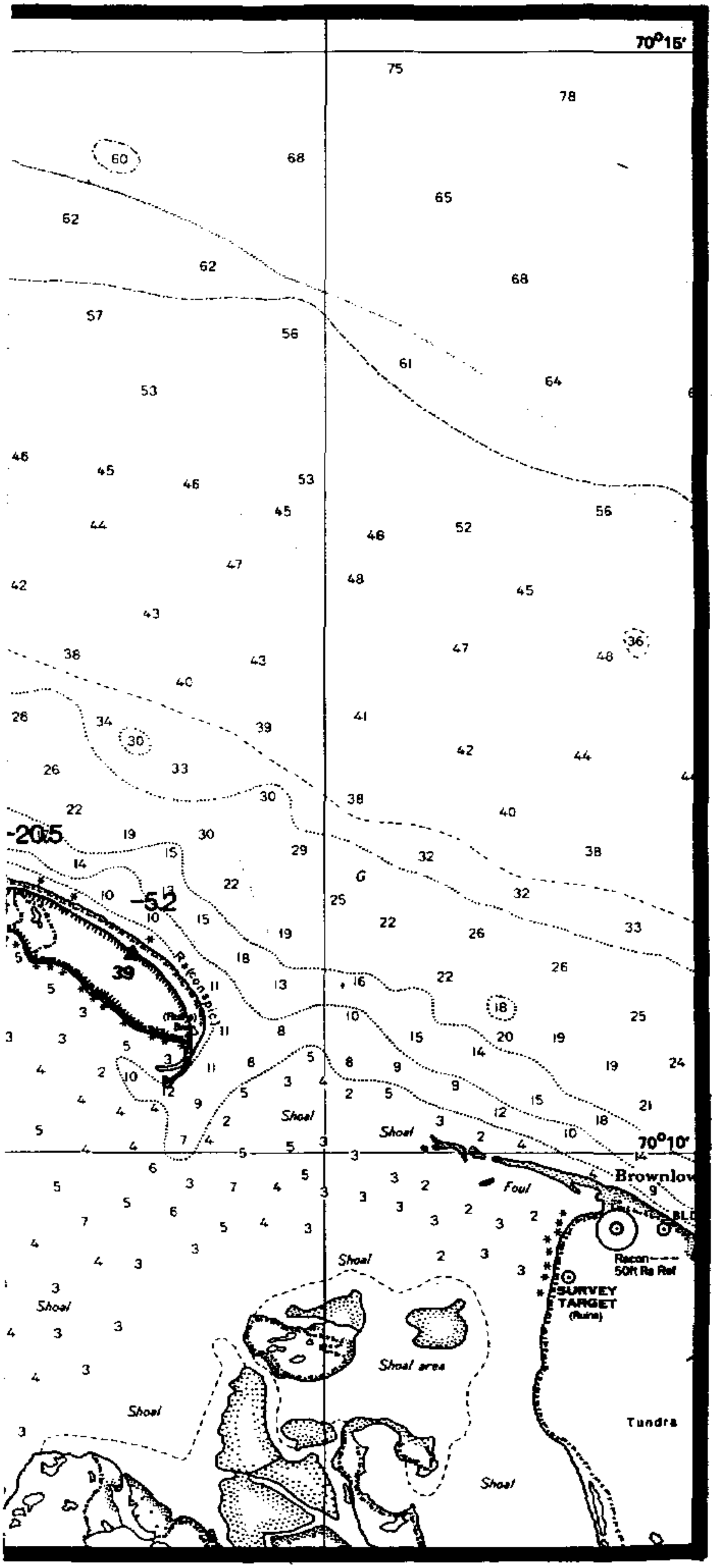


MAGUIRE IS
Challenge Entrance
Challenge Island
Alaska Island
Pt Gordon
Pt Hopson
ROUSE (Ruins)
Hard gravel beach
SURVEY TARGET
Good weasel tra
Slope 25 feet
NOTES:
BASEMAP FROM NOAA CHART NO. 16045
ORIGINAL SHORE AND BATHYMETRY FROM USC AND GS SURVEY, 1950
SOUNDINGS IN FEET BELOW MLLW DATUM
*1982 ISLAND CONFIGURATION FROM NORTH PACIFIC AERIAL SURVEYS, INC. AUGUST 6, 1982
KEY: 3.2 CHANGE IN SHORE POSITION (FEET)
COASTAL TRANSECT LOCATION
BLUFF LINE
BEACH
EXPOSED TUNDRA AT WATER LINE
DRIFTWOOD DEBRIS LINE
OFFSHORE SAND BAR
EXISTING DRILLING PAD
0 2000 4000 6000 8000 10000
FEET
0.5 0 1 2
NAUTICAL MILES



LANDS
Duchess Island
North Star Island
Mary Sachs En
Breakers
Pt Sweeney
Pt Thomson
INLET
Shoal
Marsh
146°20'


146°10'
146°00'
Mary Sachs Entrance
MARY SACHS ISLAND
Flaxman Islan
INLET
Shoal area
SURVEY TARGET
Marsh
Shoal



70°15'
70°10'
Brownlow
Ra (conspic)
Shoal
Shoal
Foul
Shoal
Shoal
Shoal area
Shoal
Shoal
Racon
50ft Ra Ref
SURVEY TARGET
(Ruins)
BLD
Tundra

5. SURVEY FINDINGS

Based on the analysis of the recent field data presented in Section 4, a judgement can be made concerning the relative stability exhibited by the five characteristic shoreline types mentioned previously (mainland bluffs, mainland spits, low mainland shore, Flaxman Island bluffs, and the barrier islands). This section of the report will assess those areas which have exhibited relative long-term stability (the first three categories listed above) and those which have proven to be less stable (Flaxman Island bluffs and the barrier islands) over the period of record.

5.1 Areas of Relative Shoreline Stability

The mainland coast of the study area exhibits a high degree of stability. While all three shoreline classes occurring on the mainland (the bluffs, spits, and low shore) have exhibited a high degree of stability, the bluffs and spits tend to be more dynamic than the low mainland shore. These three types of mainland coastal terrain will be discussed individually to illustrate the findings that support this general conclusion.

5.1.1 Mainland Bluffs

Three coastal transects were surveyed over mainland bluffs that achieve heights in excess of nine feet. The survey results are presented in Table 5.1, which show that the average bluff erosion for the July-September, 1982, period was 1.3 feet while the fronting beach at these sites eroded an average distance of 1.1 feet.

TABLE 5.1 : CHANGES IN MAINLAND BLUFFS, 1982

SUMMARY OF SURVEY DATA - MAINLAND BLUFFS

(ALL MEASUREMENTS EXPRESSED IN FEET)

TRANSECT	BEARING (Deg)	TRANSECT LENGTH		SOUTH WL TO MNT		MNT TO NORTH WL		ELEVATIONS		SHORELINE CHANGE AT JULY SWL DATUM	
		JULY	SEPT	JULY	SEPT	JULY	SEPT	ON MNT	SEPT SWL	SOUTH SHORELINE	NORTH SHORELINE
2	024.T	142	142			131	132	10.2	-.3		.8 EROSION
											.7 EROSION (BLUFF)
5	000.T	108	103			74	73	19.0	-.2		2.3 EROSION
											3.1 EROSION (BLUFF)
34	056.T	104	107			98	101	10.0	-.6		.3 EROSION
											0.0 EROSION (BLUFF)

AVERAGE SHORE CHANGE : 1.1' EROSION

AVERAGE BLUFF CHANGE : 1.3' EROSION

Due in part to the protection provided by the sand and gravel beaches existing at the base of the bluffs, bluff recession along the majority of the mainland shore is relatively mild. At several unsurveyed locations, however, extensive bluff recession was observed in spite of the energy-dissipating beachfront, as shown in Photo 2, taken near Transect #5. The major mechanism of bluff erosion in this case is the thawing and subsequent failure of the ice-laden bluff sediments.

5.1.2 Mainland Spits

Spits composed of sand and gravel project from a number of mainland promontories within the study area. These low-lying, sinuous sedimentary structures are formed by persistent littoral transport that constantly serves to nourish the spits. Gravel spits protect the mainland shore located to the south by dissipating incoming wave and ice forces.

Photo 3 shows a typical coastal spit located at Transect #27. This spit projects westward from the Pt. Thomson pad location, which can be seen in the background. This site was chosen for the littoral drift experiment described in detail in Section 6.

The surficial sediments of the coastal spits are a very uniform coarse gravel having a mean diameter of about one inch. In Photo 4, a trench that was excavated near Monument #27 shows the surface veneer of gravel quite clearly. At the time of the photo, the elevation of the spit was one foot above the prevailing still water level.

PHOTO 2. COASTAL BLUFF EROSION ON THE MAINLAND SHORE NEAR TRANSECT #5

PHOTO 3. TYPICAL GRAVEL SPIT ON MAINLAND COAST (AT TRANSECT # 27)

PHOTO 4. VERTICAL TRENCH SHOWING COMPOSITION AND DISTRIBUTION OF SEDIMENTS ON MAINLAND SPIT (TRANSECT #27)

Beneath the gravel cover lies a homogeneous mixture of sand and gravel. Wave run-up and subsequent percolation into the porous beach causes the sand to flow downward into the interstices of the underlying coarse gravel, thus creating the sand-gravel mixture observed below the beach surface at numerous locations.

The results of the recent surveys conducted on the mainland gravel spits are presented in Table 5.2. These results are summarized in the histograms that comprise Figure 5.1. Each histogram shows the number of surveyed transects (vertical scale) that experienced a given magnitude of erosion (lined area) or accretion (dotted area). Transects that changed less than two feet between July and September are judged to have undergone no change and are represented by the unshaded indicator at the midpoint of the horizontal axis. A summary is also presented adjacent to each histogram showing the number of transects experiencing erosion, accretion, and negligible change, and the average value of the change within each category.

Figure 5.1(A) shows the changes observed in the unexposed southern shoreline of the eleven coastal spits that were surveyed. Nine showed negligible change indicating that minimal wave energy is associated with the small lagoons located to the south of the spits. The average erosion computed for the south shore of all eleven spits was -0.1 feet.

The recent changes in the north shore of the coastal spits are shown in Figure 5.1(B). Of the eleven mainland spits, one experienced erosion (-5.8 feet) and five experienced accretion (average accretion = +6.5 feet). In

TABLE 5.2 : CHANGES IN MAINLAND SPITS, 1982

SUMMARY OF SURVEY DATA – MAINLAND SPITS

(ALL MEASUREMENTS EXPRESSED IN FEET)

TRANSECT	BEARING (Deg)	TRANSECT LENGTH		SOUTH WL TO MNT		MNT TO NORTH WL		ELEVATIONS		SHORELINE CHANGE AT JULY SWL DATUM	
		JULY	SEPT	JULY	SEPT	JULY	SEPT	ON MNT	SEPT SWL	SOUTH SHORELINE	NORTH SHORELINE
3	000.T	111	133	35	42	38	49	3.5	-.2	4.4 ACCRETION	9.3 ACCRETION
4	000.T	152	153	45	48	76	79	4.5	-.5	1.0 EROSION	.7 EROSION
6	355.T	112	115	32	35	56	58	3.4	-.3	.1 EROSION	.1 ACCRETION
7	000.T	127	143	51	54	55	67	4.2	-.5	.0 ACCRETION	10.7 ACCRETION
9	350.T	82	322	21	27	31	87	3.6	-1.0	.3 ACCRETION	3.3 ACCRETION
11	300.T	90	161	16	20	45	51	3.6	-.8	.2 ACCRETION	3.0 ACCRETION
15	030.T	72	111	19		35	36	4.3	-.7	.1 EROSION	2.0 EROSION
25	003.T	176	211	46	47	119	128	2.8	-.6	2.2 EROSION	6.0 ACCRETION
26	000.T	130	161	50	61	65	72	1.6	-.7	1.0 EROSION	.6 EROSION
27	000.T	68	81	22	25	34	34	3.0	-.7	1.1 EROSION	5.0 EROSION
28	344.T	100	102	27	29	55	57	3.4	-.7	.2 EROSION	1.3 EROSION

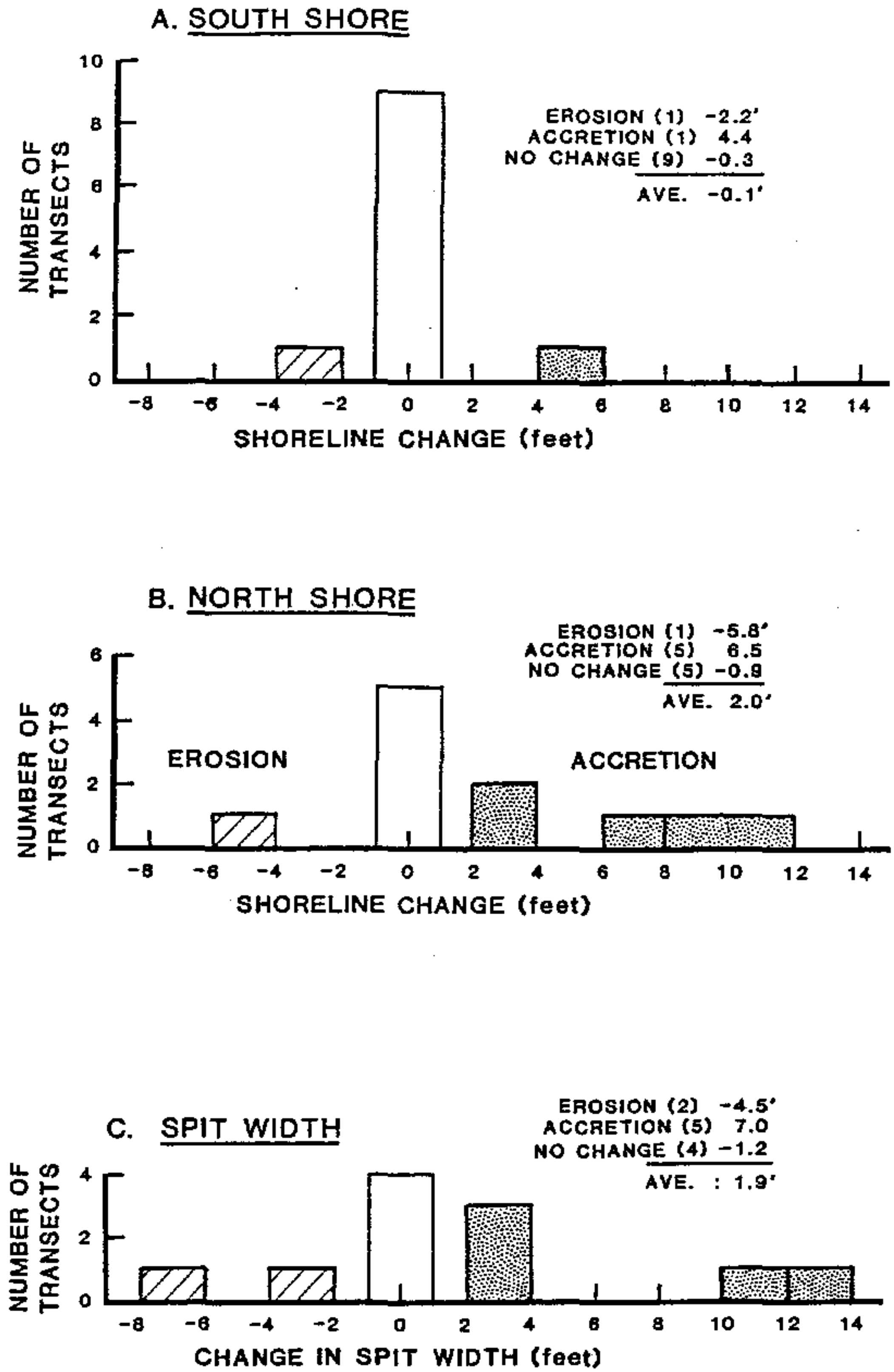


FIGURE 5.1 : SHORELINE CHANGE HISTOGRAM, MAINLAND SPITS, 1982

addition, five transects experienced negligible change (less than two feet of measured change) that averaged 0.9 feet of erosion.

By combining the results of the data measured for the north and south shores of the surveyed spits, a histogram can be developed to show the changes in total spit width. As shown in Figure 5.1(C), the two spit transects that narrowed had an average loss of 4.5 feet. For the five spits that widened, the average accretion was 7.0 feet, while four spits showed negligible change. For all the coastal spits, the average change was 1.9 feet of accretion.

While the results show that the mainland spits of the study region experienced both erosion and accretion during the recent summer, spit widening appears to be dominant at this time. It is quite clear that the south sides of mainland spits were quite static. Because wave overtopping is the major mechanism of shoreline change on the back side of the spits, this lack of southern shoreline change implies that very few, if any, spits were overtopped by waves during periods of high water level this past summer.

5.1.3 Low Mainland Shore

Twenty-four transects remain on the mainland coast when one eliminates the previously discussed coastal bluffs and spits. Table 5.3 lists the survey specifics of these low-lying profiles. A histogram illustrating the range of shoreline changes is presented as Figure 5.2. The data shows that the majority (71%) of the transects of this group exhibited negligible shoreline change which emphasizes the stability that has been recently observed. Six of the 24 transects experienced erosion, averaging -3.9 feet. The

TABLE 5.3 : CHANGES IN LOW MAINLAND SHORE, 1982

SUMMARY OF SURVEY DATA - LOW MAINLAND SHORE

(ALL MEASUREMENTS EXPRESSED IN FEET)

TRANSECT	BEARING (Deg)	TRANSECT LENGTH		SOUTH WL TO MNT		MNT TO NORTH WL		ELEVATIONS		SHORELINE CHANGE AT JULY SWL DATUM	
		JULY	SEPT	JULY	SEPT	JULY	SEPT	ON MNT	SEPT SWL	SOUTH SHORELINE	NORTH SHORELINE
1	035.T	146	142			128	128	4.3	-.1		.2 EROSION
8	010.T	57	80			47	54	3.3	-.7		2.7 EROSION
10	334.T	160	195			144	151	4.7	-1.1		.1 ACCRETION
12	000.T	125	159			113	119	7.4	-1.1		6.2 EROSION
13	000.T	115	180			100	114	5.0	-.8		4.0 ACCRETION
14	020.T	73	82			63	64	3.4	-.5		2.0 EROSION
16	040.T	93	135			81	88	3.1	-.6		.4 EROSION
17	343.T	79	262			51	56	3.6	-.5		1.2 EROSION
18	040.T	84	106			70	71	3.7	-.1		.4 ACCRETION
19	036.T	106	139			78	79	4.1	-.3		3.0 EROSION
20	352.T	197	243			172	177	3.9	-.2		6.8 EROSION
21	300.T	92	134			53	54	3.2	-.2		0.0 ACCRETION
22	350.T	101	205			78	77	5.2	-.2		2.2 EROSION
23	000.T	126	195			103	118	4.2	-.3		2.0 ACCRETION
24	000.T	172	224			108	145	2.1	-.7		.4 EROSION
29	019.T	115	120			82	87	3.1	-.6		.4 EROSION
30	045.T	91	93			78	80	5.8	-.6		1.7 EROSION
31	000.T	101	105			87	92	7.8	-.6		1.5 ACCRETION
32	000.T	130	141			109	115	7.8	-.5		.4 ACCRETION
33	008.T	160	168			141	145	3.0	-.5		1.0 EROSION
35	002.T	145	170			114	116	6.7	-.6		1.9 EROSION
36	062.T	158	162			142	145	3.2	-.5		.5 EROSION
37	066.T	122	126			105	112	7.5	-.5		1.6 ACCRETION
38	028.T	195	243			129	161	7.0	-.7		2.2 EROSION

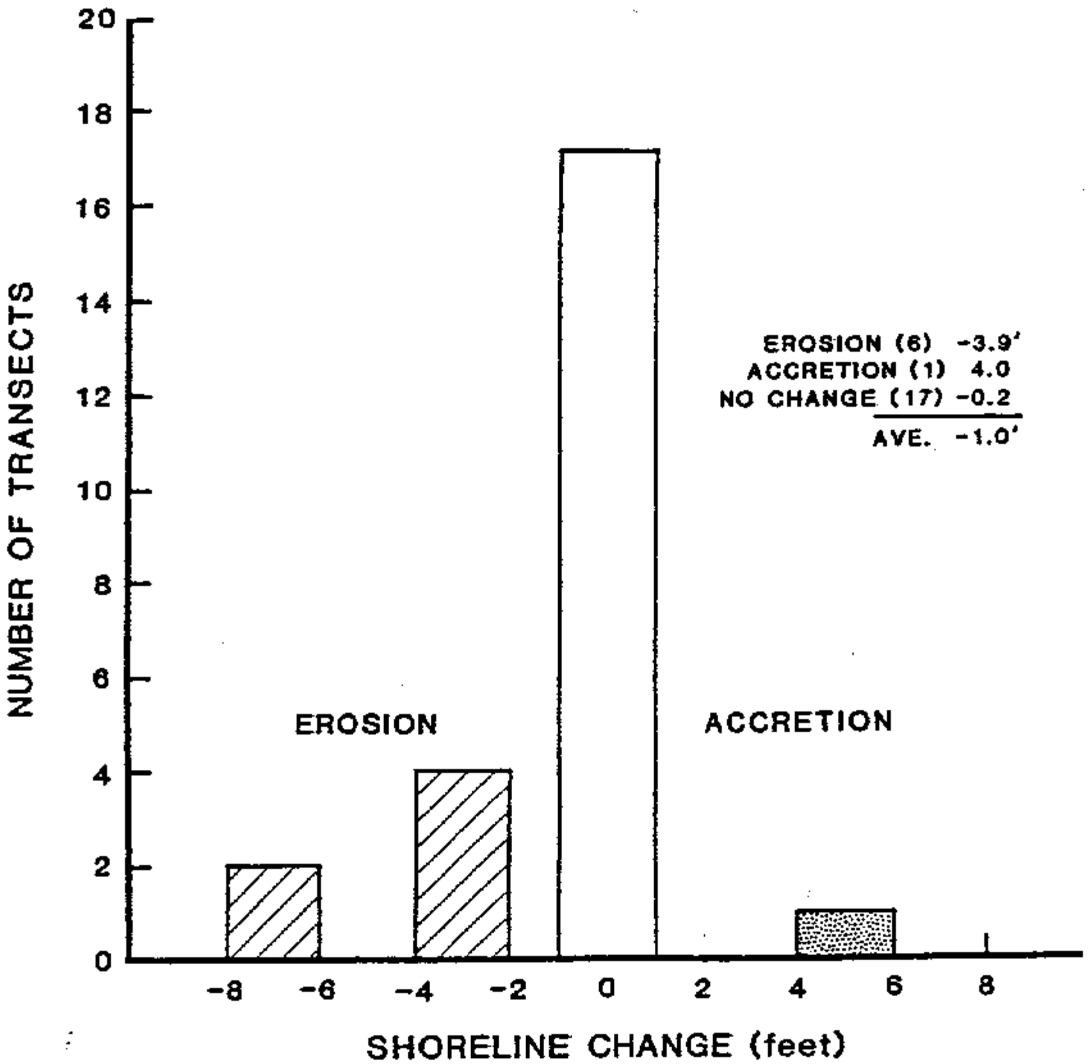


FIGURE 5.2 : SHORELINE CHANGE HISTOGRAM, LOW MAINLAND SHORE, 1982

only significant accretion measured was +4.0 feet at Transect #13, located on Pt. Hopson. The overall average change in these 24 transects was erosion of -1.0 foot.

The most recent findings underscore the generally held view that the mainland shore is relatively stable. Although there were several transects that experienced large shoreline fluctuations, the majority showed changes of less than two feet, implying general overall stability.

Figure 5.3 shows the change in shore position for all the mainland shore transects, represented by Monuments #1 - 38 (Ref. Figure 4.6). The areas of maximum accretion are at Transects #3 (a gravel spit), #7 (Pt. Hopson), and #25 (Pt. Thomson). All of these transects are located on sand spits, the latter two at the terminal ends of spits where sediment accumulation would be expected.

The sites of major erosion are Transects #12, 20, and 27. Both Transects #20 and #27 are located to the south of Mary Sachs Entrance, the only area within the study region that is not protected from northeast wave action by the offshore islands. With the exception of Transect #25 (an area of deposition at the end of Pt. Thomson), the reach of coast that is opposite Mary Sachs Entrance (Transects #18-28) experienced predominant erosion. This region of shore, by virtue of the lack of offshore island protection, is subject to the highest degree of easterly wave impact in the mainland portion of the study area.

The low-lying mainland shore is classified as a "chenier" beach formation, in which the sand and gravel beach sediments exist as a thin lens above a dense tundra foundation (King, 1961). During periods of strong westerly

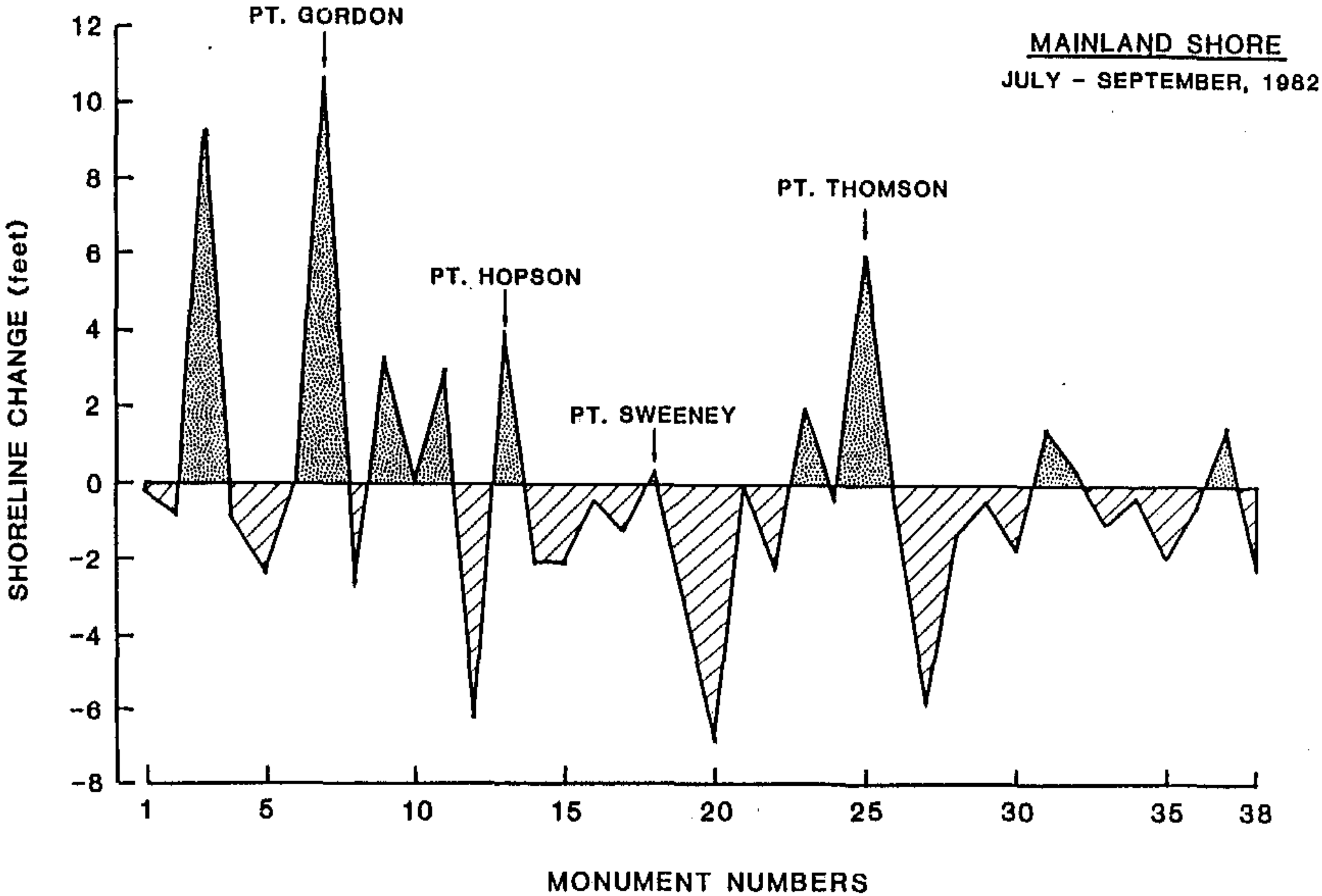


FIGURE 5.3 : CHANGES IN MAINLAND SHORE POSITION, 1982

winds, the water level rises, allowing the waves to push the beach sediments further and higher on the tundra base. In many areas of the mainland shore where beach sediments are sparse, the tundra has been exposed by wave energy at the existing water line, as shown in Photo 5. At other coastal transects exhibiting a larger beach volume, a steep storm scarp exists which was formed in the chenier beach during a period of high wave activity. Photo 6, taken near Transect #36, is an example of a typical wave-generated scarp.

Trenching of the mainland beach sediments was found to expose the tundra foundation at depth, as shown in Photo 7. Successive trenching along a profile allowed estimation of the beach sediment volume.

At Transect #18, the total volume of beach sediment was computed to be seven cubic yards per lineal foot of shoreline, as shown in Figure 5.4. This small volume of beach sediment is typical of the chenier beach environment within the study area and renders this formation highly sensitive to disruption in the supply of littoral drift.

At most of the surveyed transects, the mainland beach sediments extend offshore for a very short distnce. No sand bars exist along the mainland shore due to the sparseness of the necessary sediments. In the shallow nearshore, at the toe of the chenier beach, eroding tundra forms a highly organic, dense mud. The dense, vegetative matric that comprises the tundra resists erosion from the rather low, ambient wave energy. This results in the rather stable condition of the mainland shore that was documented previously.

PHOTO 5. MAINLAND BEACH OVERLYING TUNDRA BASE. NOTE TUNDRA EXPOSURE NEAR WATER LEVEL.

PHOTO 6. TYPICAL WAVE-GENERATED COASTAL SCARP NEAR TRANSECT #36, MAINLAND COAST.

PHOTO 7 VERTICAL TRENCH SHOWING SEDIMENT DISTRIBUTION OVER TUNDRA BASE

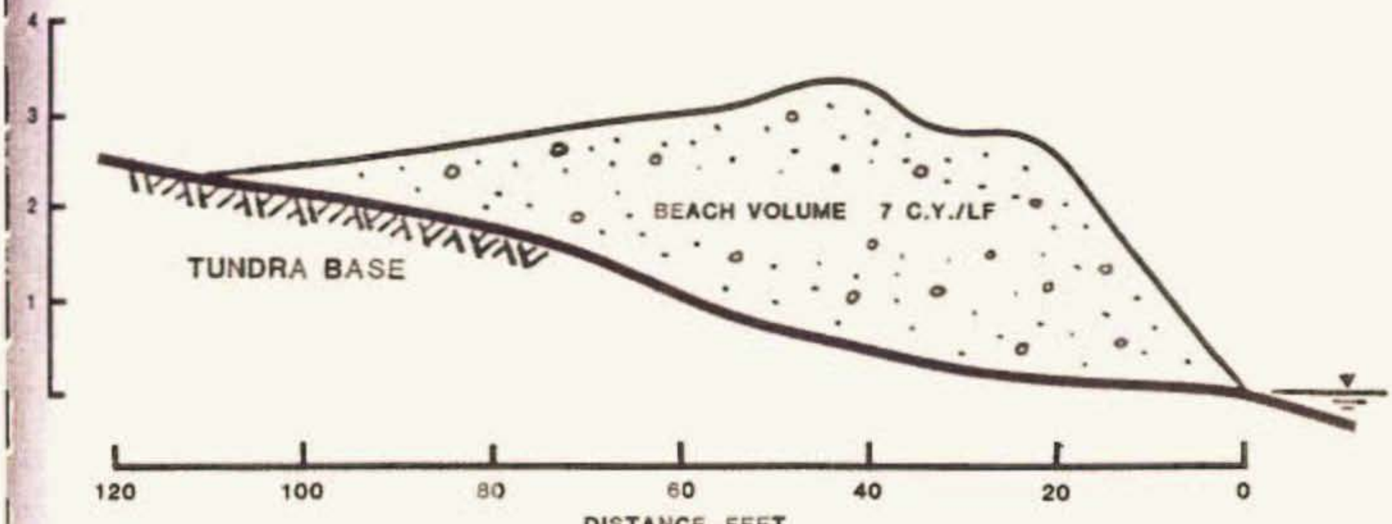


FIGURE 5.4 : CROSS-SECTION OF CHENIER BEACH, TRANSECT #18

The distinct and sudden boundary between the beach sediments and the underlying tundra at the back of the beach is quite dramatic. Photo 8 illustrates the complete and well-defined coverage of the beach veneer over the tundra base. It is believed that this is due to the stability of the sediments at this elevation which are subject to waves and currents only during the rare, extreme storm events. During the interim calm weather periods, the vegetation existing on the tundra can flourish, thus, creating the very stable and distinct interface that is evident in the photo.

An aerial photo taken above the Pt. Thomson spit and adjacent shore is shown in Figure 5.5. The chenier beach that exists atop the mainland tundra appears as a sinuous white line near the land-water interface. Along the coast shown in this photo, the chenier beach is located slightly inshore of the tundra shore, implying that the beach sediments in this sheltered area are active only during times of major storm wave activity.

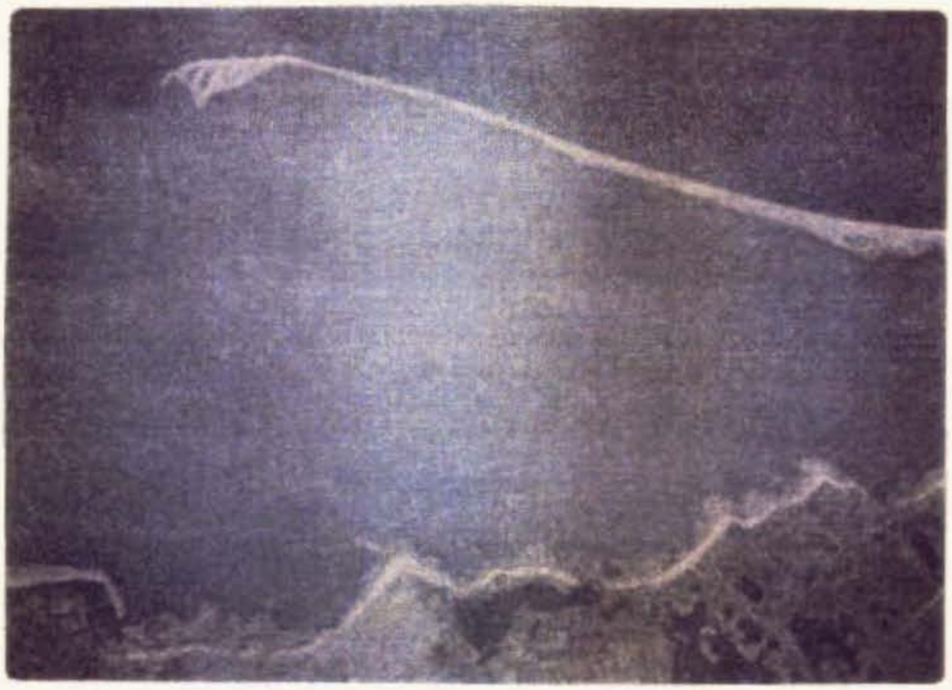
5.2 Areas of Significant Shoreline Change

The most active shoreline areas in the study zone are the bluffs of Flaxman Island and along the low-lying barrier islands. These two zones are related in that the eroding bluffs of Flaxman Island serve as the source of the sediments that nourish the down-drift barrier islands.

5.2.1 Flaxman Island Bluffs

Flaxman Island has been noted to experience a high-level of bluff erosion dating back to the reports of the earliest explorers of the region. The high, flat island form is shown in Photo 9, taken in early July, 1982. The

PHOTO 8. VIEW OF THE BACK OF MAINLAND "CHENIER" BEACH SHOWING DISTINCT SEPARATION BETWEEN BEACH AND TUNDRA



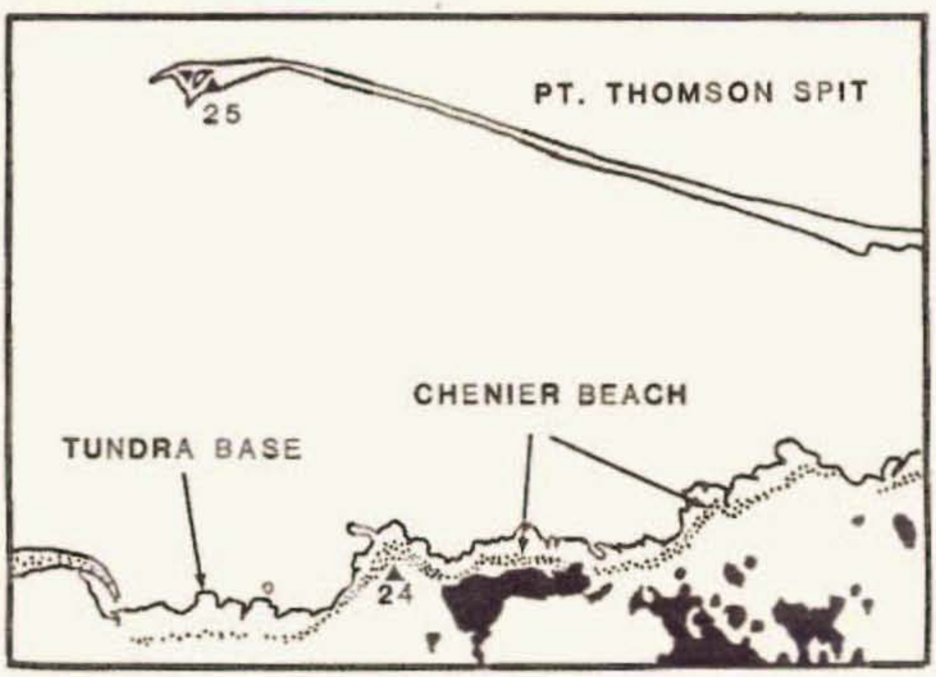


FIGURE 5.5 : AERIAL VIEW OF CHENIER BEACH

eroding bluff along the northern shore is shown in Photo 10 to be in contact with a protective ice foot at the bluff base. Until this ice foot melts or is dislodged, incoming wave energy cannot affect the stability of the bluff. A second view of the eroding bluff (Photo 11) shows a thick ice wedge that exists below the surface veneer of tundra. Also noteworthy is the variability of eroded sediment size, as illustrated by the large boulder that is on the verge of falling out of the bluff face. The unusual lithology of the Flaxman Island formation has been described previously in Section 2.1.

The northern bluffs of Flaxman Island are characterized by the massive blocks of tundra that are slumping downslope. Unlike beach erosion that can progress in small increments, much of the bluff erosion witnessed on Flaxman Island occurred in large sections measuring approximately fifty feet in length and 10-20 feet in the offshore direction. Photo 12 illustrates an example of an eroded bluff portion of this size. This eroded block of tundra may serve to protect and insulate the remaining bluff face, thereby slowing the future bluff erosion at this location until the block erodes.

Table 5.4 documents the changes noted between surveys at the transects located on the high Flaxman Island bluffs. Disregarding the transect having southwesterly wave exposure (Transect #45), the bluff recession averaged 10.7 feet during the July-September comparison period.

A comparison of the Flaxman Island shoreline of 1982 with that of 1955 (from the NOAA chart) can be used to determine the expected annual volume of the material eroded from the northern bluff. In Figure 5.6, the change in bluff

PHOTO 9. AERIAL VIEW, EAST END OF FLAXMAN ISLAND

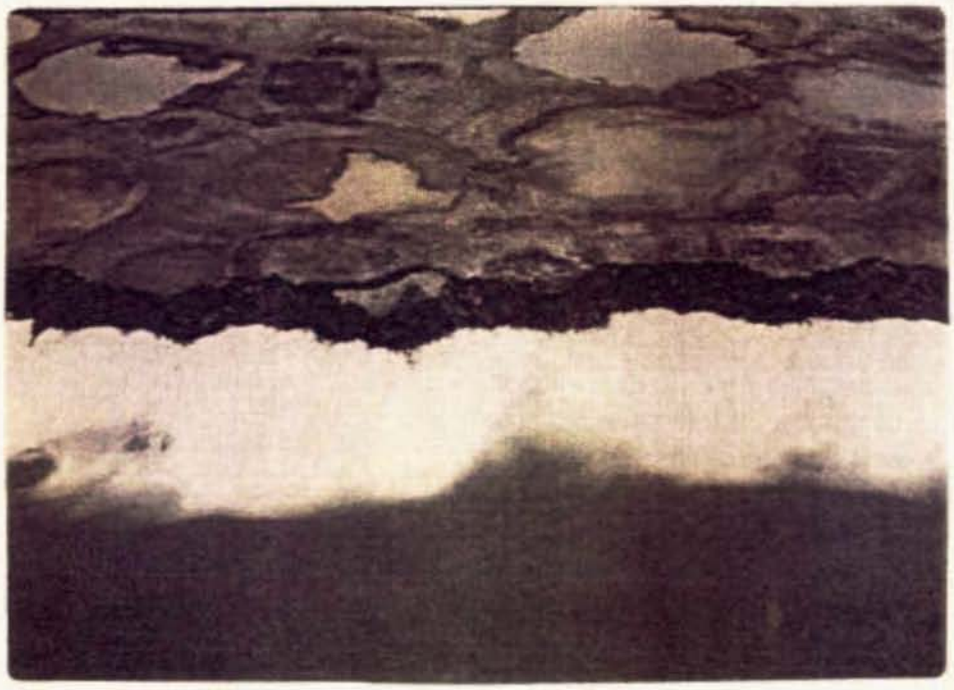


PHOTO 10. AERIAL VIEW OF ERODING NORTHERN BLUFF, FLAXMAN ISLAND, JULY, 1982. NOTE ICE ATTACHED TO BLUFF TOE

PHOTO 11. ERODING BLUFF ON FLAXMAN ISLAND SHOWING UNDERLYING ICE LENS AND LARGE BOULDER

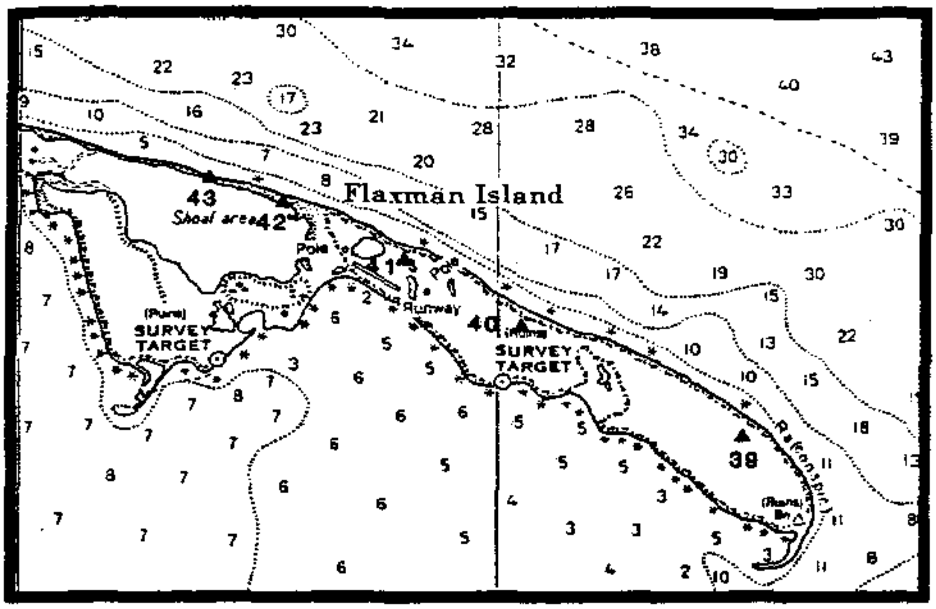
PHOTO 12. TYPICAL BLUFF EROSION, NORTHERN SHORE OF FLAXMAN ISLAND

TABLE 5.4 : CHANGES IN FLAXMAN ISLAND BLUFFS, 1982

SUMMARY OF SURVEY DATA - FLAXMAN ISL BLUFF

(ALL MEASUREMENTS EXPRESSED IN FEET)

TRANSECT	BEARING (Deg)	TRANSECT LENGTH		SOUTH WL TO MNT		MNT TO NORTH WL		ELEVATIONS		SHORELINE CHANGE AT JULY SWL DATUM	
		JULY	SEPT	JULY	SEPT	JULY	SEPT	ON MNT	SEPT SWL	SOUTH SHORELINE	NORTH SHORELINE
39	034.T	144	161			108	108	20.3	0.0		5.2 EROSION (BLUFF)
40	023.T	177	186			120	102	16.4	0.0		20.5 EROSION (BLUFF)
41	029.T	107	128			107	111	13.9	0.0		6.5 EROSION (BLUFF)
45	080.T	115	134			69	68	8.0	-.3		2.2 EROSION
											0.0 EROSION (BLUFF)



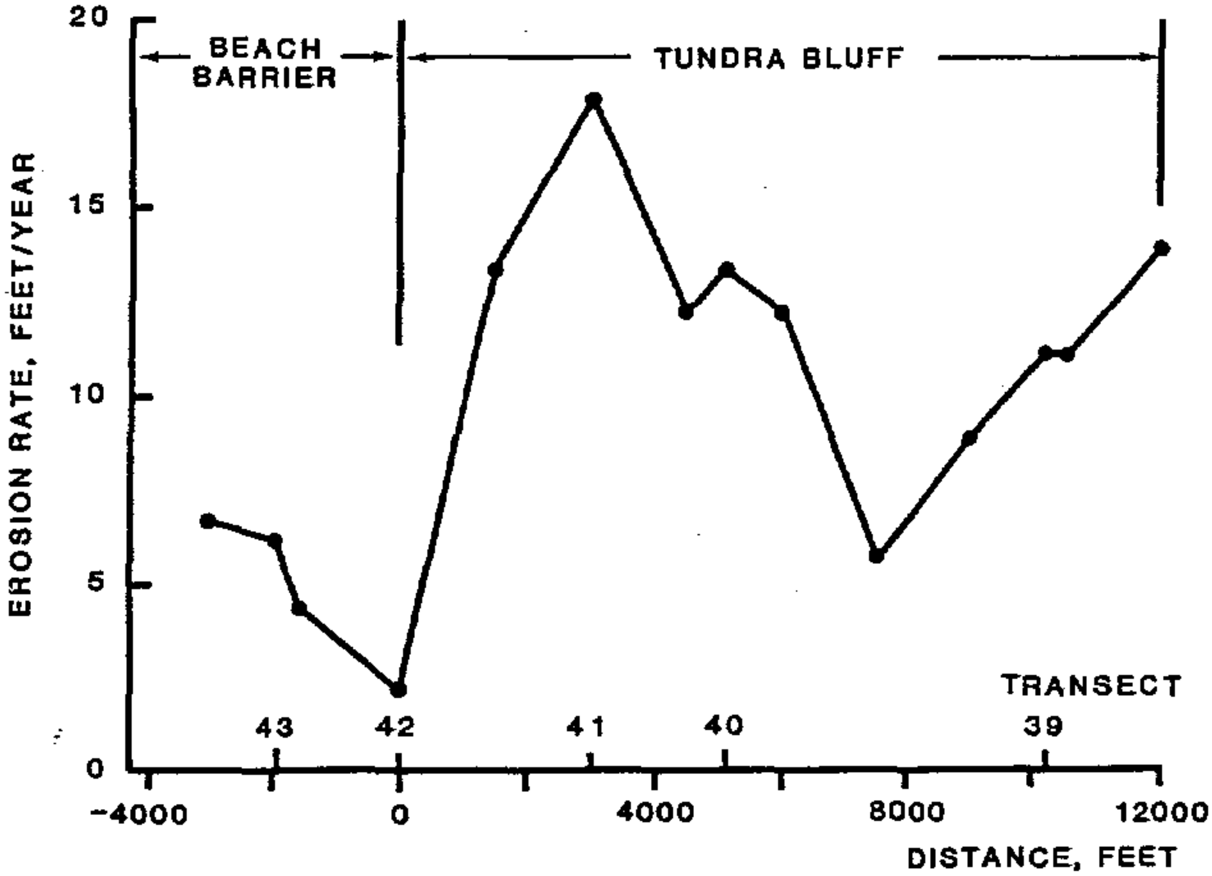


FIGURE 5.6 : FLAXMAN ISLAND EROSION, 1955–1982

position for the two surveys is shown. Erosion of the northern bluff has averaged 12 feet/year during the 32-year period of comparison, however, the magnitude of the erosion measured in any given year could vary considerably from this figure. The relatively higher erosion rates experienced on the bluffs are in contrast to the lower rates seen on the adjoining beaches to the west. Given the historical measurement of bluff retreat (Figure 5.6) and knowing bluff elevations as measured by the recent survey, an average annual eroded bluff volume of 70,000 cubic yards has been computed.

Because a large portion of the bluff that erodes is ice, or fine-grained silts and clays that do not remain in the beach zone, the gross eroded volume must be reduced to determine the volume of sands and gravels derived from the bluff that add to the downcoast beach volume. Estimating a total sand and gravel content of 20% for the eroding bluff material, the net volume is reduced to 15,000 cubic yards of beach sediments annually. By virtue of this sediment contribution, Flaxman Island can be considered to be a sacrificial source of beach material which maintains the barrier island chain located directly downdrift.

The on-going bluff erosion has greatly diminished the size of Flaxman Island over the past 150 years. Future erosion, if unchanged from the rates of the recent past, will lead to total breaching of the bluffed portion of the island within the next 100 to 200 years. As this source of barrier island sediments diminishes, the islands will diminish in size and volume. While this could be a slow process, the persistent ice and wave forces will lead invariably to reduction of barrier island size as the source of nourishment grows smaller.

5.2.2 Barrier Islands

Since 1955, the barrier islands have experienced a high degree of change in both shape and location. These islands show a degree of instability that, along with the Flaxman bluffs, yields the highest rates of coastal change in the study area. During the recent summer, erosion predominated along the shores of the barrier islands, as evidenced by the data presented in Table 5.5 and Figure 5.7. The changes associated with the positions of the southern shores are shown in Figure 5.7(A). Of the twenty-five island transects, ten experienced negligible movement of the southern shore. An equal number of the southern transects eroded (averaging -4.8 feet) while the remaining five transects experienced accretion to the south (average accretion = +5.3 feet). The average change of all of the southern transects was erosion of 0.9 feet.

The general trend of erosion identified on the south shore of the barrier islands intensified on the northern shore. This was expected due to the greater exposure to wave and ice forces on the north sides of the islands. Figure 5.7(B) shows that shoreline changes experienced on the north shores varied from nine feet of accretion to nearly 25 feet of erosion. At ten of the 25 north transects, erosion occurred (average loss = 11.0 feet), while at nine locations, northern shore accreted (average growth = +5.7 feet). At six sites, negligible change occurred. For all the northern transects, the average change was erosion of 2.4 feet.

TABLE 5.5 : BARRIER ISLAND SHORELINE CHANGES, 1982

SUMMARY OF SURVEY DATA - BARRIER ISLANDS

(ALL MEASUREMENTS EXPRESSED IN FEET)

TRANSECT	BEARING (Deg)	TRANSECT LENGTH		SOUTH WL TO MNT		MNT TO NORTH WL		ELEVATIONS		SHORELINE CHANGE AT JULY SWL DATUM	
		JULY	SEPT	JULY	SEPT	JULY	SEPT	ON MNT	SEPT SWL	SOUTH SHORELINE	NORTH SHORELINE
42	018.T	207	223	78	80	101	106	4.0	-.2	1.2 ACCRETION	3.4 ACCRETION
43	014.T	171	172	63	68	71	72	3.7	-.3	3.0 ACCRETION	.9 EROSION
44	033.T	261	296	59	60	05	85	2.8	-.2	.5 EROSION	1.6 EROSION
46	000.T	214	250	41	58	146	159	1.1	-.7	8.7 ACCRETION	4.8 ACCRETION
47	020.T	151	193	42	53	61	77	2.0	-.9	5.5 EROSION	8.3 ACCRETION
48	026.T	177	272	64	89	64	76	2.8	-1.0	3.5 EROSION	7.6 ACCRETION
49	000.T	687	723	375	384	281	292	3.9	-1.5	3.6 EROSION	9.6 EROSION
50	356.T	442	678	196	443	178	195	2.2	-1.3	4.2 EROSION	16.6 EROSION
51	358.T	474	523	322	342	110	135	2.7	-1.7	5.9 EROSION	9.0 ACCRETION
52	340.T	523	1409	225	1011	263	294	1.0	-1.9	.0 ACCRETION	5.1 EROSION
53	026.T	129	509	44	296	49	51	2.3	-.5	5.6 EROSION	2.6 EROSION
54	006.T	476	514	360	372	79	94	4.1	-1.7	1.2 EROSION	2.4 ACCRETION
55	020.T	191	334	96	179	55	69	2.7	-1.5	.4 ACCRETION	.1 EROSION
56	015.T	214	248	76	89	103	116	2.7	-1.5	.2 EROSION	.2 EROSION
57	000.T	171	194	68	78	69	86	5.7	-1.3	.3 ACCRETION	7.4 ACCRETION
58	000.T	317	336	137	147	138	150	5.2	-1.7	1.5 EROSION	.3 ACCRETION
59	340.T	388	424	205	217	127	150	2.4	-1.7	2.8 EROSION	8.0 EROSION
60	332.T	445	485	310	320	92	120	2.3	-1.7	2.0 EROSION	22.0 EROSION
61	040.T	92	236	21	97	32	55	1.7	-1.6	8.9 EROSION	5.5 EROSION
62	012.T	145	213	29	63	66	77	3.3	-1.7	1.4 ACCRETION	3.3 ACCRETION
63	015.T	141	289	61	90	52	68	3.3	-1.5	6.0 ACCRETION	4.7 ACCRETION
64	008.T	435	497	48	65	352	369	2.5	-1.5	4.5 ACCRETION	24.7 EROSION
65	012.T	273	455	132	162	92	186	4.2	-1.7	4.9 EROSION	5.0 EROSION
66	000.T	190	207	80	96	69	81	3.4	-1.5	4.3 ACCRETION	1.0 ACCRETION
67	008.T	252	477	42	245	152	171	2.7	-1.7	.2 EROSION	10.2 EROSION

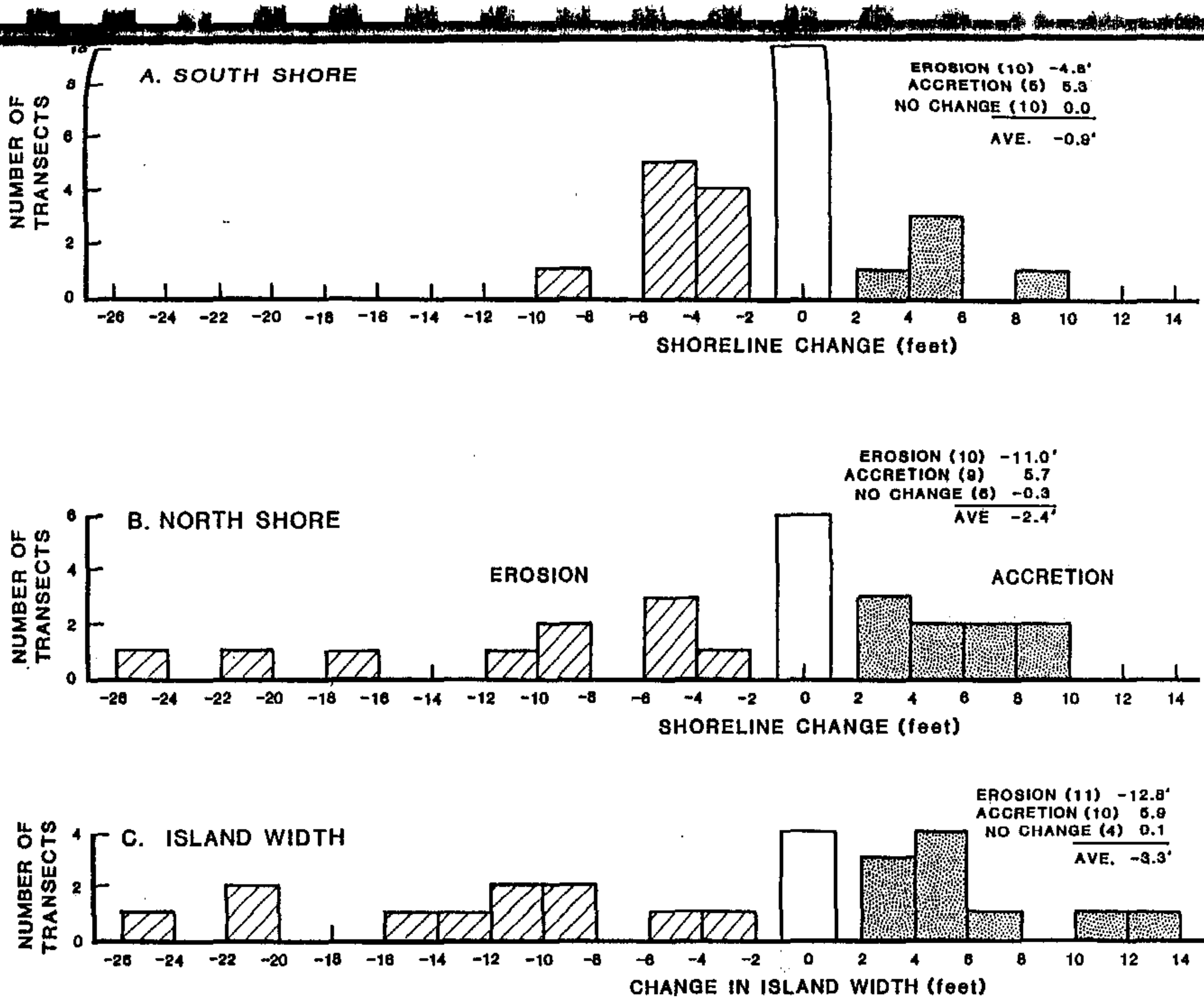


FIGURE 5.7 : SHORELINE CHANGE HISTOGRAM, BARRIER ISLANDS, 1982

Combining the results of the north and south shore changes, the total changes in island width at each transect can be presented in Figure 5.7(C). As one would expect from the data presented previously, the predominant trend during the recent survey period was one of diminishing island width. Only four of the twenty-five island transects experienced negligible change. Eleven experienced erosion (average loss in width = 12.8 feet) while ten transects increased in width (average gain = 5.9 feet). The average change in island width for all transects was erosion of 3.3 feet.

While it is difficult to attribute a great deal of significance to shoreline comparisons that span only a six week period, the high degree of shoreline fluctuation on the barrier islands as well as the general trend towards erosion is consistent with previous investigators (Wiseman, et al., 1973).

Figure 5.8 summarizes the recent changes in shoreline position associated with the entire barrier island chain under study, bounded by the east end of the Flaxman Island spit (Transect #42) and the west end of Alaska Island (Transect #67). On the northern shores, moderate accretion (4-10 feet) occurred at four distinct areas of the central portions of each of the island complexes. Erosion of large magnitude (15-25 feet) occurred near the center of Mary Sachs and Alaska Islands, and on the west end of Duchess Island.

Along the southern shore, less dramatic changes occurred. Erosion appears to dominate the south shore of Mary Sachs Island. On Duchess-North Star Island, virtually

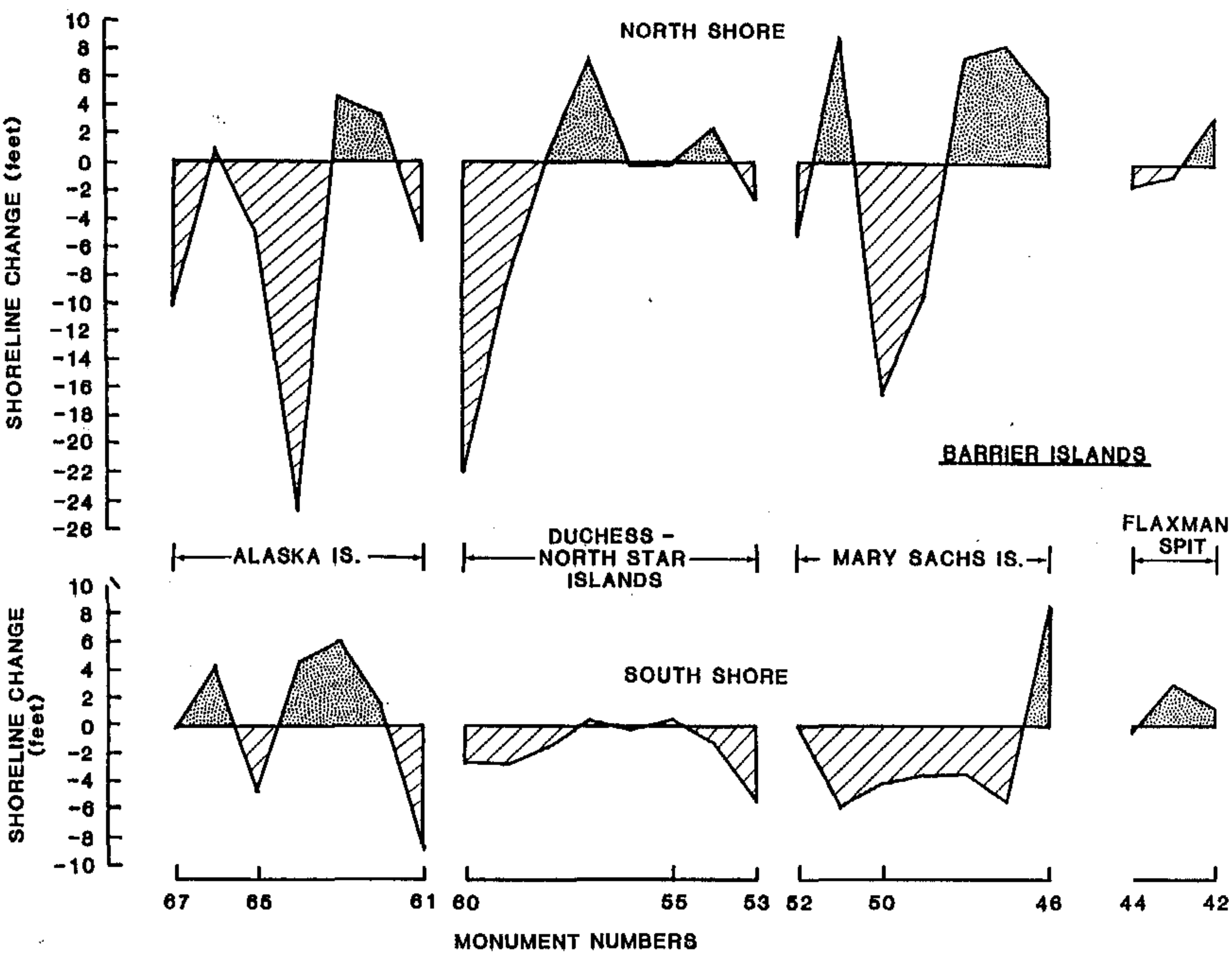


FIGURE 5.8 : BARRIER ISLAND SHORELINE CHANGES, 1982

no changes have occurred along the central island south shore. On Alaska Island, the south shore fluctuates between mild erosion and accretion.

It is significant to note in Figure 5.8 that the ends of islands adjacent to major inlets are showing a recent erosional trend. The trend towards island erosion at these inlets is caused by a number of factors which include high speed currents generated by tides and meteorological events and a high degree of wave-induced sediment transport. The sediments that migrate off the island end and into the inlets cannot be recovered in total when the wind and wave conditions reverse.

The very small inlet that has formed between Flaxman and Mary Sachs Islands has not caused erosion on the adjoining island ends (see Figure 5.8). This narrow, shallow feature is relatively protected and may be subject to predominant sediment deposition at the present time.

During the summer surveys, major changes were observed at several survey transects along the barrier island chain. Photo 13 shows a view of Monument #61, located just east of the Alaska Island exploration pad, at the time of the initial survey target on July 25, 1982. Following a strong westerly storm on the following day, the target was observed to be partially buried by sand that had been transported onto the target during the storm (Photo 14). At the time of the September survey, the target had been buried to an even greater extent, as shown in Photo 15, by a subsequent westerly storm event or events. The depth of total burial was about six inches, as shown in the plot of comparative surveys, Figure 5.9. During the July-September period, the sediment that buried the target was apparently derived from

PHOTO 13. TRANSECT #61, EAST END OF ALASKA ISLAND, JULY 25, 1982. SOHIO'S EXPLORATION PAD IS SEEN IN THE BACKGROUND

PHOTO 14. AERIAL VIEW SHOWING PARTIAL BURIAL OF TARGET AT TRANSECT #61 IMMEDIATELY FOLLOWING WESTERLY STORM OF JULY 26, 1982

PHOTO 15. TARGET BURIAL AT TRANSECT #61, SEPTEMBER 11, 1982

PHOTO 16. PARTIAL TARGET BURIAL CAUSED BY WESTERLY STORM EVENTS AT TRANSECT #53, EAST END OF NORTH STAR ISLAND, SEPTEMBER 11, 1982

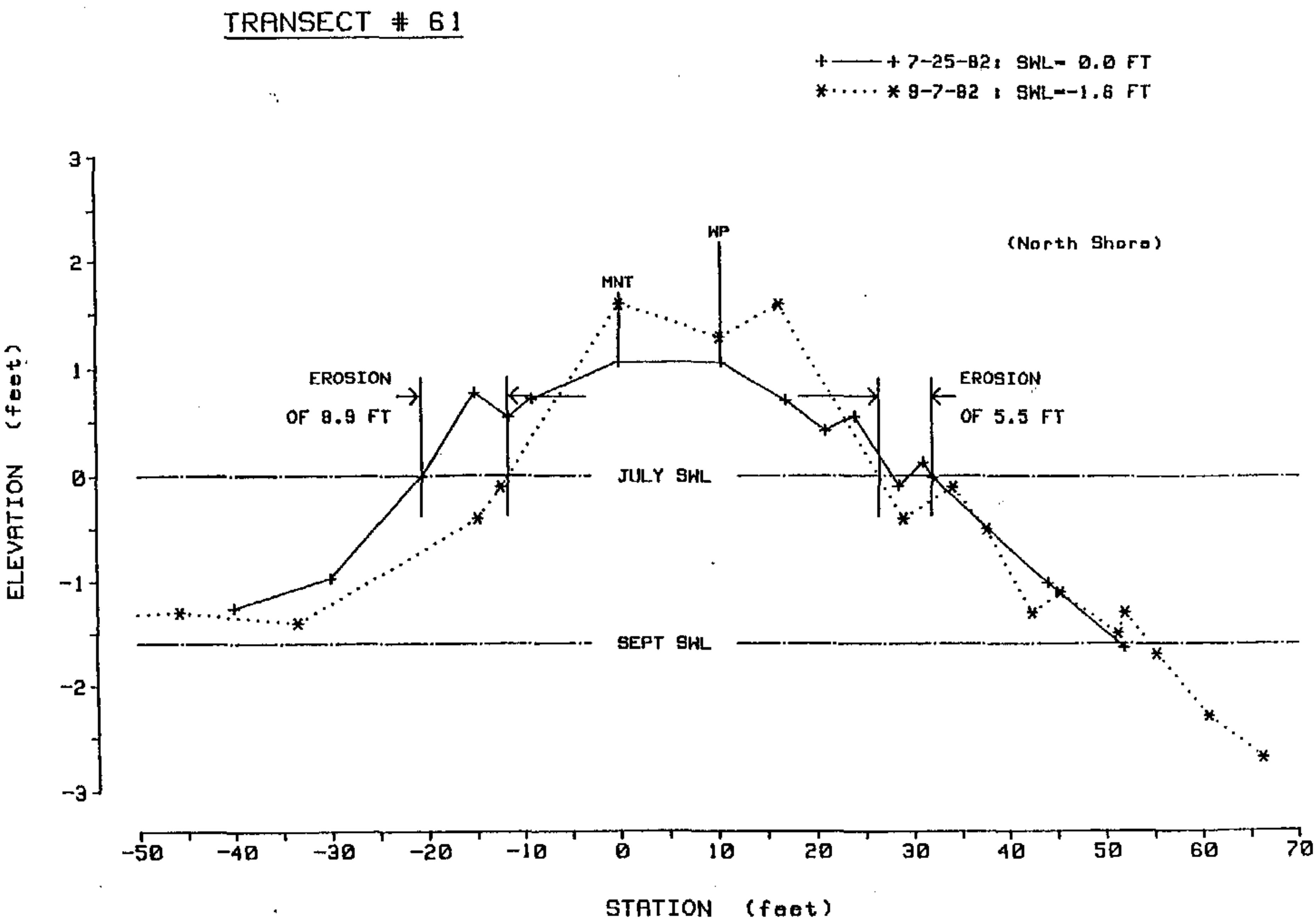


FIGURE 5.9 : BARRIER ISLAND EROSION AND DEPOSITION, TRANSECT #61

erosion of the southern shore. The deposition of the eroded sediment on the island surface occurred during periods of wind-induced storm surge caused by westerly storm events.

A similar depositional event occurred on North Star Island at Monument #53, as shown in Photo 16. A layer of sediment (10 inches thick) is seen to overlie the target at this location. These two cases of major sediment deposition atop the island surface occurred at sites of similar exposure to westerly storm events. Monument #61 is located on the southwest-facing shore of Alaska Island, while Monument #53 has the identical orientation on the east end of North Star Island.

5.3 Island Migration Trends

Changes in the overall form and location of the low-lying barrier islands are occurring constantly. The results of the 1982 survey allows the long-term comparison of island configuration within the Maguire group shown in Figure 5.10. The major observations of note are the changes of location and form of the various inlets, the dynamic nature that is evident at the island ends adjacent to these inlets, and the general westward movement of the islands.

In 1955, Flaxman Island and Mary Sachs Island were connected by a thin strip of sediment. Today, a narrow, shoal inlet exists, as illustrated in Photo 17. The very shallow nature of this inlet, in addition to the sediment accumulation that is active here (See Figure 5.8), indicates that this inlet may be in the process of filling, thereby connecting the two islands once again.

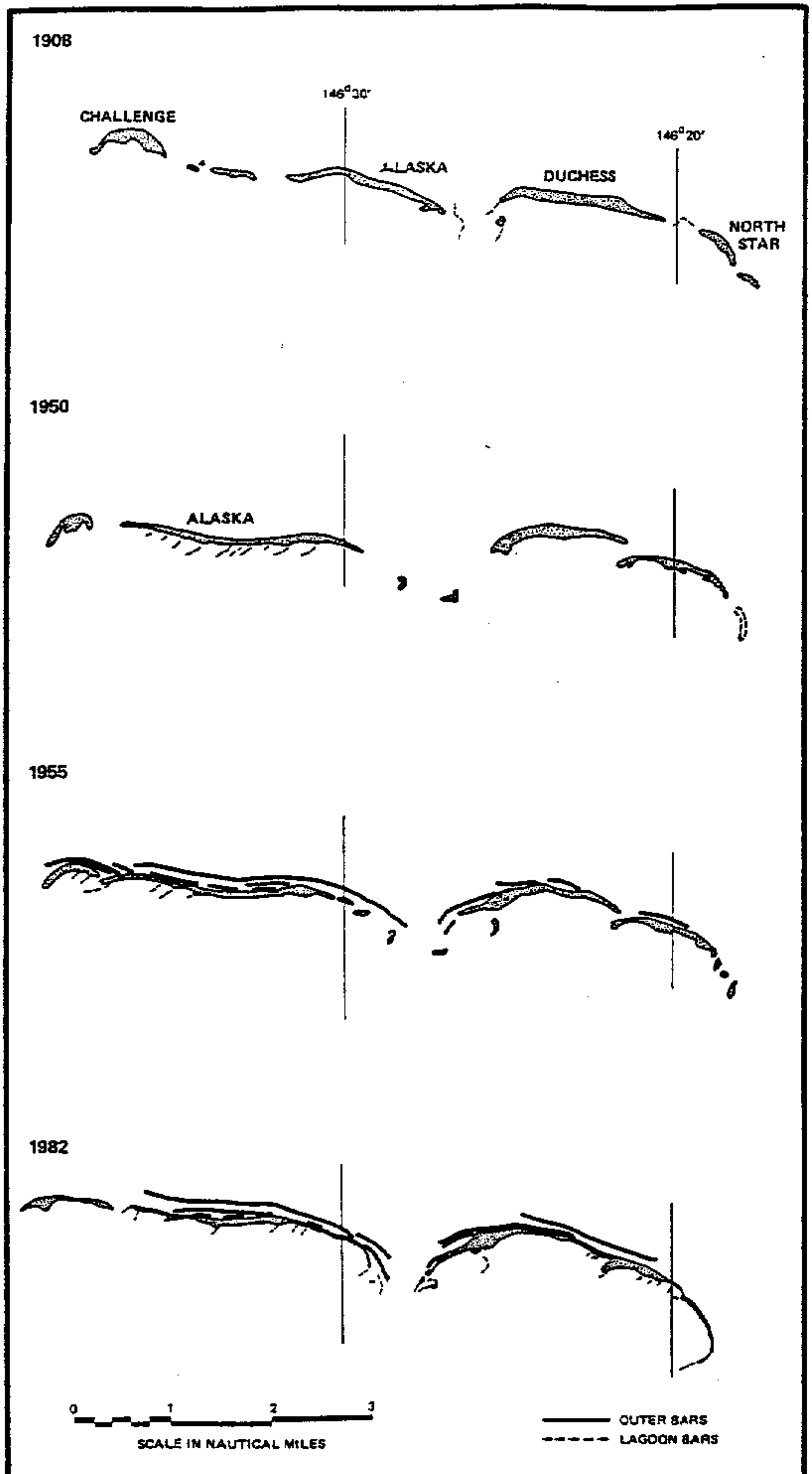


FIGURE 5.10 : MAGUIRE ISLAND MIGRATION, 1908–1982

PHOTO 17. OVERHEAD VIEW OF INLET RECENTLY FORMED BETWEEN FLAXMAN AND MARY SACHS ISLANDS. INLET IS 750 FEET WIDE AND TWO TO FOUR FEET DEEP

A major island breach existed in 1955 between North Star and Duchess Islands. On the NOAA chart, an inlet depth of seven feet was measured in 1950. At the present time, the inlet has been filled and a continuous island exists in this area, located just west of the North Star exploration pad. A photographic comparison has been achieved by presenting a 1982 survey photo and one collected by Dr. Andrew Short in 1972. In Photo 18, a view of the inlet between Duchess and North Star Island is shown in 1972. Breaking waves can be seen within the inlet. In July, 1982, Photo 19 was taken from approximately the same location showing a thin sediment strip that presently exists over the former inlet.

Also evident in these photos is the location of Exxon's North Star drilling pad relative to the site of the inlet, and the similar shape of the island shoreline in both 1972 and at the present. The recent filling of the inlet, documented in these photographs, is a process that is common to barrier island environments.

Figure 5.11 shows a conceptual view of inlet formation and filling. A large storm event can cause the initial breach formation which is followed by initial inlet deepening by tidal currents (Stage 1). With time, however, the persistent easterly wind and waves transport sediment in a westward direction, thereby reconnecting the two island segments with a thin strip of sand and gravel (Stage 2). As this sediment body continues to be nourished by the updrift sediment supply, the filling of the inlet proceeds (Stage 3). This total process can occur within a span of several years, as witnessed during the 1979-1981 period on No Name Island (Gadd, <u>et al</u>., 1982).

PHOTO 18. AERIAL VIEW OF INLET BETWEEN NORTH STAR AND DUCHESS ISLAND, AUGUST, 1972 (SOURCE: DR. ANDREW SHORT)

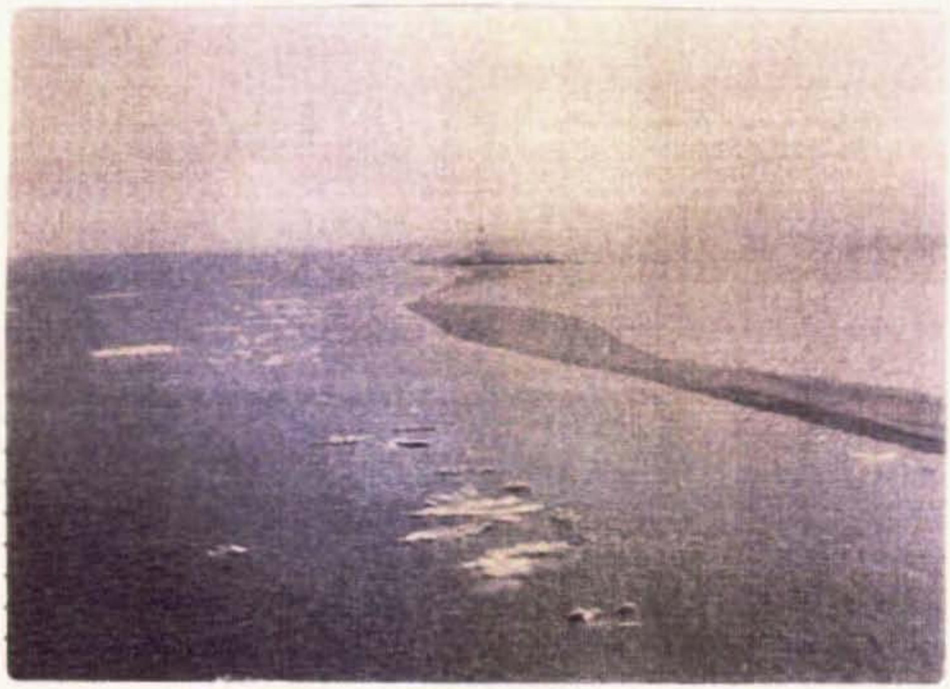


PHOTO 19. VIEW OF FILLED INLET THAT NOW CONNECTS DUCHESS AND NORTH STAR ISLANDS, JULY, 1982. EXXON'S NORTH STAR DRILLING PAD IS SEEN IN THE BACKGROUND

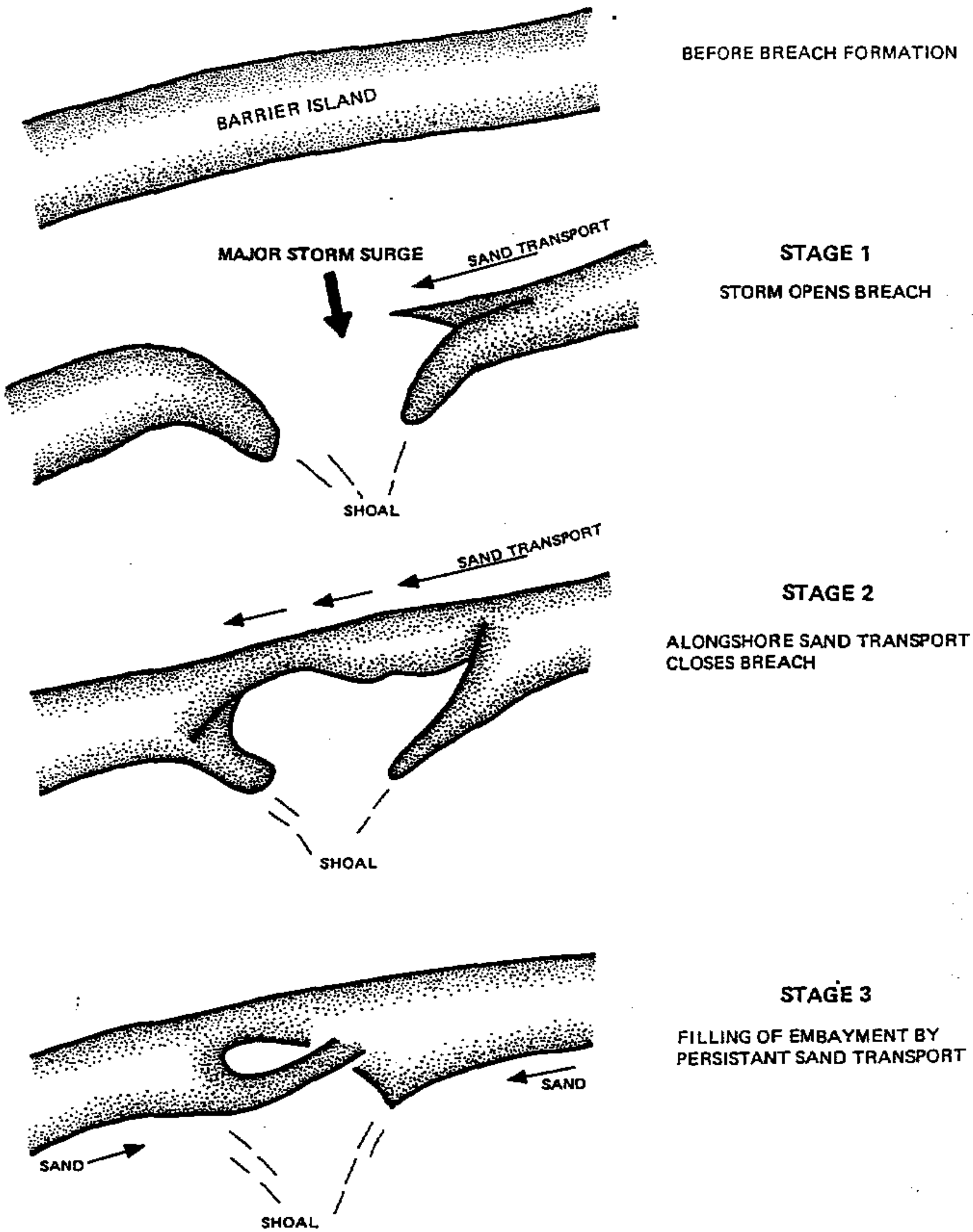


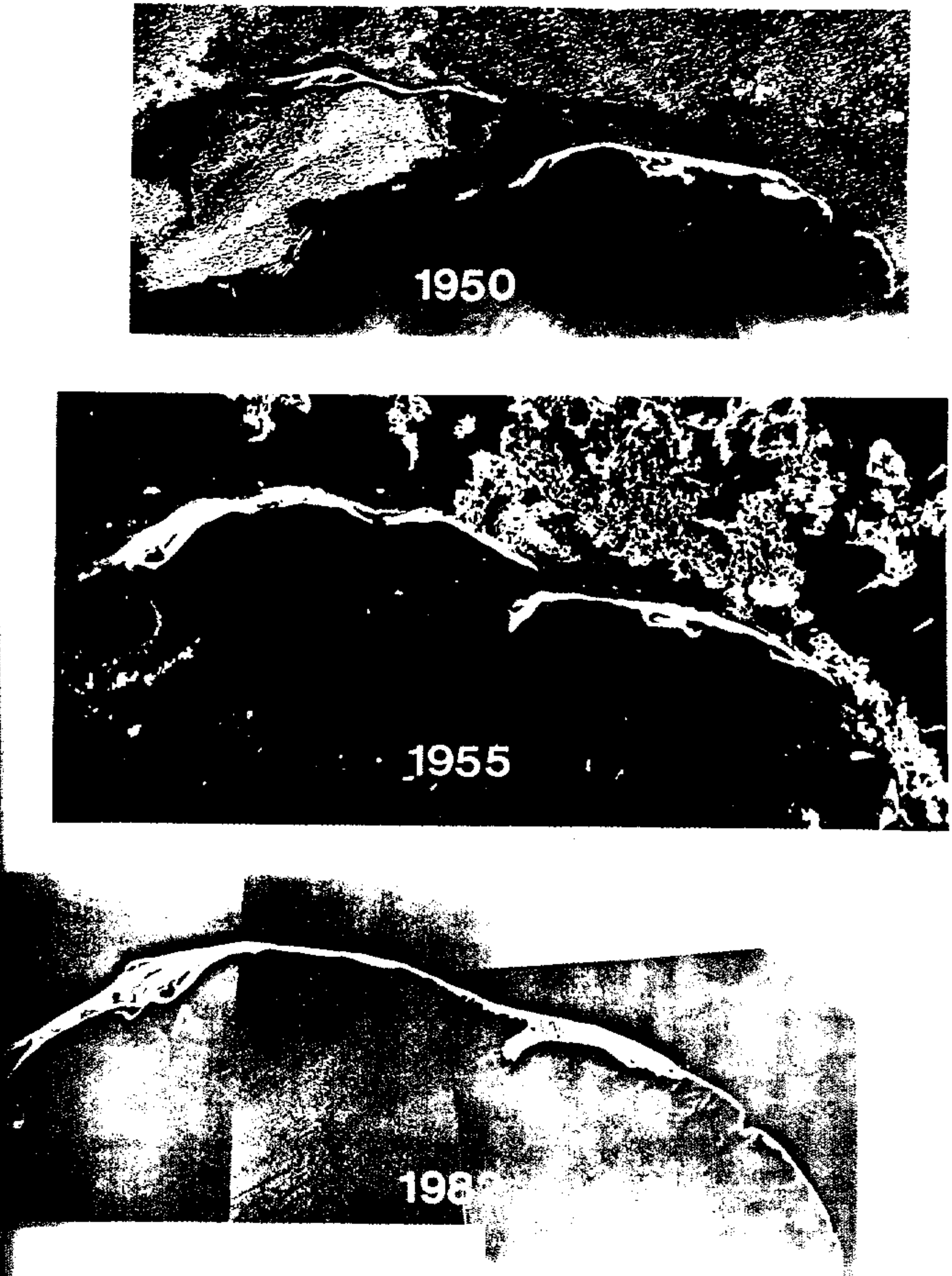
FIGURE 5.11 : BARRIER ISLAND INLET FORMATION

Another historical photo comparison is shown in Figure 5.12, illustrating the changes that have occurred at the Duchess-North Star complex since 1950. In the bottom photo, showing the present condition, three coastal features are noted. Feature "A" is a large lobe of sediment that was once the western end of Duchess Island, as seen in 1950. The growth of the sand spit towards the west in the past 32 years has advanced the west end of the island a total of 4500 feet, an average annual rate of 140 feet/year.

The second feature noted on the 1982 photo, designated "B", is the site of the former inlet that separated North Star and Duchess Islands. Exxon's North Star exploration pad is located just east of this location. Sand spits and striations are seen in the 1982 photo on the south side of the island at the former inlet location, implying that this area is still subject to wave overtopping during periods of high water levels. The comparative photos of the inlet (Photos 17 and 18) show that the inlet filled within the past 10 years, although it is seen in Figure 5.12 that the width of the inlet was continuously decreasing during the 1950-1955 period.

The feature designated "C" in the photo is a broad expanse of sediment that is now diminished from the size it exhibited in the 1950's. In the 1950 and 1955 photos, the intricate structure of this feature remained relatively unchanged, as did the structure of feature "A" during the 1950-1982 period.

Both of these features (A and C) are former western island ends which have been isolated from the active northern shore by continual sediment accretion and the resulting island widening at these locations. The continual



12 : PROGRESSIVE CHANGE OF DUCHESS-NORTH STAR ISLAND, 1950-1982

westward sediment transport which predominates here has elongated the island to the west, thereby preserving these features on the southern shores of the islands.

TABLE 5.6

PT. THOMSON PROJECT
ISLAND MIGRATION RATES, 1955-1982

ISLAND	WEST END	EAST END
Challenge	42 ft/year (west)	39 ft/year (east)
Alaska	68 ft/year (west)	90 ft/year (southeast)
Duchess	96 ft/year (southeast)	-----
North Star	-----	151 ft/year (south)
Mary Sachs	83 ft/year (southwest)	-----
AVERAGE:	72 ft/year	93 ft/year

The long-term rates of island migration between 1955 and 1982 have been measured and are presented in Table 5.6. The exact locations of the island ends were determined in July using the helicopter-borne electronic navigation system. These survey methods were described previously in Section 3.1 for the determination of the individual transect locations. The position of the island ends were reduced to latitude/longitude for direct comparison with the charted positions of 1955 which are documented on NOAA chart #16045. The average rate of westward island migration during this period was 72 feet/year which agrees very well with the data derived by Wiseman, et al., (1973) for the 1908-1955 period. The expected westerly island migration is noted on the ends of Challenge, Duchess and Mary Sachs Islands. Interestingly, eastward movement of sediment which caused migration of the eastward island ends at an average rate of 93 feet/year, was noted on North Star and Alaska Island. The growth observed on these eastern island ends over the past 30 years is due to infrequent westerly storm events and to sediment transport reversals induced by local wave refraction effects.

5.4 Sediment Characteristics

During the field investigation, sediment samples were collected at numerous transect sites. During the July field trip, 40 sediment samples were taken, while 67 samples (one at each transect location) were collected during the September field trip.

Initially, it was believed that a size distribution analysis should be performed to quantify the sediment characteristics at each transect location. Close examination in the field, however, showed a high degree of variability of beach sediments along each transect. Thus, the choice of a "typical" sediment sample, intended to represent the sediments at a particular location, was not possible. For this reason, laboratory analysis to determine the precise sediment size distribution has been judged to be a meaningless exercise.

To document the sediment samples, photographs were taken and a visual description was provided in written form. The descriptions are included in the Appendix to this report. The photos of each sample (in 35 mm slide form) and the sediment samples themselves have been forwarded to Exxon Company U.S.A., Production Department, Western Division, Los Angeles.

5.5 Predicted Coastal Changes

Based on the results of this study, general comments can be made concerning the future coastal changes that are expected during the next 50 years within the project study area. A summary of the anticipated changes is presented below for each of the major coastal environments in the Pt. Thomson region.

Mainland Shore: With the exception of the receding coastal bluffs, the mainland shore is expected to retain its relative long-term stability. While shoreline fluctuations have been noted in this area during the recent summer survey period, long-term comparisons show that the general trend is for mild coastal changes to occur.

Flaxman Island: The high rate of bluff recession (averaging 12 feet/year) along the northern shore of Flaxman Island is expected to continue. The on-going erosion along these bluffs has been noted by various observers dating back to the early 1800's. Based on bluff recession comparisons, it appears that the erosion measured this past summer is consistent with that determined for the 1950-1982 period. Assuming that the present bluff recession rate continues, the erosion of the main body of Flaxman Island will be complete within 100 to 200 years.

Barrier Islands: The barrier islands of the study area will continue to fluctuate in form and location in response to the environmental forces of this region. It is difficult to predict specific changes as these fragile sedimentary structures can undergo significant modification in response to very brief storm events. In general, one can expect continued westward migration of the islands at an average annual rate of 70-80 feet/year. Also, southward recession of the island's northern shore at a rate of from 3 -10 feet/year is expected to continue.

The inlets which exist along the barrier islands are highly dynamic. Small inlets can form during a major storm event and can proceed to widen in response to current flow and wave attack, or these inlets can be filled by persistent sediment transport processes. As a result, the ends of the islands adjacent to these inlet are also highly dynamic.

The eventual loss of Flaxman Island as the primary sediment source will lead, in the next few hundred years, to a dramatic reduction in barrier island size.

5.6 Island/Coastal Inundation Potential

The potential for coastal and island flooding to occur exists throughout the study area during westerly storm periods when water levels rise in response to winds and waves. The damage associated with such events is related to the magnitude of both the storm surge and the incoming waves.

Due to low elevations, particular areas of the study region are quite susceptible to flooding during such events. For all the surveyed transects, four categories (the mainland bluffs, the non-bluff mainland, the Flaxman Island bluff, and the barrier islands) have been chosen to represent the characteristic coastal elevations that exist within the study area. The average elevation associated with each category is listed in Table 5.7.

TABLE 5.7

COASTAL ELEVATIONS
PT. THOMSON STUDY AREA

CLASSIFICATION	NUMBER OF SURVEYED MONUMENTS	AVERAGE MAXIMUM TRANSECT ELEVATION	STANDARD DEVIATION
Mainland Bluffs	3	11.75 Ft	4.59 Ft
Non-Bluff Mainland Sites	35	3.85	1.14
Flaxman Bluffs	4	13.77	5.60
Barrier Islands	25	2.79	0.88

It is apparent that the high bluffs on Flaxman Island and at several mainland locations offer the only protection from flooding within the study area. The low-lying mainland coast (mean elevation < 4') and the barrier islands (mean elevation < 3') are subject to flooding during even moderate storm surge episodes.

The expected storm surge potential in the study area cannot be easily identified without conducting an extreme event analysis incorporating weather hindcasting and numerical modeling techniques. Some insight can be gained, however, by studying the elevations of driftwood debris lines that exist in the Pt. Thomson area. Distinct debris lines were noted at 10 locations on the mainland shore that appear to represent the historical high water elevation (see Figure 4.6). Two of the debris lines were surveyed during the course of this study (near Monuments #19 and #22). The results of the surveys are presented in Table 5.8.

TABLE 5.8

DEBRIS LINE SURVEY

Transect	Distance Inshore	Debris Elevation*	Draft Of Debris	Total Storm Surge Elevation
19	270'	4.19'	1'	5.19'
22	360	5.01	1'	6.01'

*Relative to waterline of July survey.

Based on the storm surge investigation conducted by Reimnitz and Maurer (1978), it is believed that these debris lines were deposited at their present locations during a severe storm in 1970 which was judged to produce the most severe storm surge conditions in the Beaufort Sea during the past 100 years. A more thorough investigation of extreme water level elevations can be undertaken through numerical modeling methods to gain more site-specific information in other areas of interest within the study region.

Exxon is currently a participant in a numerical modeling study of oceanographic conditions along the entire Beaufort Sea coast which is being conducted by Oceanweather, Inc., of White Plains, New York. This model, which uses historical weather hindcasting techniques, will determine extreme wave height and storm surge predictions over a coarse grid for the entire area. The grid scale can be reduced to determine ocean conditions at specific sites within the Pt. Thomson study region (V. Cardone, Oceanweather, Inc., personal communication).

6. ENGINEERING ASSESSMENT

6.1 Existing Facilities

Various exploration facilities have previously been constructed within the Pt. Thomson project area. A number of these were inspected during the course of the field work in the belief that knowledge of the performance of these structures will benefit future design efforts. The coastal structures that were most closely studied are listed in Table 6.1.

TABLE 6.1. PT. THOMSON AREA EXPLORATION FACILITIES

Structure	Location	Date of Construction
Pt. Thomson Pad, Well #3	Mainland Shore, Base of Pt. Thomson	1978
Flaxman Island Pad	West End, Mary Sachs Island	Winter, 1980-81
North Star Pad	Central Portion, North Star-Duchess Island Complex	Winter, 1980-81
Alaska Island Pad	East End, Alaska Island	Winter, 1980-81

A brief description of each of these structure follows with specific reference to the slope protection systems used for each design.

- Pt. Thomson Pad #3: This elevated drilling site, constructed of gravel on a plateau near the base of Pt. Thomson, served as the survey team base camp during the July field trip. Constructed in 1978, it is one of four pads of similar design which exist along the mainland shore of the study area. An aerial photo depicting the general dimensions (825' x 800') and layout of the drilling facility is presented in Photo 20. The gravel pad was built to an elevation of about 10 feet above sea level with a portion of the total elevation provided by the slight plateau that exists in the natural terrain at this location. The pad slopes are unarmored and the work surface appears to lie well above the level of expected storm surge.

  This site is fronted by a stable natural beach. In Leffingwell's early map (1910-1914), the sand spit and the small islet in the interior lagoon shown above the pad in the photo have similar configurations to the present.

- Flaxman Island Pad: This facility is a steel sheet-pile enclosed structure which was constructed by Exxon during the winter of 1980-81. The "Flaxman Island" designation is actually a misnomer, as the pad is located on the wide, flat western extremity of Mary Sachs Island. The width of the island at this location allows the sheetpile structure to be contained completely upon the island surface, as shown in Photo 21.

The steel perimeter has been designed to withstand both wave and ice impact (Galloway, et al., 1982). The sheet pile has been driven to a depth of 20 feet below the natural island surface and the enclosed interior has been backfilled to raise the work surface to an elevation of 7 feet above the island. The top of the sheet pile enclosure lies 14 feet above the island surface in order to reduce the rate of wave overtopping during major storm events. The pad dimensions measure approximately 350 feet by 450 feet.

As seen in the photo, the northern side of the pad lies quite close to the shoreline. Inspection of the northern sheet pile wall showed that previous wave impact had not damaged the wall or eroded the foundation of the sheet pile. Photo 22 shows a view of the northern wall of the drilling pad.

- North Star Island Pad: This structure, constructed by Exxon during the winter of 1980-81, is situated on a wide section of the North Star-Duchess Island complex. The pad lies just east of the location of the former inlet that was mapped between Duchess and North Star Island in 1955. At this time, the inlet is closed thereby merging the former separate islands into one continuous body.

The design of this sheet pile enclosed drilling pad is identical to that described previously for the

PHOTO 20. PT. THOMSON DRILLING PAD, MAINLAND SHORE

PHOTO 21. FLAXMAN ISLAND DRILLING PAD, MARY SACHS ISLAND

PHOTO 22. SHEET PILE WALL ON THE NORTH SIDE OF FLAXMAN ISLAND DRILLING PAD SHOWING THE CLOSE PROXIMITY OF THE WATERLINE

PHOTO 23. AERIAL VIEW OF THE NORTH STAR DRILLING PAD

Flaxman pad, however, the North Star pad has a broad (120' wide) beach separating it from the northern shoreline, as shown in Photo 23. This set-back from the active shoreline allows wave and ice energy dissipation across the beach and protects the structure from the on-going beach fluctuations that are characteristic of the natural barrier island environment.

o <u>Alaska Island Pad:</u> During the winter of 1980-1981, Sohio constructed an elevated drilling pad on the narrow eastern end of Alaska Island. The pad dimensions are approximately 300 feet by 750 feet with a work surface elevation of seven feet above sea level.

The Alaska Island pad is characteristically different from the sheet pile enclosures mentioned previously. The major differences are, as follows:

1) The entire pad is not contained on the narrow island surface. The south side of the pad projects into the lagoon a distance of 225 feet. Photo 24 shows the general configuration of this drilling facility.

2) The location of the pad is on the very eastern end of the island, in close proximity to the channel separating Alaska and Duchess Islands. The general condition of easterly wind and wave persistance and the resulting westerly island migration implies that this is a tenuous position for

a drilling facility if a long design life is contemplated. Photo 25 shows a high elevation aerial view which indicates the pad position relative to the inlet. Duchess Island and the North Star drilling pad are shown in the upper right corner of the photo.

3) The slope protection that completely surrounds the Alaska Island pad is composed of high strength fabric bags filled with two cubic yards of gravel overlying fabric filter cloth. The approximate weight of the individual bags is 3.2 tons. The slope protection was placed during the summer of 1981.

In order to allow the expected dynamic shoreline changes to progress without affecting the drilling pad, the base of the pad was setback a distance of 50 feet from the waterline. This decision resulted in the further incursion of the pad into the lagoon, however, avoidance of immediate wave/ice impact was considered to be a high priority.

A number of innovative slope protection concepts were tested at the Alaska Island drilling pad (Leidersdorf, et al., 1982). Photo 26 shows the following slope protection elements:

1) Concrete wedges, termed "tank traps", placed at the north waterline of the island to inhibit the onshore movement of incoming ice sheets (Vaudrey and Potter, 1981).

PHOTO 24. AERIAL VIEW, ALASKA ISLAND DRILLING PAD. NOTE DISTANCE TO WHICH SOUTHERN PORTION OF PAD EXTENDS INTO THE LAGOON

PHOTO 25. AERIAL VIEW SHOWING ALASKA ISLAND AND NORTH STAR ISLAND PADS.

2) A recurved, modular concrete seawall placed along 100 feet of the work surface perimeter.

3) An articulated, linked concrete mat placed as toe protection along the front of one-half of the seawall length. The mat consists of 4'x 4'x 0.5' concrete slabs (slab weight = 1200#) linked together by heavy steel cable. The mat is underlain by filter cloth.

The slope of the Alaska Island pad has sustained virtually no damage since its construction. A limited amount of scour along the base of the northern slope is evident at several locations, however, this is due to wave impact during relatively rare storm events.

- o <u>Coastal Transportation Routes:</u> In addition to the man-made engineering facilities within the study area, it is worthwhile to mention that the natural gravel beaches that exist along both the mainland shore and the barrier islands support vehicular travel during the winter and summer months. In Photo 27, taken near Transect #16, recent wide-wheel (rollagon) tracks can be seen atop the thin, narrow gravel beach. Thus, the gravel beaches of the study area may be considered to be viable transportation routes throughout the region.

PHOTO 26. INNOVATIVE SLOPE PROTECTION SYSTEMS ON ALASKA ISLAND DRILLING PAD.

PHOTO 27. ROLLAGON TRACKS ON THE SURFACE OF THE MAINLAND COAST ILLUSTRATE THE UTILITY OF NATURAL CHENIER BEACH AS TRANSPORTATION ROUTE

6.2 Engineering Implications of Coastal Processes

The coastal processes that are active in the Arctic environment will play a role in the engineering design solutions that will be developed to support oil development within the Pt. Thomson area. Failure to properly respect the existing environmental conditions will cause high expenditures for over-design or for costly and persistent maintenance activities. A major goal of this study is to identify these processes and to provide engineering guidance which will allow more complete design solutions to be developed in the future.

The various coastal processes that exist along the Arctic coast have been identified by Short (1973). A relationship has been developed between the frequency of coastal events and the volume of coastal sediments that these events displace, as shown in Figure 6.1. Based on this data, a relationship exists between the period of time over which the various morphological changes take place (beach response, bar migration, storm-induced sediment movement, inlet migration, island erosion and migration) and the associated movement of sediment per unit time. It is seen that the longer the period of morphological response, the greater the volume of sediment movement and the larger the forms involved. While the data used to develop this relationship was collected at locations substantially west of the Pt. Thomson area (Pingok Island, Barrow, Pt. Lay), the general conclusions are believed to be representative of the entire Arctic coast.

This information identifies the coastal events which will affect future structures to include minor storm events that may occur frequently during a typical summer season,

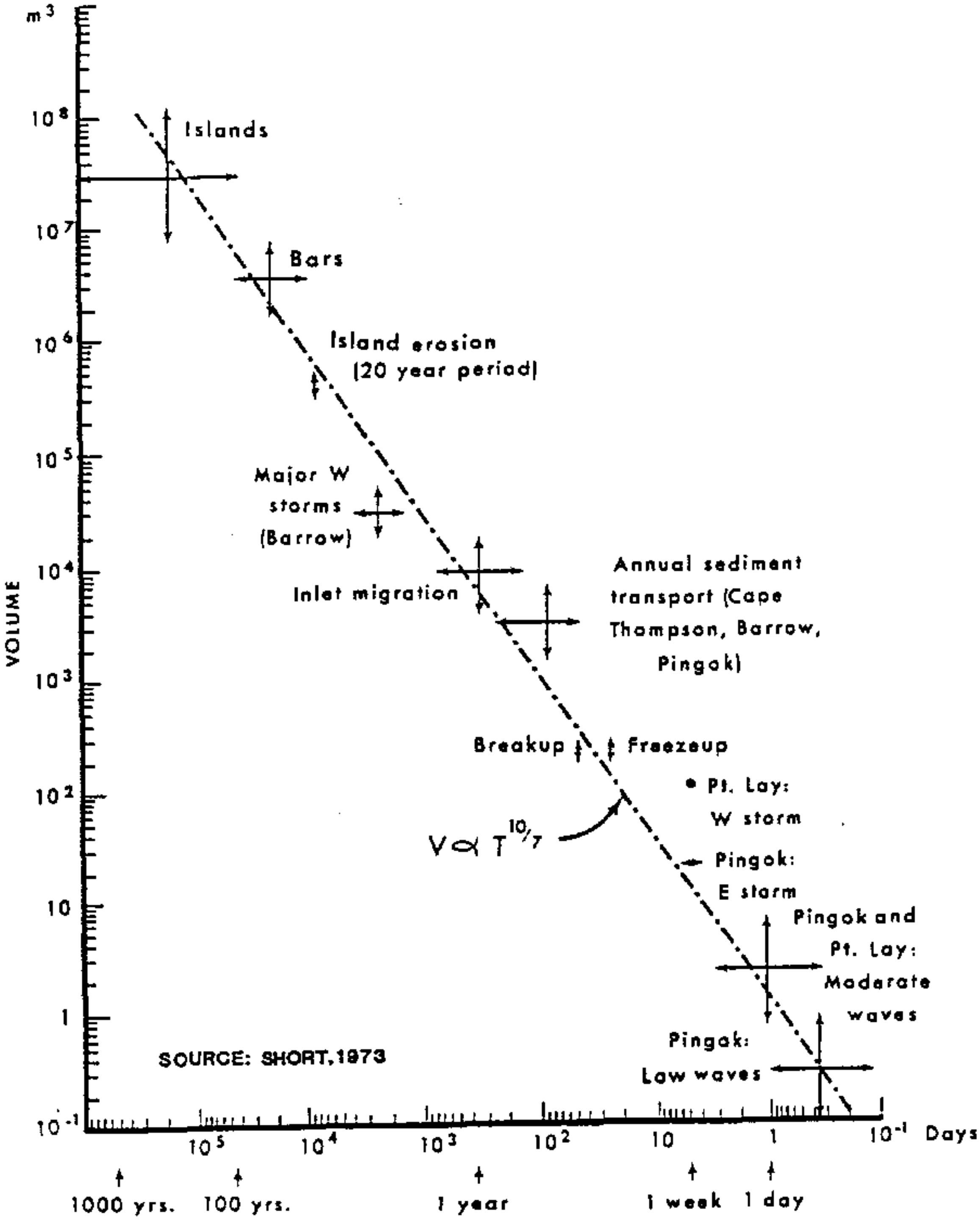


FIGURE 6.1 : RELATIONSHIP BETWEEN PERIOD OF MORPHOLOGICAL RESPONSE AND VOLUME OF TRANSPORTED SEDIMENT

the long-term shore erosion associated with persistent storm wave occurrences, and the dramatic coastal changes associated with rare storm events of extreme magnitude.

Given this general background, the major coastal processes or events which will have an impact on future facilities design in the Pt. Thomson area are described below.

o Coastal Erosion

Erosion of the mainland coast and the offshore islands is active at various locations within the study area. If possible, this on-going erosion should not be controlled. This natural process produces sand and gravel beach material which will protect the adjacent coastline. If this supply is diminished through artificial means (i.e. coastal bluff/beach protection), erosion is expected to occur on the adjacent shores due to the deprivation of the normal, natural sediment supply. Thus, it is recommended that appropriate "set-back" distances be respected so that new facilities will be sited at a safe distance from the eroding bluff or shoreline. This strategy allows the natural erosion to proceed unimpeded without threatening the coastal facility during its design life.

The appropriate set-back distance should be determined at a specific location based on the erosion rates measured in the vicinity. It is important to note that an average long-term rate of erosion should not simply be extrapolated to the future condition because long-term rates tend to diminish the ultimate importance of the catastrophic short-term storm events. For example, a long-term erosion rate developed by chart comparisons spanning a thirty year period may show an average value of five feet/year. Within this period, however, severe storm events of major consequence may have occurred separated by years of quiesence. It is conceivable that a location having a long-term erosion rate of 5 feet/year is capable of recording a single year in which 25 feet of erosion occurs. To support this contention, Sonu, et al. (1977) report that short-term erosion rates may exceed long-term rates by a factor of from three to five along the western bluffed coast of Lake Michigan.

In Section 6.3 of this report, general recommendations for proper "set-back" distances are given for various areas of the study region. As future development plans become more specific, the coastal data base should be expanded to yield information for localized areas of interest. This would require use of the data contained in this survey as well as the development of site-specific data (through the establishment of additional monumented profiles) for areas of concern.

o Island Erosion/Migration

The provisions for coastal "set-back" guidelines should be followed on the offshore islands as previously described for the mainland shore. Unlike the bluff coast, however, the low-lying barrier islands can both erode and accrete in response to the fluctuations of sediment supply and the environmental forces of waves, currents, wind and ice.

As stated previously, the persistent easterly winds cause the predominant sediment transport to be directed westward. This causes island erosion to occur on the eastern shore and allows sediment deposition (and the resulting island growth) on the western shores. Based on this generalization, future siting of facilities could be judged to be proper on the accreting western island shores. Facilities should not be constructed on the eroding eastern extremities of the islands. While recent experience at the Alaska Island pad has shown the short-term stability of this site, locations such as this should not be considered appropriate for long-term production facilities. As specified in Section 6.3, the extreme ends of the islands are to be avoided as construction sites, if possible, due to the dynamic nature of both the island periphery and the adjacent inlets.

One factor that contributes a measure of stability to an island location and protection to a coastal structure is the existence of longshore sand bars. Such bars, which are prevalent along the shores of Mary Sachs Island and the Maguire Island chain cause the natural dissipation of incoming ice and wave energy. In Figure 6.2, the role of the nearshore bars is illustrated. During open-water periods, the shallow offshore bars precipitate wave breakage within the surf zone, as shown in Photo 28, thereby causing wave energy to be partially expended prior to arriving at the shore. During colder weather periods, floating ice will ground on the bars as was commonly seen during the September field trip, as shown in Photo 29. The resulting ice barrier will both decrease wave energy prior to freeze-up and, following freeze-up, the grounded ice will serve to stabilize the nearshore ice sheet and inhibit ice over-ride on the island surface. An accurate knowledge of the offshore bar locations should be used to assist in siting island facilities. These bars should be recognized for the natural shore protection that they provide the islands.

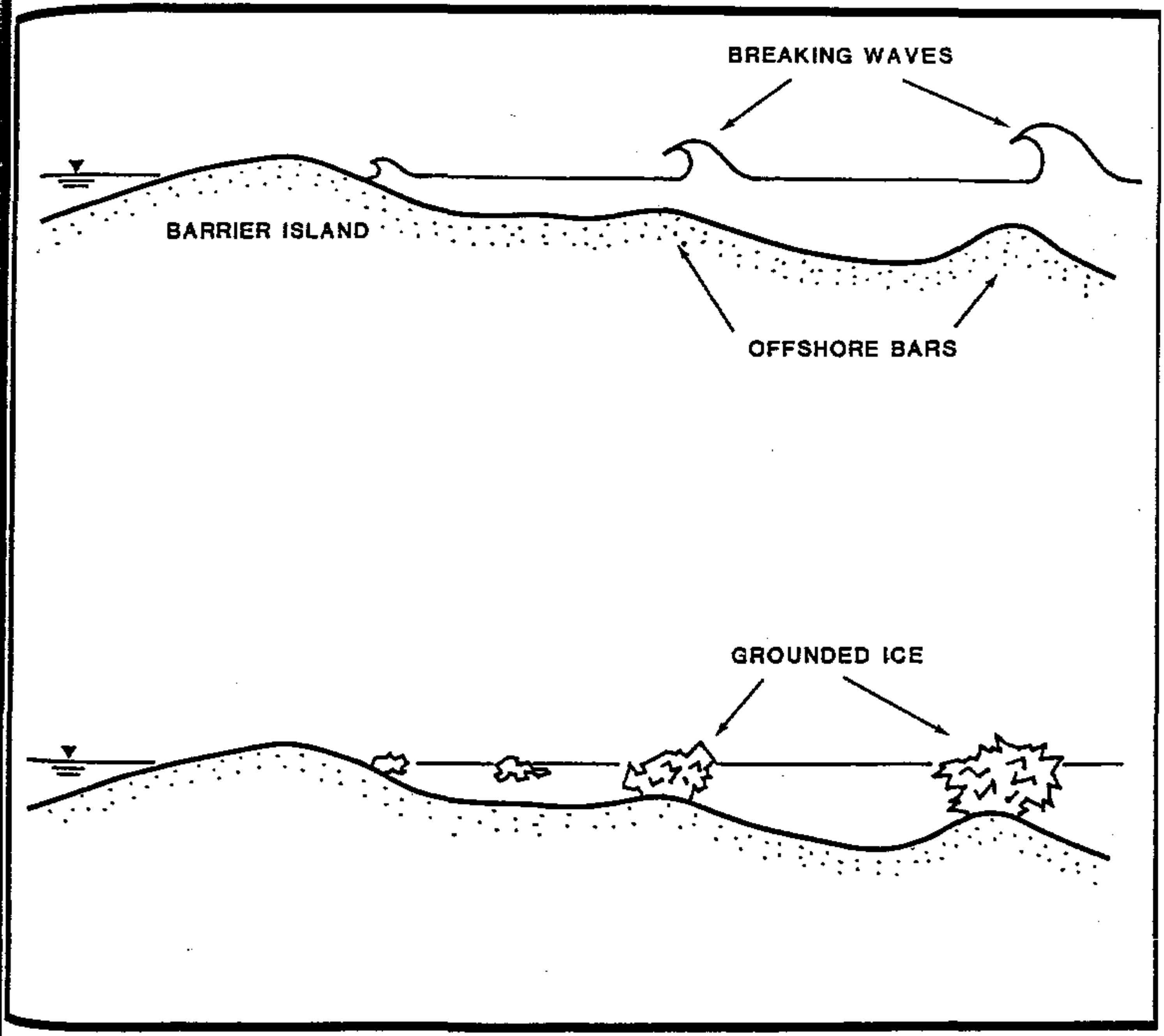


FIGURE 6.2 : INFLUENCE OF LONGSHORE BARS ON WAVE AND ICE IMPACT

PHOTO 28. WAVES BREAKING ON LONGSHORE BARS FRONTING BARRIER ISLAND

PHOTO 29. GROUNDED ICE FRAGMENTS CLEARLY SHOW THE POSITION OF OFFSHORE SAND BARS

o Littoral Drift

As waves break at an oblique angle to the beach, a component of the wave energy is directed downcoast. This energy produces a shore parallel current that can entrain sediment and carry it along the beach. If a barrier is placed perpendicular to the beach for any reason, the sediment moving along the coast will be trapped by the barrier. This "impounded" sediment will not be available to nourish the downdrift shore, causing erosion to occur downcoast.

An example of sediment impoundment and downdrift erosion is shown in Figure 6.3 which illustrates a field experiment performed during the July field trip. In this experiment, a short length of driftwood was placed perpendicular to shore at Transect #27, located on a long, narrow gravel spit (see Photo 3). Wave conditions during this period were quite mild (wave height = 0.8', wave period = 3 sec). Within an hour, the west (updrift) side of the barrier had trapped sediment while the east (downdrift) shore had eroded. A photo of this driftwood barrier and the adjacent pattern of accretion and erosion is presented in Photo 30.

Based on the results of this experiment, it was calculated that the rate of littoral drift at this location during this calm weather period was 3 cubic yards/day. While this seems like a small volume, it is equivalent to the cross-sectional volume per lineal foot of shore contained within the above-water profile at Station 27. This volume extrapolated to an annual basis yields a sediment transport rate of about 1000 cy/year if these wave conditions persisted. Using methods prescribed by the U.S. Army Corps of Engineers (1977), the identical wave conditions would yield a sediment transport rate which would exceed

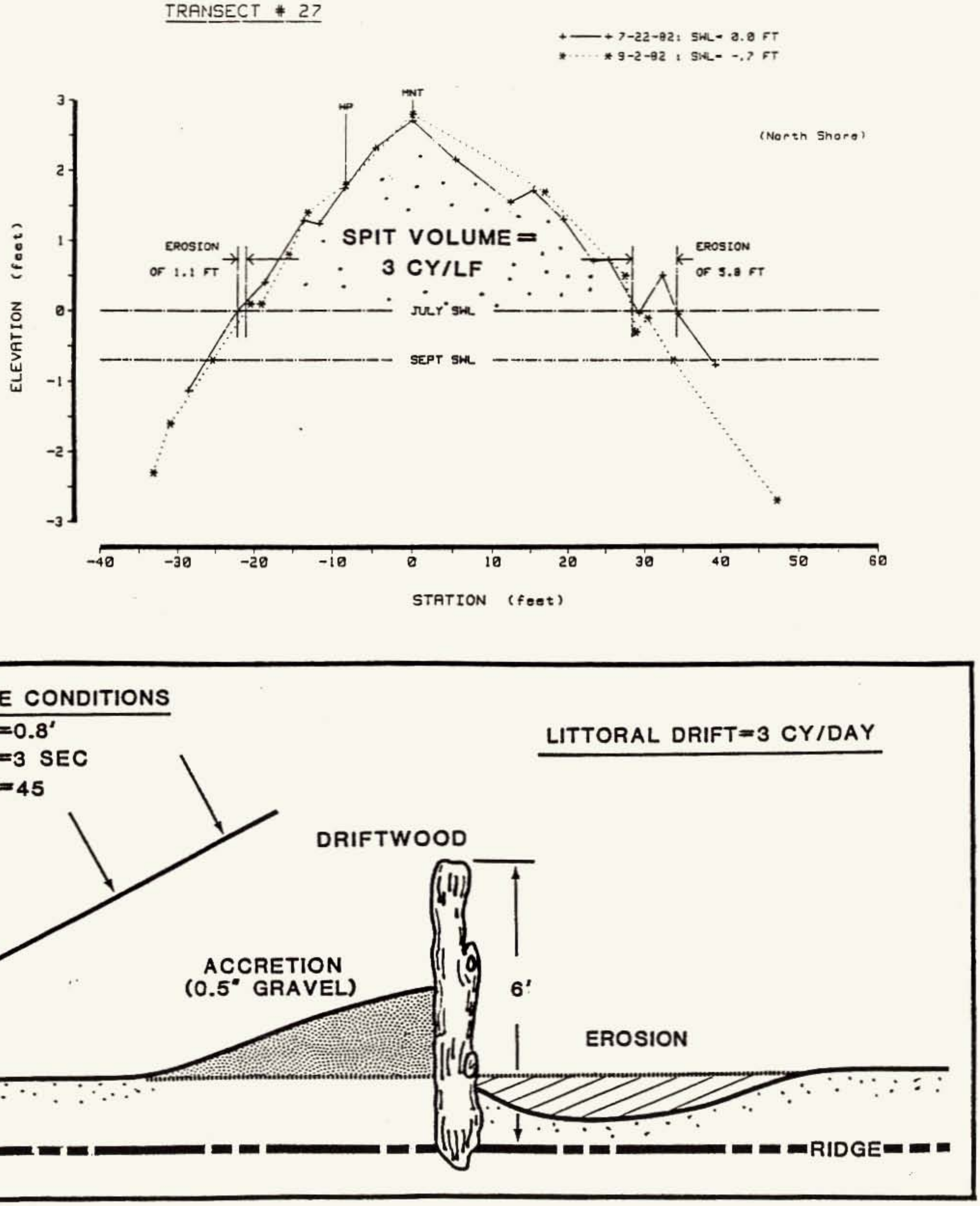


FIGURE 6.3 : LITTORAL DRIFT EXPERIMENT , TRANSECT #27

PHOTO 30. SEDIMENT BLOCKAGE AT BARRIER AFTER ONE HOUR, LOCATED ON GRAVEL SPIT NEAR TRANSECT #27

that measured in this experiment by two orders of magnitude (~100,000 cy/year). The discrepancy that exists is due to the blockage of only a portion of the total sediment movement by the groin and the unusually large size of the beach sediments (1/2 - 1") relative to the sand-sized material considered in the Shore Protection Manual.

It is clear that large-scale sediment blockage created by a causeway or other man-made projection extending from shore would have a dramatic effect on the nearshore sediment distribution. Loss of the protective beach material (caused by coastal structure impoundment) would led to an increase of coastal erosion relative to that which was measured recently under natural conditions.

6.3 Engineering Design Recommendations

Based on the inspection of the existing facilities within the study area, as well as the findings of this study, recommendations can be made concerning general design guidelines that can be implemented for future coastal structures in the Pt. Thomson region.

o Coastal Set-Back

The survey results show that beach and bluff recession are occurring along the coastline and island shores of the study area. The long-term trend for the bluffed coast is one of erosion as shown by long-term as well as short-term comparisons.

Unlike bluffs (which in this environment can only erode), the beaches of the study area can both erode and accrete in response to the incoming wave and ice forces and the fluctuations in the sediment sources and sinks.

One must remember that the precise measurements of beach profile and shoreline position collected in 1982 are only considered to be representative for the recent summer. It is conceivable that the results obtained may be somewhat anomalous, since the close proximity of the nearshore ice field during the survey period may be atypical of the expected summer conditions within this area. Future surveying efforts and continued monitoring of summertime ice and weather conditions are required to discern the degree to which the recent summer exhibited "typical" conditions.

To protect structures against the insidious damage caused by beach and bluff erosion, coastal structures must be set back from the existing shore some distance in order to allow expected erosion to occur without threatening the structure. If this is not possible, erosion prevention measures should be implemented. The distance of this coastal set-back is derived from the design life of the structure, the local erosion rate (both long-term and short-term), and the composition of the bluff or shore. It is very important to inspect local conditions in the vicinity of proposed development in order to avoid areas showing evidence of incipient slope erosion.

To provide some guidance for future facilities planners and designers, information concerning coastal set-back recommendations along the shores of the study area is presented in Table 6.2.

Please note that the set-back recommendations are based on certain historical (long-term) data, and the results of the coastal surveying tasks performed this summer (short-

TABLE 6.2

COASTAL SET-BACK RECOMMENDATIONS
PT. THOMSON STUDY AREA

Area	COASTAL SET-BACK	
	Exploration Structure (3 Year Life)	Production Structure (25 Year Design Life)
Mainland Bluffs	50* Ft	200 Ft
Low Mainland Coast	50*	200
Flaxman Island Bluff	100*	300
Barrier Islands	50*	250

*Exact facility location should be carefully chosen based on localized conditions.

term data). The potential for an episodic storm event combined with the general high value of oil production facilities yields a conservative set-back requirement.

As was mentioned in Section 6.2, short-term beach change rates can exceed long-term rates by a factor of from three to five due to the occurrence of major, yet relatively rare, storm events (Sonu, et al., 1979). Thus, the use of coastal change rates compiled for this past summer (which may, in fact, have been an atypically calm summer) to extrapolate expected coastal changes for the next thirty years is difficult, and should be augmented in the future with more pertinent, site-specific data.

In all cases, the data presented in Table 6.2 is the set-back distance for the northern shore or bluff edge. The barrier islands must also be depicted as exhibiting a high degree of shoreline fluctuation at their western and eastern ends. Because of these natural fluctuations, a construction exclusion zone should also be respected at the island ends. Figure 6.4 illustrates a generalized island configuration and the areas within such an island where construction of either exploration or production facilities should be avoided.

Relative to exploration structures, production facilities on barrier islands require a much wider buffer zone to promote structure longevity. The buffer zone dimensions are so great, in fact, that only a few existing locations can accomodate production facilities atop the island surface. For the remaining areas within the barrier island chain, it is recommended that production facilities be built in the shallow waters to the south of these

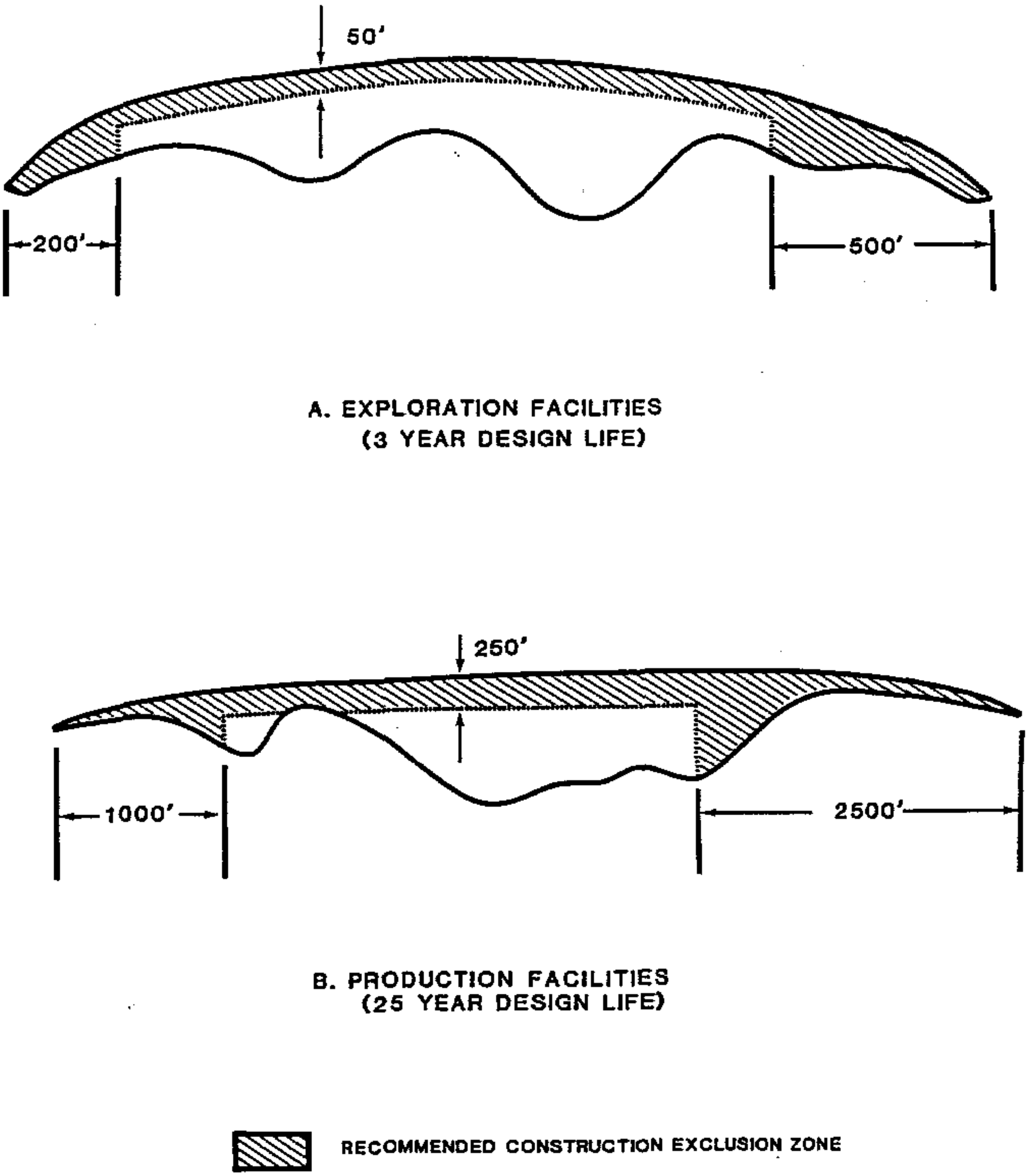


FIGURE 6.4 : COASTAL SET-BACK FOR BARRIER ISLAND FACILITIES

islands. In this way, the structures can benefit from the wave and ice protection afforded by the islands without impeding the natural dynamics of the island systems.

o <u>Inundation Prevention</u>

Due to the low-lying nature of the coastal areas of the study region, all facilities should be constructed upon an elevated foundation pad to protect the work surfaces from coastal flooding that can occur during periods of high storm winds and seas. The existing drilling facilities of the region have work surface elevations of from seven to ten feet above sea level. In addition, an elevated berm is constructed on the weather shore of the Alaska Island pad to prevent wave overtopping during storm events. To date, no serious flooding of the work surface has been reported at any of the existing structure sites. While the exact determination of work surface elevations must be specific to the location and structure type, Table 6.3 is presentd to provide general guidelines for the various zones of the Pt. Thomson region.

o <u>Erosion Prevention</u>

A proper design of slope protection for any coastal structure requires an analysis of the structure type, profile, location, and environmental forces as well as consideration of costs and construction feasibility. Because no specific information concerning proposed facilities in the Pt. Thomson area is presently available, only general guidelines can be given at this time.

TABLE 6.3

RECOMMENDED WORK SURFACE ELEVATIONS
PT. THOMSON STUDY AREA

Area	Type of Structure	WORK SURFACE ELEVATIONS, FEET (MLLW)	
		Exploration (3 Year Life)	Production (25 Year Life)
Mainland[1]	Gravel Pad	5 - 8	8 - 12
Flaxman Island[1]	Gravel Pad	5 - 8	8 - 12
Barrier Islands	Gravel Pad	7 - 10	10 - 20[2]
Lagoon	Gravel Island	10 - 12	15 - 20[2]

1. If existing grade exceeds recommended elevation, pad can be limited to foundation support considerations.

2. Depends on location, slope protection type and slope cross-section.

The study area exhibits high variability in terms of wave and ice exposure and the resultant slope protection required. Therefore, the entire study region has been separated into four zones for which a conceptual slope protection design has been developed. The unique zones which have been identified and the structure types required for each zone are described below. The location of the various zones is illustrated in Figure 6.5.

Zone 1: This zone is situated on the mainland shore above the elevation of the historical high water line (+6 to 8 feet, MLLW) as defined by the mapped driftwood debris lines. Within this zone, an elevated gravel pad is required as a foundation to support facilities, however, inundation of the natural terrain at these elevations is considered to be unlikely. The side slopes of a gravel pad constructed within Zone 1 could be steep and do not require structural slope protection, as shown in Figure 6.6(A). A coastal setback distance should be respected (see Table 6.2) to allow erosion to continue without affecting the structure.

Zone 2: This zone exists on the mainland shore and within a small area of Flaxman Island at coastal elevations that lie below the historical high water line of 6-8 feet. The coastal setback guidelines presented in Table 6.2 must be respected. As in Zone 1, an elevated gravel pad is sufficient to support facilities. The pad work surface elevation should exceed the maximum high water level of 6-8 feet. No structural slope protection is recommended for short-lived exploration structures located in Zone 2. For production facilities, however, slope protection should be considered if the pad is located at a low-lying location which may be susceptible to inundation over the long life of the structure. Figure 6.6(B) presents a conceptual drawing

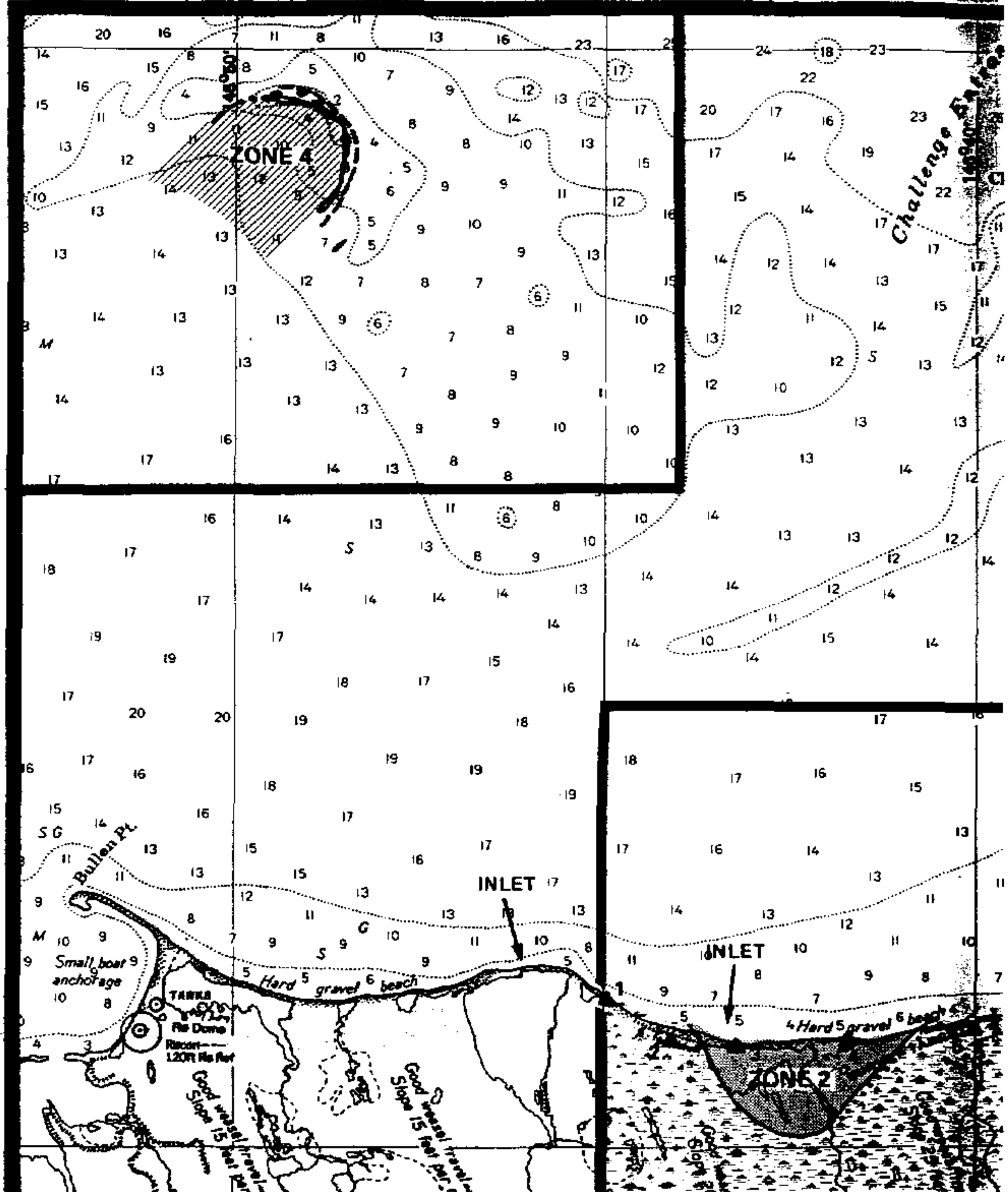
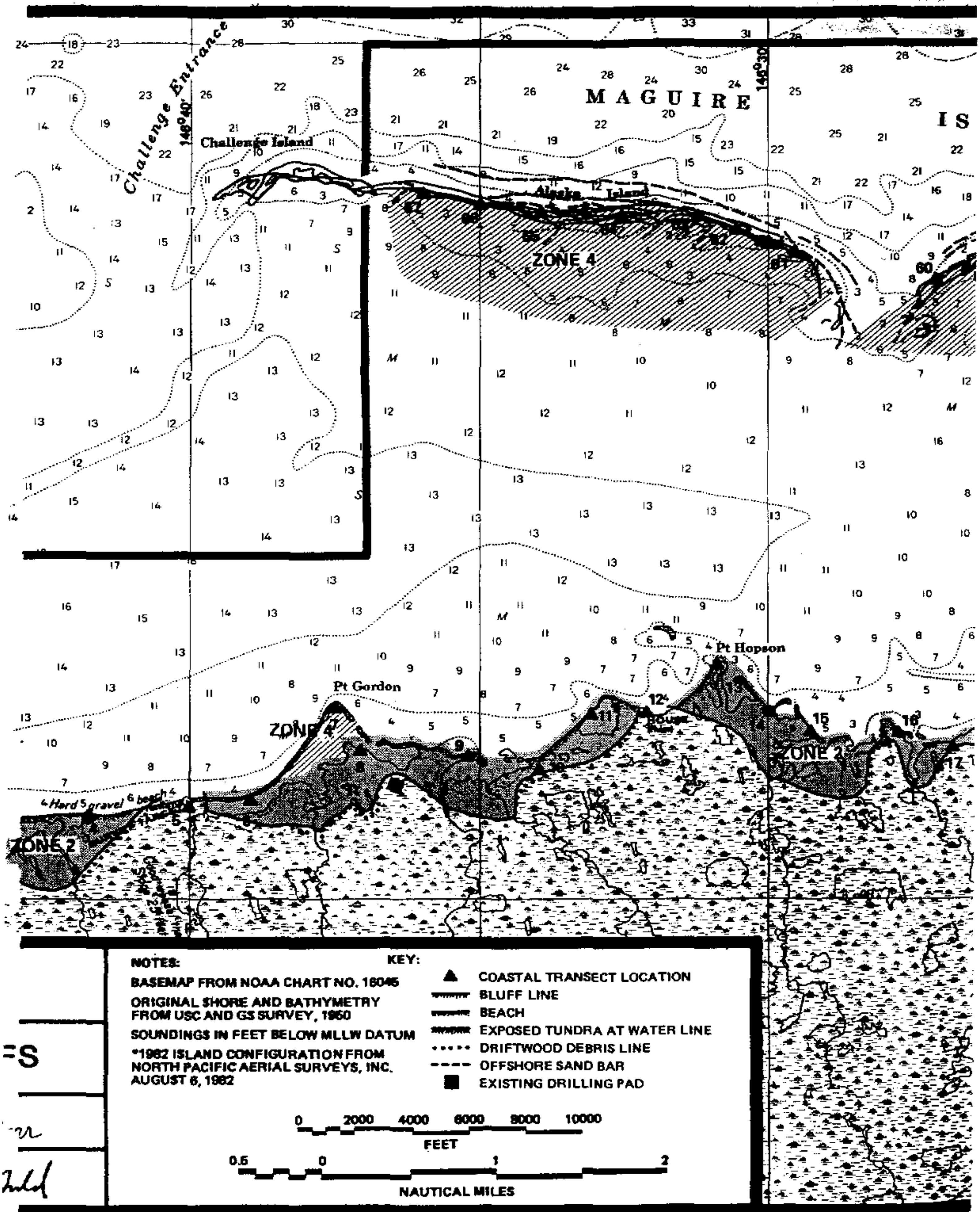


FIGURE 6.5

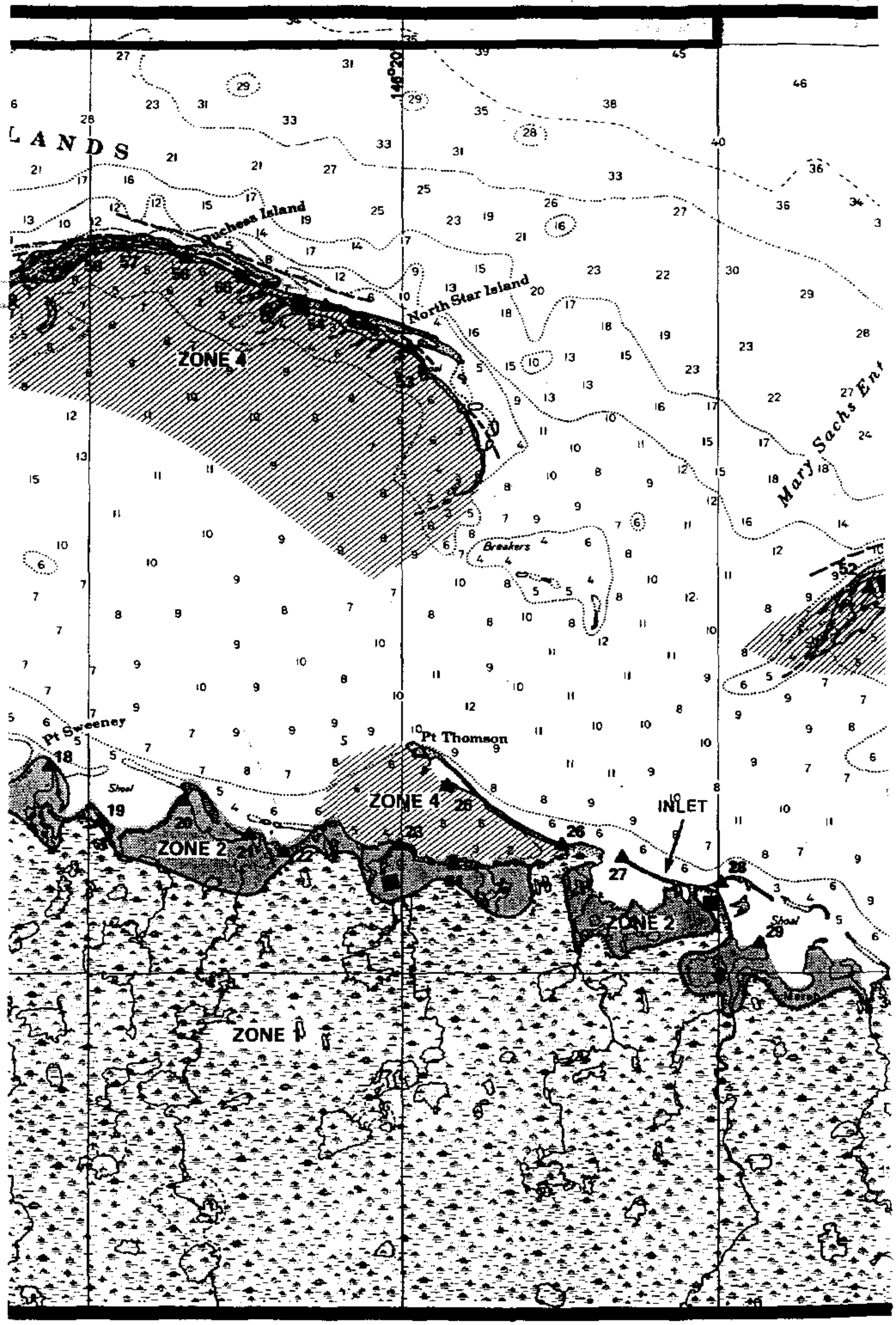
COASTAL CONSTRUCTION ZONES

PT. THOMSON DEVELOPMENT PROJECT
COASTAL PROCESSES AND SEDIMENT DYNAMICS
CONTRACT PTD–8206
TEKMARINE, INC.

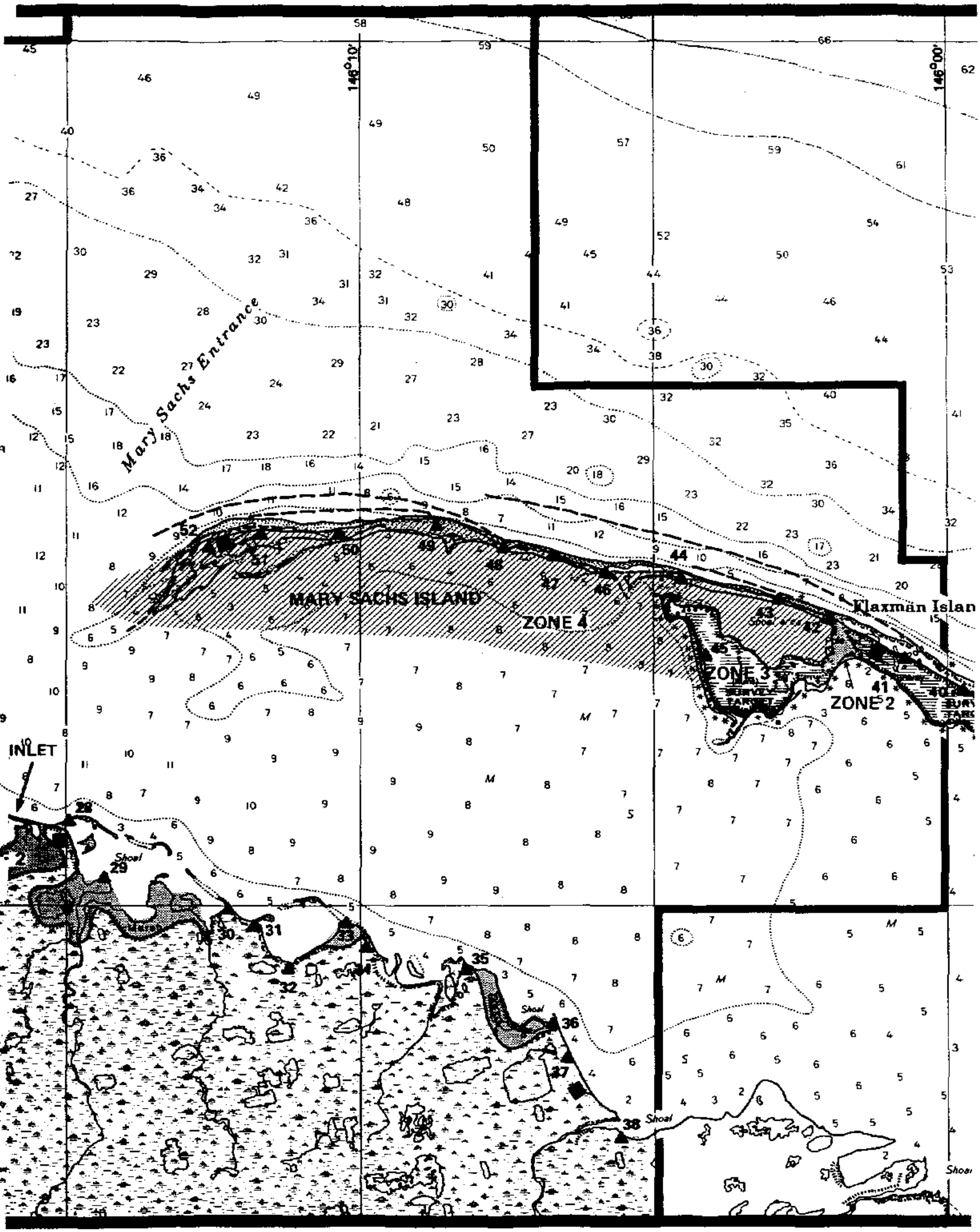
DRAWN
APPROVED



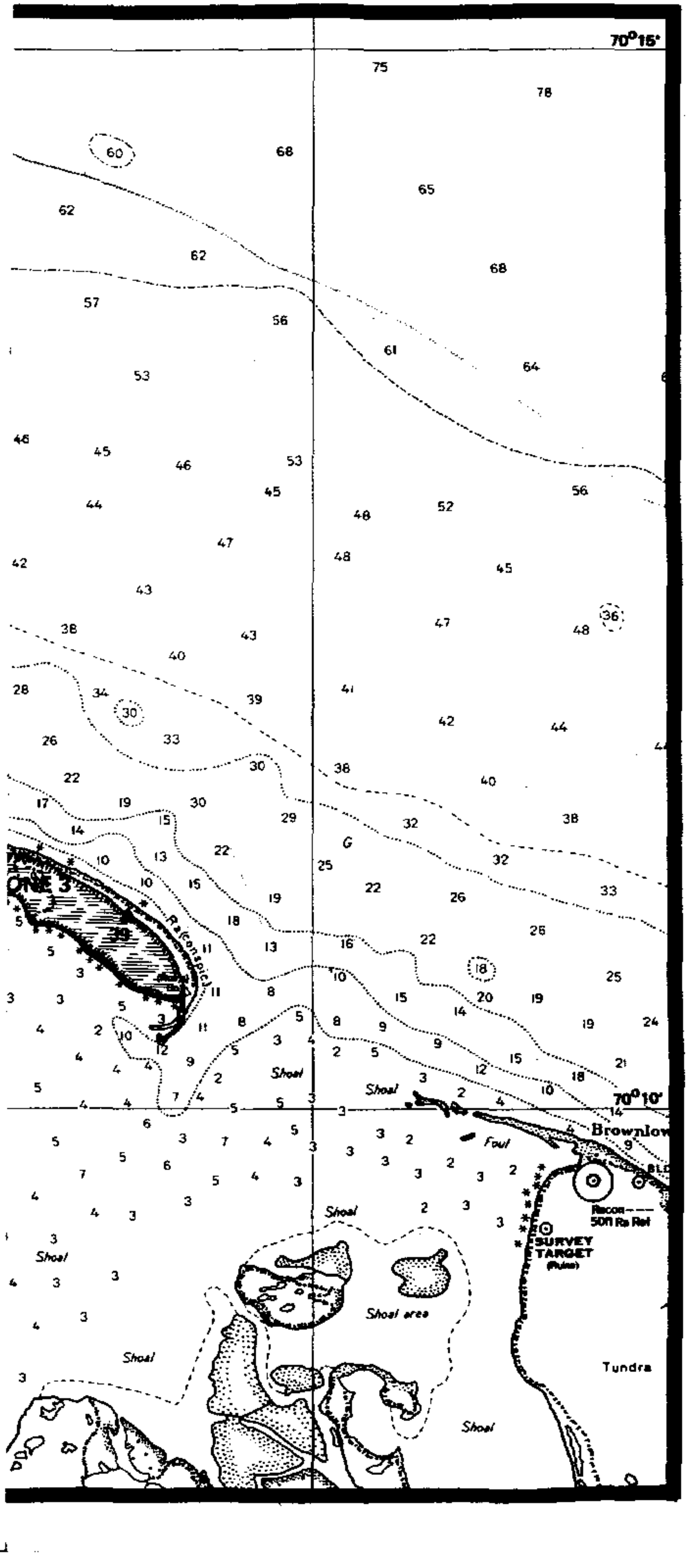
MAGUIRE IS
Challenge Entrance
146°40'
146°30'
Challenge Island
Alaska Island
ZONE 4
Pt Gordon
Pt Hopson
ZONE 4
ZONE 2
ZONE 2
Hard gravel beach
NOTES:
BASEMAP FROM NOAA CHART NO. 16045
ORIGINAL SHORE AND BATHYMETRY FROM USC AND GS SURVEY, 1950
SOUNDINGS IN FEET BELOW MLLW DATUM
*1982 ISLAND CONFIGURATION FROM NORTH PACIFIC AERIAL SURVEYS, INC. AUGUST 6, 1982
KEY:
COASTAL TRANSECT LOCATION
BLUFF LINE
BEACH
EXPOSED TUNDRA AT WATER LINE
DRIFTWOOD DEBRIS LINE
OFFSHORE SAND BAR
EXISTING DRILLING PAD
0 2000 4000 6000 8000 10000
FEET
0.5 0 1 2
NAUTICAL MILES



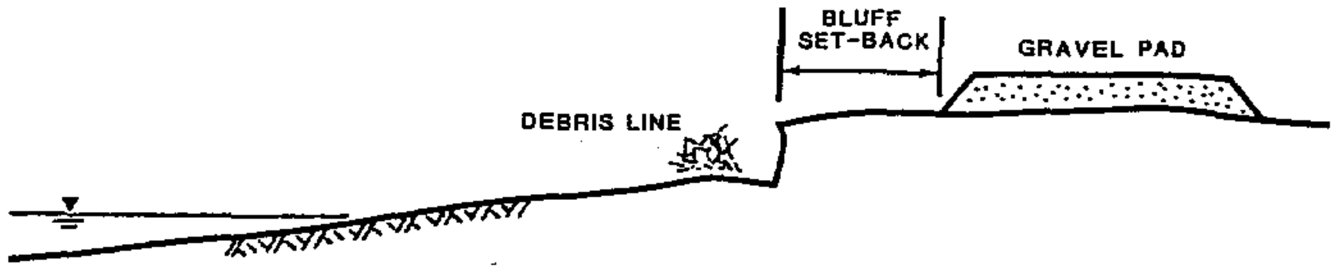
LANDS
Duchess Island
North Star Island
Mary Sachs Ent
ZONE 4
Breakers
Pt Sweeney
Pt Thomson
Shoal
ZONE 4
ZONE 2
INLET
ZONE 2
Shoal
ZONE 1



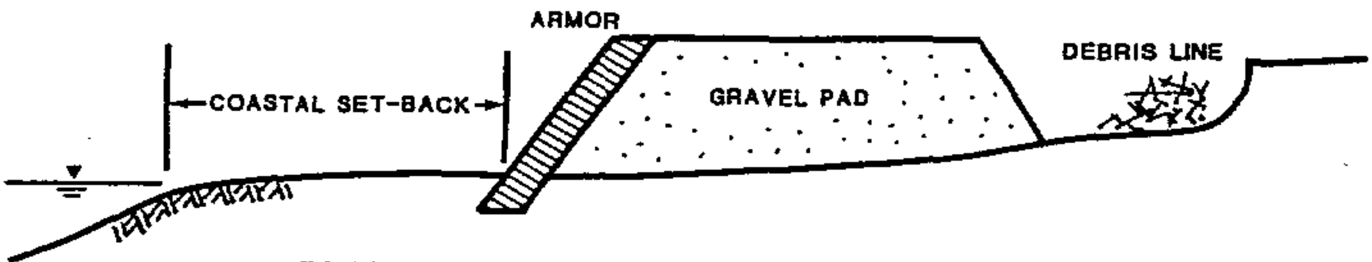
146°10'
146°00'
Mary Sachs Entrance
MARY SACHS ISLAND
ZONE 4
ZONE 3
ZONE 2
Flaxman Islan
INLET
Shoal



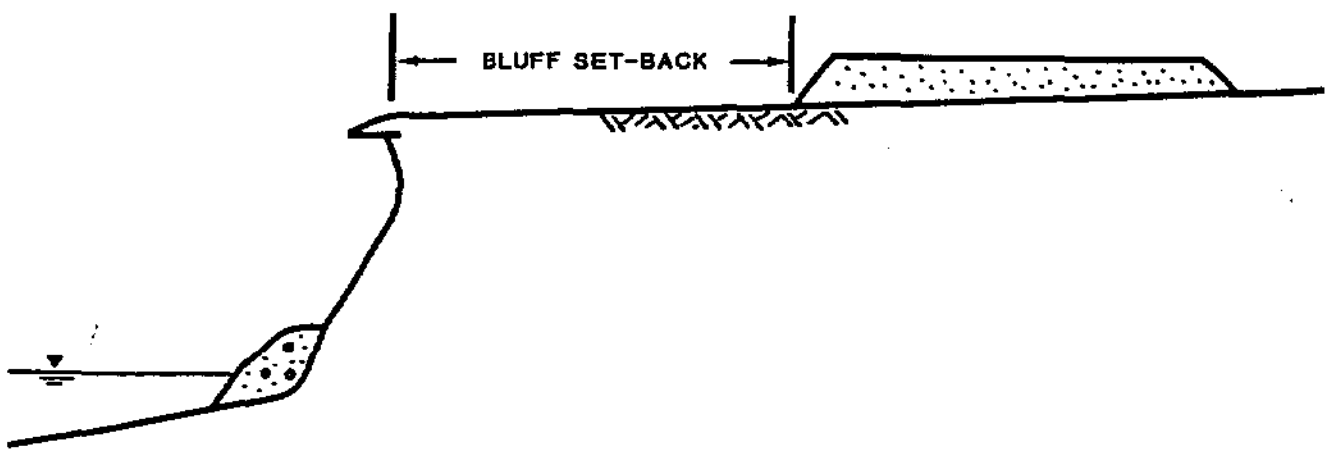
70°15'
70°10'
Ra (conspic)
Shoal
Shoal area
Foul
Brownlow
Recon
50ft Ra Ref
SURVEY
TARGET
Tundra



ZONE 1: HIGH ELEVATION MAINLAND SHORE



ZONE 2: LOW ELEVATION MAINLAND SHORE



ZONE 3: FLAXMAN ISLAND BLUFF

FIGURE 6.6 : CONCEPTUAL PAD DESIGN, ZONES 1 – 3

of a structural foundation for Zone 2. The actual elevation of the work surface and the setback distance should be finalized only after considering site-specific information.

Zone 3: Zone 3 exists on the elevated plain of Flaxman Island. The active bluff erosion which occurs along the shores of this zone requires a substantial setback to prevent loss of the underlying foundation of the proposed structure. Wave impact is not a factor at this elevated location, therefore, structural slope protection is not required. The critical setback distance must be determined at the time of facility design, however, the general guidelines presented in Table 6.2 shows the need for a setback of 100 feet for a exploration facility (3-year design life). The necessary elements of this design are shown in Figure 6.6(C).

Zone 4: Zone 4 consists of the barrier island surfaces, the shallow waters located to the south of the islands, and the coastal spits and adjacent small lagoons of the mainland coast.

Previous experience is available for slope protection alternatives on Arctic barrier islands. For a one-year exploration pad on No Name Island, Amoco Production Company constructed an unprotected, elevated gravel pad similar to the previously decribed design for Zone 1 (Gadd, et al, 1982). In the Pt. Thomson study area, Exxon has constructed two steel sheet-pile enclosed structures to contain elevated gravel pads. Also, Sohio has developed a gravel pad that rests partially on the surface of Alaska Island. The slopes of this pad lie on a 1V:3H slope and are protected by gravel bags having two cubic yard capacity. Further description of these facilities has been presentd in Section 6.1.

Based, in part, on this previous experience, three designs have been formulated for Zone 4, as shown in Figure 6.7. The first two designs are for use on the surface of the barrier islands. The third design describes an offshore island intended for the shallow waters located directly south of the barrier islands and for the mainland coastal lagoons adjacent to the major sand spits (Pt. Thomson, Pt. Gordon).

For the gravel pad option, the work surface elevation and slope armor are dictated by the environmental conditions and the design life of the structure. A set-back distance from the north shore must be respected. Note that the slope armor is buried at the structure toe to allow some measure of protection against wave scour.

The vertical-walled sheet pile alternative is also illustrated as a potential pad design. It is recommended that this option should be pursued only when the entire structure can be contained on the island surface. If the vertical walls project into nearshore waters, incoming waves can cause scour at the base of the wall thereby weakening the structure. For this reason, toe protection is recommended at the base of the wall, especially for structures having a design life in excess of five years. This will guard against scour during storm periods that bring high water levels and direct wave impact to the structure.

The protected waters of Zone 4 require island construction in water depths of from two to eight feet. Wave and ice impacts in this area are expected to be mild to moderate, due to the protection afforded by the barrier islands. For this alternative, the work surface elevation

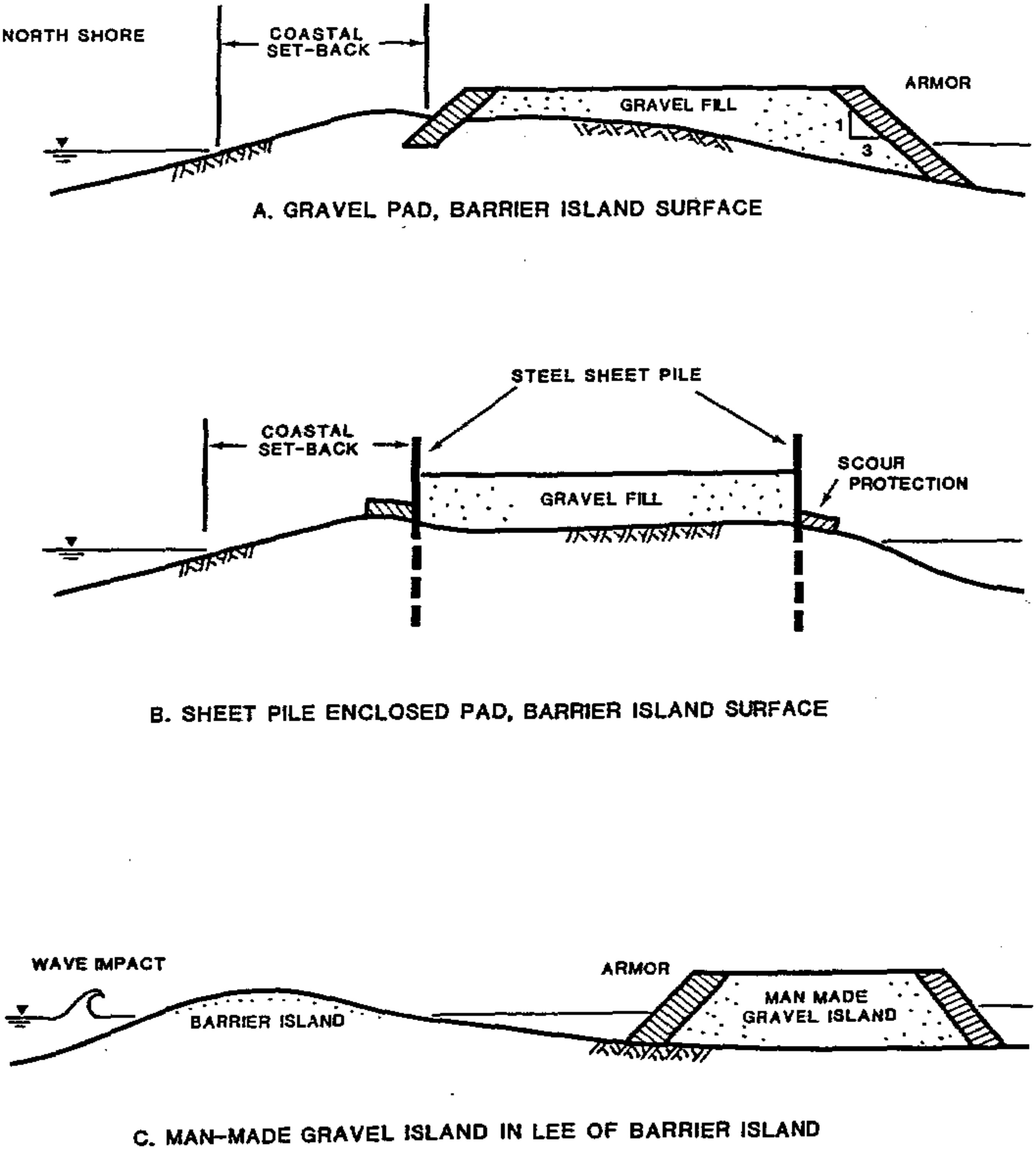


FIGURE 6.7 : CONCEPTUAL PAD DESIGN FOR ZONE 4

must exceed the level of storm surge and the slope protection requirements are dictated by the expected wave conditions and the design life of the structure.

Recent experience on artificial islands in the Sag Delta area has shown the need for durable slope protection in the wave impact zone to resist damage caused by large waves and floating ice. For conventional Arctic slope protection using gravel-filled bags, periodic maintenance and repair should be expectd to insure the strength and stability of this slope protection system. For a long design life, the high maintenance costs associated with "soft" armor (gravel bags) may dictate the need for a durable concrete mat to cover the most exposed portions of the island slope.

6.4 Coastal Causeway Conception Design

The possibility of constructing a causeway to connect an offshore drilling location to the mainland coast is a feasible development scenario. Such a causeway would provide transportation to and from the offshore site and would serve as a path over which oil or gas could be piped onshore. As an example of the necessary considerations and concerns generated by such a project, a conceptual design has been undertaken in this study for a causeway which would connect Flaxman Island to the mainland coast.

- Location

Figure 6.8 shows the chosen route of the causeway. The structure would connect the mainland point located just east of Transect #35 to the south west shore of Flaxman Island, just south of Transect #45. The causeway length at this location would be about two nautical miles (12,000 feet)

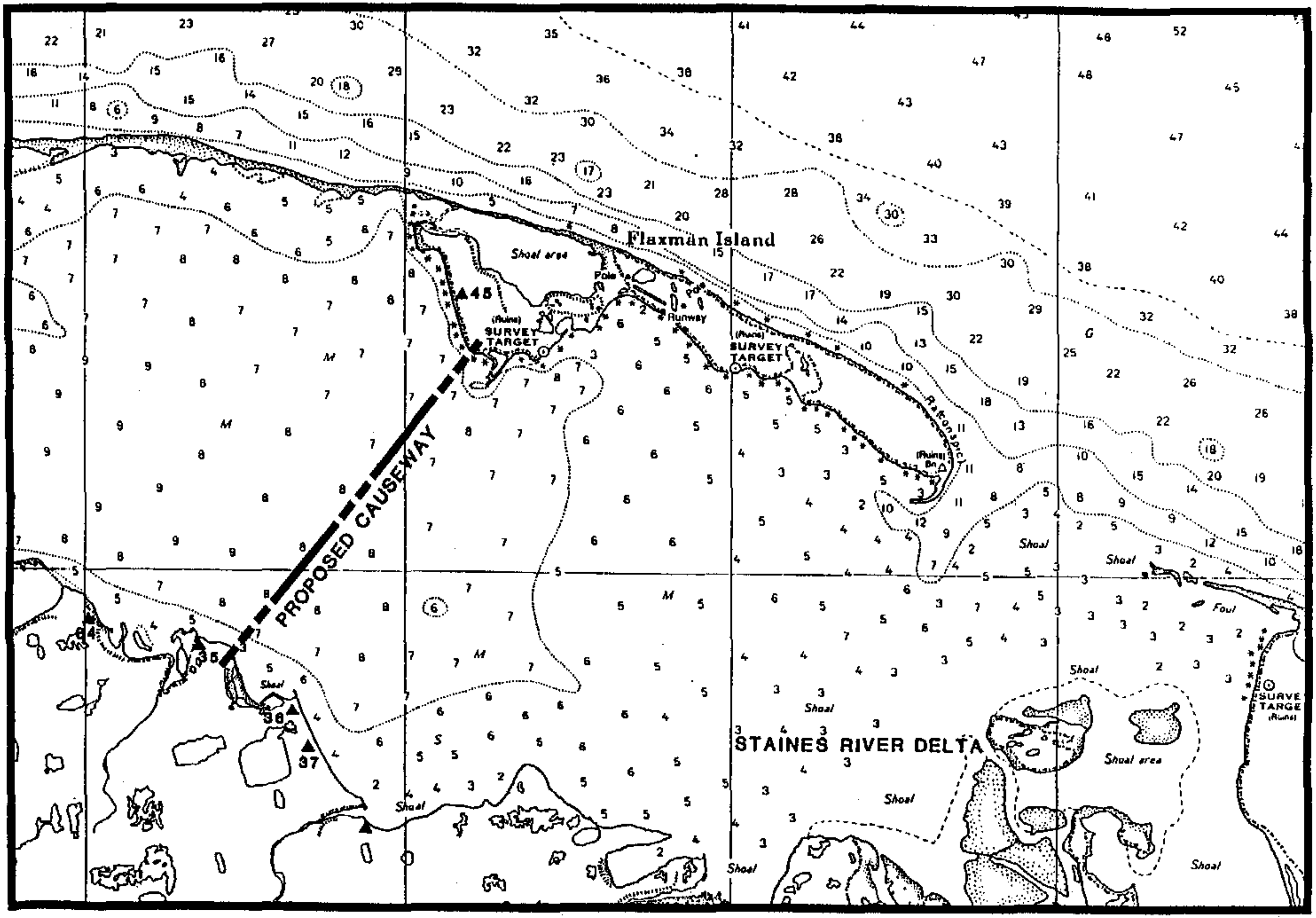


FIGURE 6.8 :PROPOSED CAUSEWAY LOCATION

over a fairly constant water depth of 8 feet. This site was chosen in order to minimize total causeway length, to avoid the Staines River delta and the additional structures (bridges) required in that region, and to take advantage of the shelter provided by Flaxman Island.

o Design

The causeway has been envisioned to be a solid, rubble-mound structure composed of gravel, similar in design to West Dock, located on the west side of Prudhoe Bay. The environmental conditions of waves and ice are not well understood in the Flaxman Island lagoon area. For this reason, the erosion control of the causeway is difficult to specify. Three plans are presented in Figure 6.9 that will encompass a range of general slope protection possibilities.

The first option is an unprotected gravel fill structure having a trapezoidal cross-section. The side slopes would be fairly mild, ranging from perhaps 1v:5H to 1v:10H. The mild slope would dissipate wave run-up and would allow the incoming wave energy to redistribute the gravel to a more stable configuration. Periodic maintenance would be required to replenish those areas where erosion is predominant.

The second option is a partially armored slope which would "compartmentalize" the causeway slope allowing retention of eroded sediments near the site of the erosion, thereby simplifying subsequent maintenance activities. The slopes of this design would be 1v:5H. The slope armor envisioned for this design would be placed at the toe of the slope. Shore-perpindicular gravel groins would also be

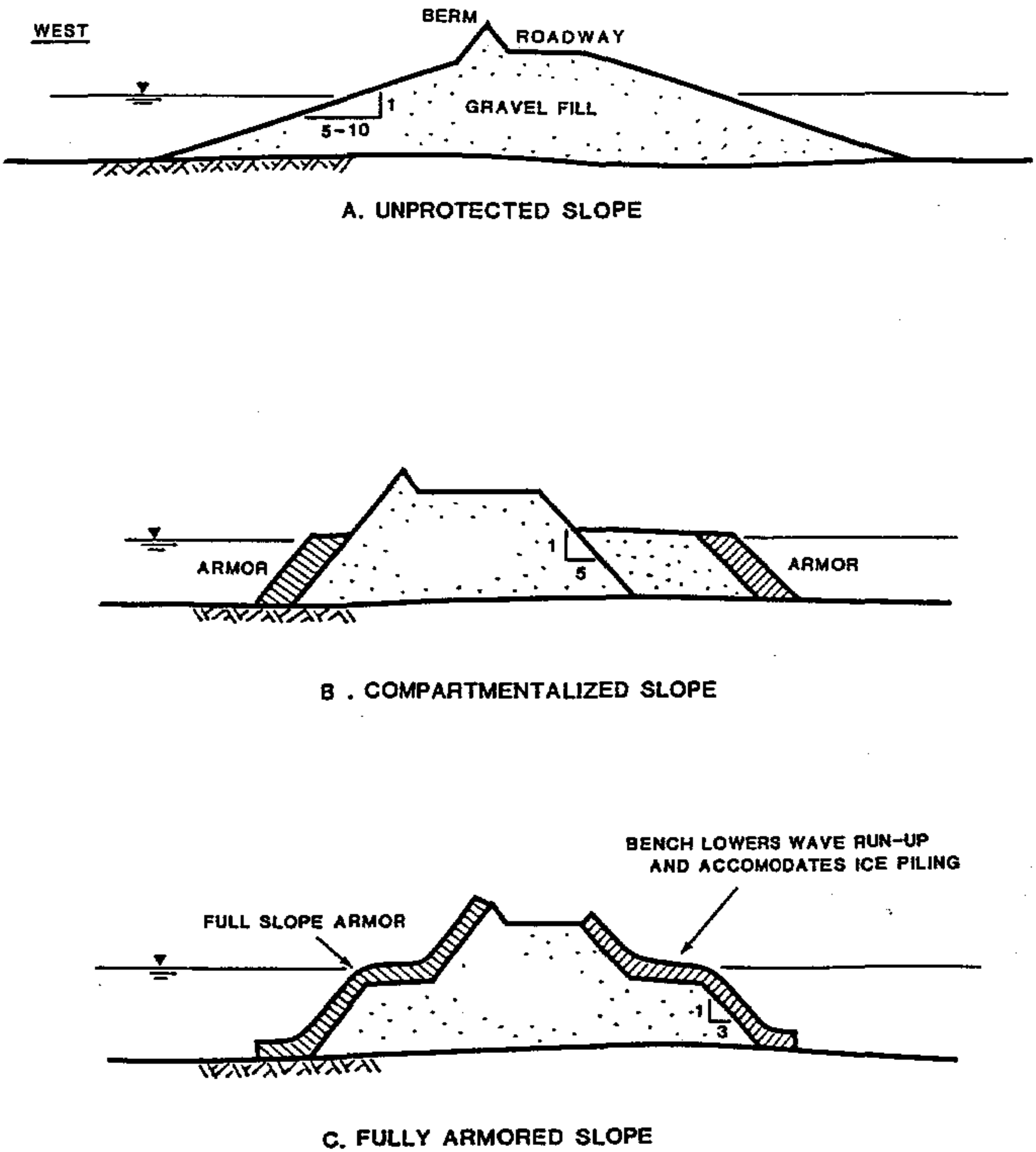


FIGURE 6.9 : CONCEPTUAL SLOPE PROTECTION, COASTAL CAUSEWAY

helpful to arrest the movement of eroded sediments migrating along the causeway length. The outer toe of these groins should also be armored to provide further stability.

The third design concept illustrated in Figure 6.9 is a fully armored slope which may be appropriate for a causeway having a 20-30 year design life. This design requires armor to be placed over a composite slope which will include a flat bench near the water level. The bench is designed to lower the wave run-up elevations and to accomodate expected winter ice pile-up.

In all cases, an elevated berm is recommended for the west side of the causeway to prevent flooding of the causeway surface during episodes of storm surge caused by westerly winds. The height of the berm must be carefully considered to allow protection from wave overtopping while minimizing the potential for snow drift formation during the winter.

The heavily armored alternatives require a relatively high initial investment with the anticipation of moderate future maintenance costs. The unarmored causeway will require more gravel initially due to the mild side slopes, however, lack of any structural protection will yield relatively low initial costs. Expensive, and, perhaps, persistent maintenance requirements will accompany this design choice.

Because the degree of natural wave and ice protection varies along the causeway length, it is conceivable that the slope protection will vary accordingly. Monitoring efforts conducted subsequent to the causeway installation would be required to ensure the adequacy of the causeway slope protection.

o <u>Impacts</u>

The construction of a solid gravel causeway across the lagoon separating Flaxman Island and the mainland will disturb the natural processes occurring in this area to some degree. The major concerns envisioned are the deterioration of water quality due to the restriction of the natural lagoonal circulation and the retardation of the nearshore coastal processes and natural sediment transport. Each of these concerns will be discussed below with particular attention given to probable mitigative actions that could be implemented.

<u>Water Quality:</u> A solid causeway will act as a barrier to the natural circulation that occurs within the lagoon. During periods of high river outflow from the Staines and Canning Rivers, the turbidity levels will increase to the east of the causeway as the river outflow is trapped by the persistent easterly wind. In addition, the causeway would restrict the natural migration of fish along the coast.

To decrease the impact of the changes in water quality created by the causeway, it is recommended that the causeway be perforated by breaches to allow passage of water and biota from one side of the causeway to the other. The width of the breaches and their distribution along the causeway length requires further study.

An additional area of study in this regard is the interaction of the causeway and breaches to the coastal ice field. Potential problems that must be considered are ice ride-up and ice incursion onto the causeway slopes, ice jam formation at the causeway breaches, and ice-slope armor interaction.

Coastal Processes: The causeway will have a measurable effect on the sediment transport that occurs along the adjacent coastline. The structure will prevent the natural passage of sediments along the coast and lower the potential for nearshore sediment migration by protecting the adjacent shore from incoming wave energy. This blockage of wave energy will yield areas of sediment starvation at locations where the shores would normally be nourished by the sediments impounded by the causeway.

The altered deposition and erosion patterns adjacent to the causeway will cause accelerated erosion in some areas. Because the exact locations and the extent of the causeway induced damage are difficult to predict, the recommended strategy is to plan to implement mitigative actions as they are required based on repeated observations of the coastal changes that occur. Generally, the action taken would be to transport (by truck, dredge or conveyor) the sediment deposited at the causeway to areas where coastal erosion has accelerated. The results of the recent field investigation show that the volumes of material moving along the coast are not massive. Perhaps the annual littoral drift on the mainland shore is 5,000-10,000 cubic yards, with only a portion of that total requiring redistribution due to erosion caused by the structure.

One aspect that is implicit to this planned mitigation effort is to have sufficient background data to identify areas that are suffering from the causeway-induced sediment impoundment. It is critically importnt to differentiate between the natural and the structure-induced coastal changes. This is best determined through annual surveys of shore configuration prior to the installation of the causeway. The survey transect baseline initiated this summer will serve as historical data, however, if the approximate location of the proposed structure is known, it would be very wise to increase the number of transects in that particular area to provide additional localized historical data.

Another effect related to the placement of a causeway will be to accelerate the coastal currents in the vicinity of the previously described causeway breaches. During periods of strong westerly winds, a hydraulic head differential will exist on opposite sides of the causeway which will drive strong currents through the breaches. These currents will likely be swift enough to erode the seabed sediments, creating patterns of scour and deposition in addition to high levels of localized turbidity. To protect against these effects, structural scour protection can be placed on the seabed at locations which are deemed appropriate based on the results of a computer-generated scour model. This structural protection will eliminate local erosion and deposition related to accelerated flows through the causeway breach as well as decrease the turbidity that results from these flows.

7. CONCLUSIONS

Historical observations and the results of the recent field work show that the mainland shore and offshore islands of the Pt. Thomson study area are changing in response to the environmental forces of the region. Specifically, the bluffs of Flaxman Island and the shores of the barrier islands are exhibiting the greatest rates of change of all the coastal regimes within the study zone. The former are retreating at a rate of about 12 feet/year, while the latter change continually in shape and location in response to the natural forces of waves, currents, wind and ice. In contrast, the shores of the mainland in this vicinity are relatively stable due, in part, to the sheltering effect of the offshore islands.

Based on these findings, it is feasible to construct and maintain oil exploration and production facilities within the Pt. Thomson study area. For all proposed facilities, however, the dynamic nature of the coastal landforms must be recognized to ensure long-term stability of the structural foundation.

To utilize this dynamic coastal area for siting oil development structures, it is recommended that coastal setback distances be respected so as to separate the new facility from the active bluff or shore. This strategy of hazard avoidance is deemed to be less expensive and ultimately more efficient than to attempt to control the erosion by artificial means.

The conceptual design of a causeway to connect the mainland shore with Flaxman Island has shown that localized changes in the lagoonal environment will accompany such a structure. Noteworthy among these impacts include changes in water quality and impoundment of nearshore sediments. Both effects are related to the blocking of nearshore processes caused by the continuous causeway structure. To mitigate these effects, the causeway can be breached at intervals to allow coastal waters to pass freely through the structure. Also, impounded sediment at the shore can be physically transported to sites where beach depletion has occurred.

The outlook for the next 50 years is for continued slow change on the mainland shore and for further major erosion and shoreline fluctuation on the offshore islands. The bluff erosion occurring on the northern shore of Flaxman Island will proceed during this time, delivering approximately 15,000 cubic yards of beach material annually to the shores of the barrier islands located downdrift.

In the longer term, the next few hundred years will see continued erosion of the Flaxman shore which will invariably reduce the size of this bluffed island. As this occurs, this source of sediments that nourish the barrier islands will diminish, resulting in accelerated erosion along the barrier island shores. As these islands erode, the mainland shore will no longer benefit from the wave protection presently provided by the islands leading, ultimately, to the recession of the mainland shore at a rate which is more rapid than that observed presently.

8. RECOMMENDATIONS FOR FUTURE STUDIES

Based on the experience gained from this study, a number of related topics are considered relevant for consideration in future study programs. The studies proposed are listed in order of perceived importance.

8.1 Continued Monitoring of Coastal Transects

In order to advance the state of knowledge of the coastal processes within the Pt. Thomson study area, it is important to continue the monitoring program of the 67 coastal transects established during the recent summer. Only through the yearly monitoring of these sites can fluctuations in the erosion or accretion at specific areas be quantified accurately. The information gained during the relatively quiescent summer months of 1982 did not include the effects of the major storms that occurred during late September which caused damage to a number of offshore islands near Prudhoe Bay. A brief survey during July, 1983, will document the coastal changes in the Pt. Thomson study area caused by the late summer storm period of 1982.

For the continued survey effort, a single summer field trip should be sufficient. For convenience and for consistency, each annual survey should be performed during the relative fair weather summer period, preferably, during late July. To minimize cost, the following recommendations are proposed:

- o Do not establish a field camp unless substantial monument/target reconstruction is required.

- Rely on helicopter transport from Deadhorse on a daily basis. A field crew and the necessary survey gear can be transported quite effectively in this way. Use of an electronic survey system is required for accurate comparisons to be made with the 1982 survey data.

- Take aerial photos from the helicopter at high altitude (5000-7000 feet) for comparison with 1982 photos. More expensive high altitude photos from a commercial aerial photography company need not be taken annually unless the helicopter photos show major shoreline changes of interest.

- Prior to taking the aerial photos, reconstruct ground targets at all monument sites so that targets will appear on the photos. Assuming that only the target fabric will degrade with time, the existing target hardware (tent pegs, monuments, spikes) may be reused for the target reconstruction. New fabric, tiedown wire, and the appropriate tools will be the only new supplies required. A magnetic locator might also be necessary to find monuments that may be buried by sediment deposition.

In the future, as specific sites of development interest are identified, the coastal processes investigation can be intensified in those areas. Additional monuments, littoral drift measurements, beach volume determination and local sediment size distributions are among the factors that will allow more rational support of the development decisions that must be made. In addition, historical aerial photos should be studied to gain some understanding of the coastal changes that have occurred at or near the sites of interest.

It should be stressed that the coastal monuments established in conjunction with this study are, in many cases, in areas that are quite dynamic. Thus, on-going erosion or accretion may eventually destroy the monuments. If vigilence is promoted through periodic (annual) site visits, the loss of monuments can be avoided by re-establishing each endangered survey transect. Only in this way can the information obtained this summer serve to answer the particular and specific questions that may be posed should development proceed in the future.

8.2 Island Migration/Inlet Dynamics Study

The dynamics of the barrier islands of the study area are understood in a general way. The islands migrate slowly westward under the influence of the persistent easterly winds. In time, the shapes of the islands change as they respond to the environmental forces acting on them. As inlets form and then fill, the characteristics of the water exchange between the interior lagoon and the offshore areas change dramatically. The character of this water exchange during the tidal cycle and in response to wind-induced set-up or set-down can certainly affect pollutant dispersion and other water quality concerns within the lagoon system. Methods of studying this mechanism of water exchange would include the following tasks, performed for a suite of inlet types and sizes along the Flaxman-Maguire Island chain.

- Current Measurements: For this program, current meter deployments would be secondary to drogue deployments. The drogues should be limited in number and located using precise on-shore surveying techniques at regular intervals. We envision two surveyors located on opposite sides of an inlet making coincident observations of a variety of color-coded drogues to determine position and velocity as they pass through the inlet.

- Remote Sensing: High altitude infrared photography may be used as a tool for observing the lagoon-wide water exchange through the inlets. The warm lagoon waters provide a sharp contrast on the infrared image to the colder waters to the north. This aerial photography should be coordinated with a "ground truth" survey such that the infrared image can be calibrated for temperature.

- Sand Tracing: Native sand can be treated to coat each particle with a thin layer of flourescent dye. The sand thus treated can be released on one side of the inlet or along the island shore and subsequently recovered at a future location. In this way, rates of sediment transport may be measured. Using this technique, it is especially interesting to determine the extent to which sediment is transported as bedload across the wider inlets. This will determine the degree to which the Maguire Islands are being nourished by the erosion of the Flaxman Island bluffs.

- Experimental Groins: The determination of the rate of sediment transport along the island shore is an important concern for planners of exploration or production facilities at these sites. Construction of individual groins, placed at specific points of interest, would assist in this effort. The groins could best be built of the driftwood that exists along the entire reach of islands. Additional weight to stabilize the groins could be provided by sand bags. The groins should be monitored periodically to measure the volume of sediment impounded. With time, as each groin achieves full capacity, incoming sand will by-pass the structure. When this occurs, the experiment would be complete and the groin could be dismantled.

- Island Migration Surveys: From selected coastal monuments, the exact location of the leading edge of each island shore can be measured using an electronic surveying system. In conjunction with aerial photos, the annual migration associated with each island could be accurately determined. In this way, the highly fluctuating short-term island migration rate could be calculated and compared to the long-term westward rate of migration documented in this report.

8.3 Barrier Island Ice Ride-Up Potential

Ice ride-up occurs when on-shore ice movement collides with the shoreline with enough force to allow the incursion of the ice sheet onto the surface of the shore.

It is believed that ice sheets can pass onto and directly over the low-lying barrier islands of the study region. The low beaches of the mainland shore can also be exposed to ice over-ride, however, the bluffs which back these beaches tend to promote buckling of the ice sheet resulting in the subsequent formation of an ice pile at the base of the bluff.

Because the barrier islands are subject to major ice ride-up episodes, future planning of facilities for the surface of these islands should be guided by the knowledge of the probable location of the expected ice over-ride. In the belief that such occurrences are partially related to the nearshore bathymetry, this study would attempt to accurately define the nature of the nearshore bottom profile. Particularly, the longshore sand bars that are attached to the island at various locations may control, to a significant degree, the point at which ice could impact and over-ride the island surface. For this investigation, the following tasks are envisioned:

- <u>Topographic Mapping:</u> Using the recently procurred aerial photography and the targeted monument baseline, develop a complete topographic map of the barrier islands (Mary Sachs and the Maguire chain). Include numerous observations of island surface elevations in addition to those obtained at each monumented transect.

- <u>Offshore Bathymetric Survey:</u> Using a small boat and precise positioning methods, perform a bathymetric survey along the monumented transects established this past summer. Augment these sub-sea profiles with intermediate transects measured on an "as needed" basis to clearly develop the position of the nearshore sand bars. The survey lines should be carried to a distance of at lest 2000 feet north of the island shore, or until the sea bottom shows no bathymetric irregularities.

While the major onshore ice motion is expected on the northern slope, ice incursion could also be directed from the lagoon. For this reason, a limited number of transects should also be surveyed on the island's southern side to delineate any notable sub-sea features.

- Historical Nearshore Bathymetric Comparison: To allow comparison of the proposed survey with that performed by the U.S. Coast and Geodetic Survey in 1950, the original fathometer records obtained in the early survey should be procured from the government archives. Using the original field bathymetric sheet as a guide, the location and size of the longshore bars in 1950 can be determined. Comparison of these two data sources can allow an interpretation of the nearshore dynamics of this study region. The knowledge gained concerning bar formation and migration and potential bar-ice interaction will provide guidance to siting facilities on these islands. This guidance will be especially valuable when production facilities having long design lives are contemplated.

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