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.

- <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,

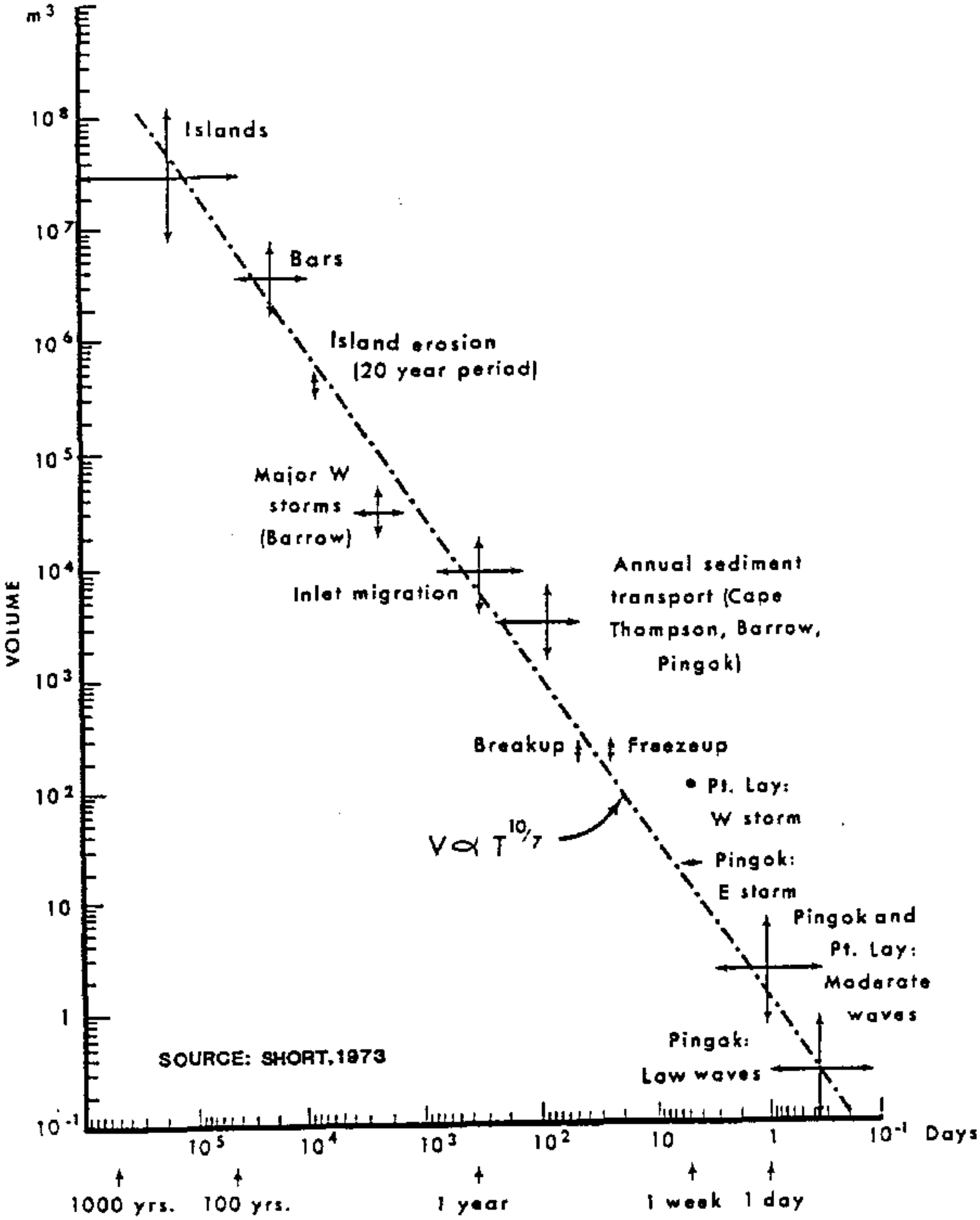


FIGURE 6.1 : RELATIONSHIP BETWEEN PERIOD OF MORPHOLOGICAL RESPONSE AND VOLUME OF TRANSPORTED SEDIMENT

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 <u>Coastal Erosion</u>

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.

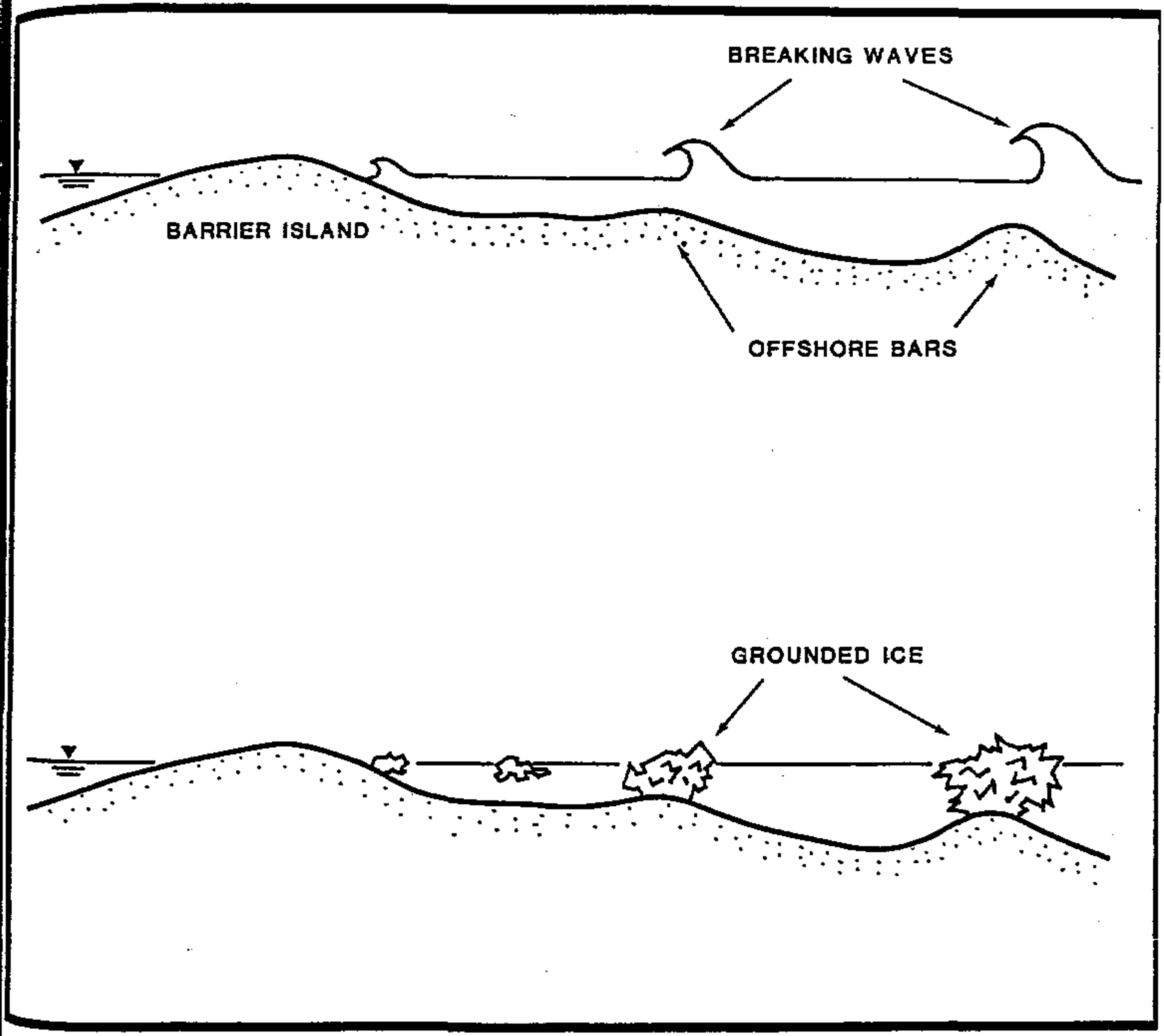


FIGURE 6.2 : INFLUENCE OF LONGSHORE BARS ON WAVE AND ICE IMPACT

PHOTO 28. WAVES BREAKING ON LONGSHORE BARS FRONTING BARRIER ISLAND

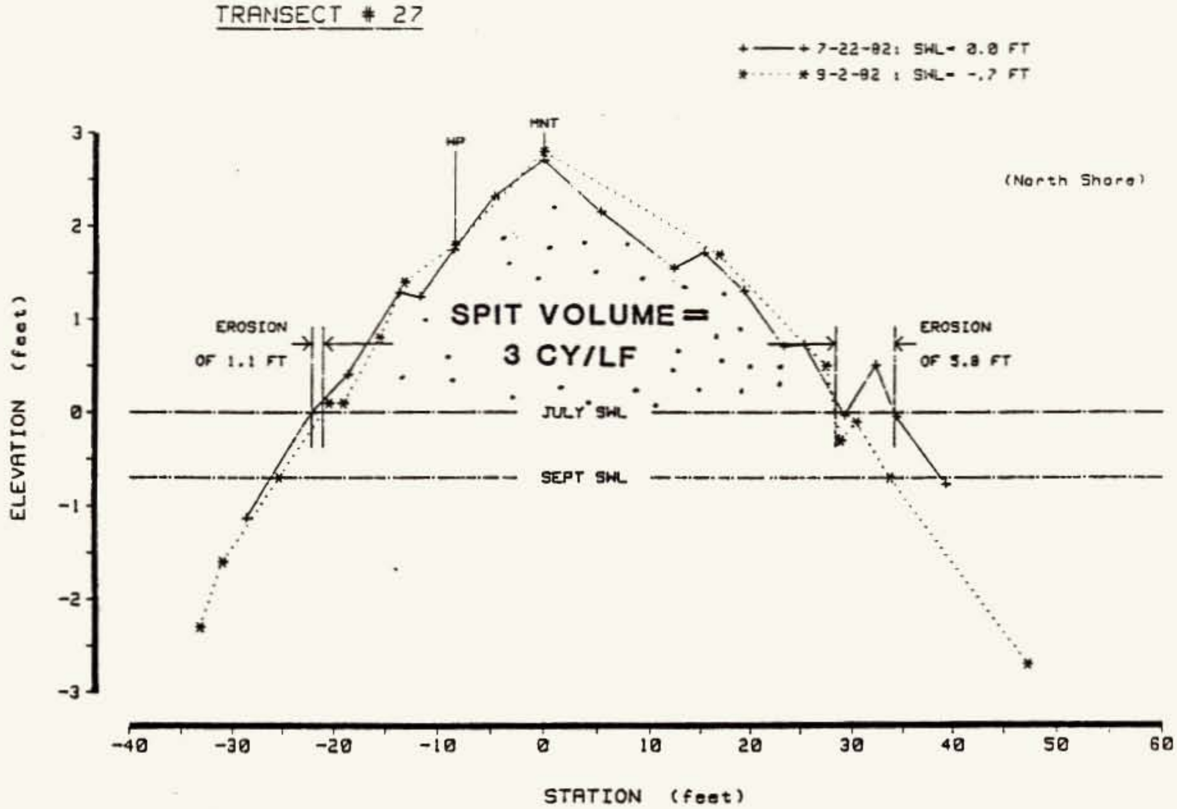
PHOTO 29. GROUNDED ICE FRAGMENTS CLEARLY SHOW THE POSITION OF OFFSHORE SAND BARS

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



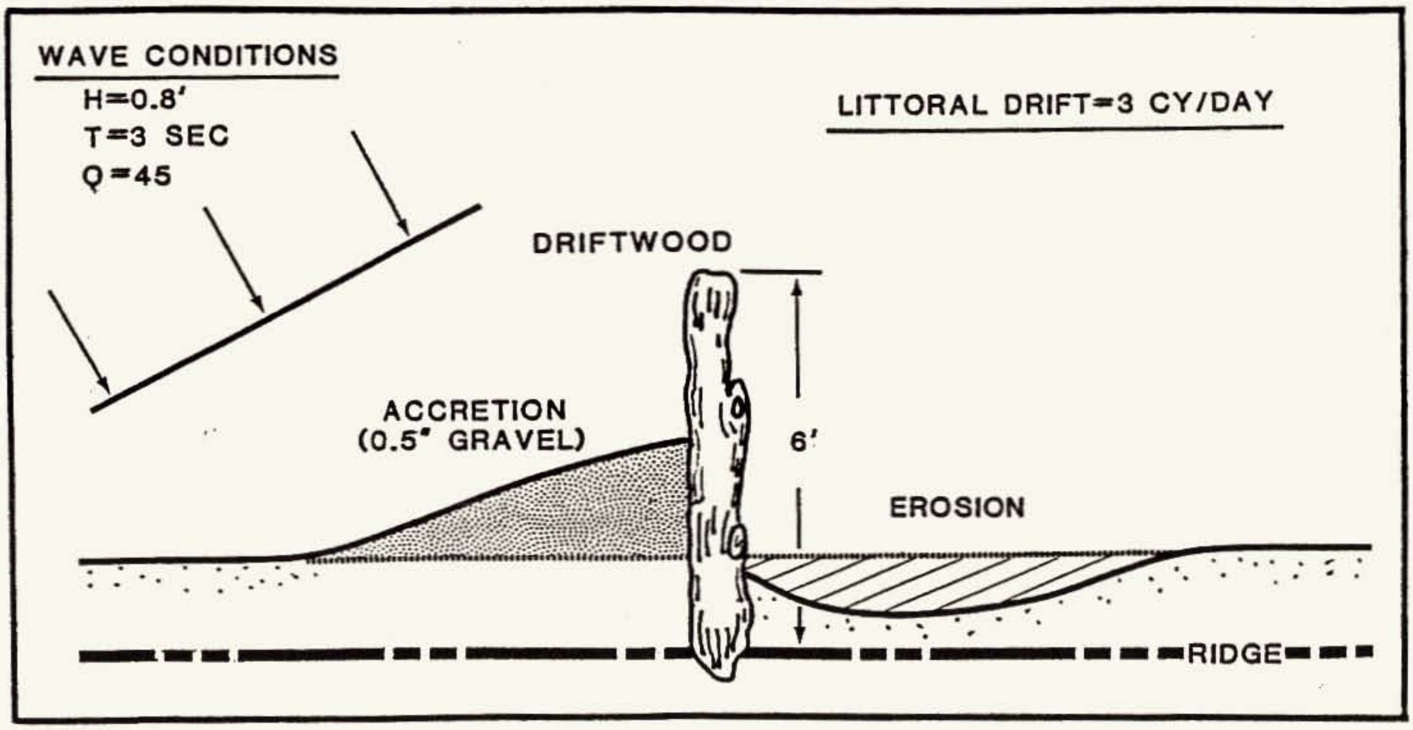


FIGURE 6.3 : LITTORAL DRIFT EXPERIMENT , TRANSECT #27

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

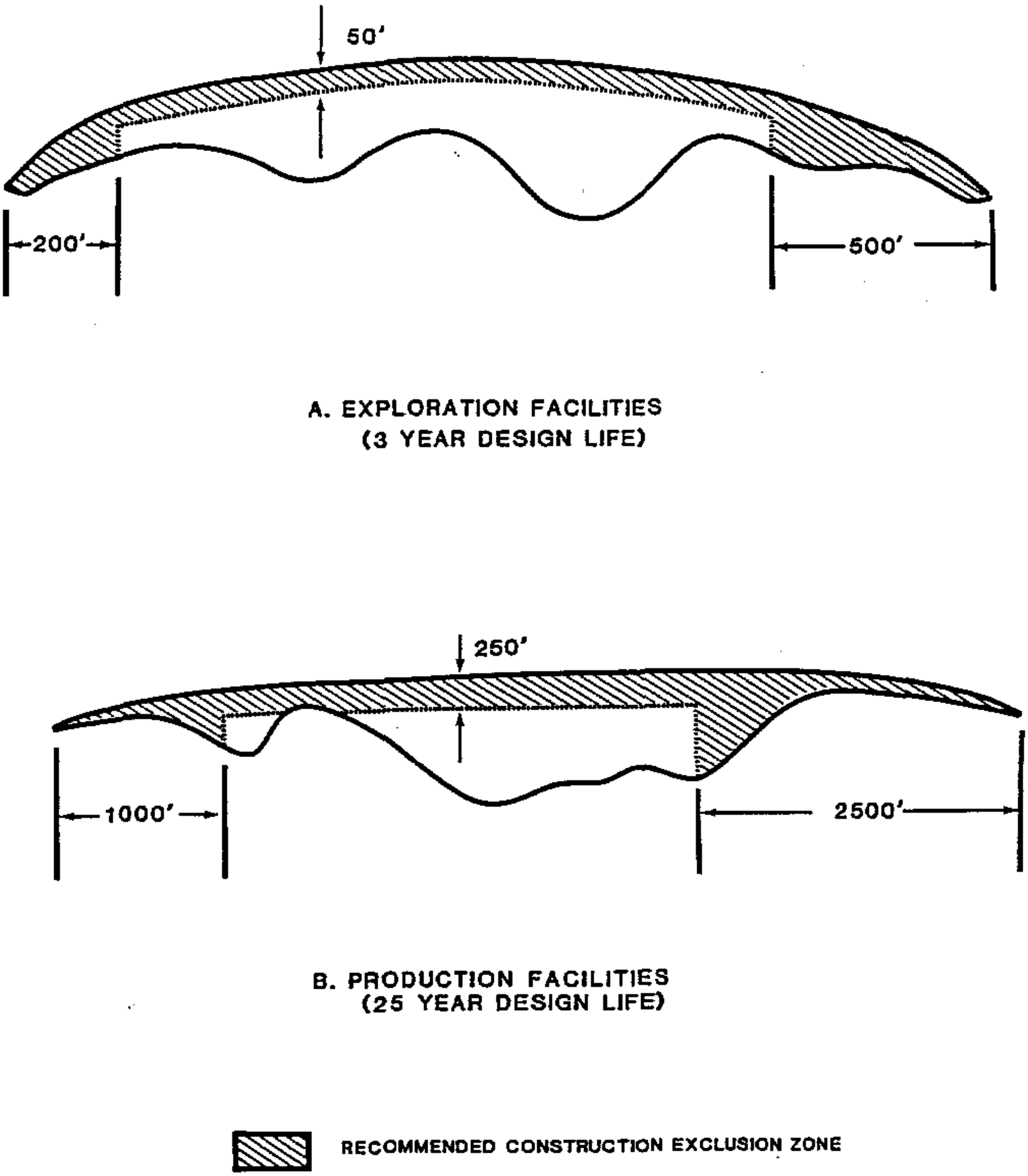


FIGURE 6.4 : COASTAL SET-BACK FOR BARRIER ISLAND FACILITIES

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 set-back 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

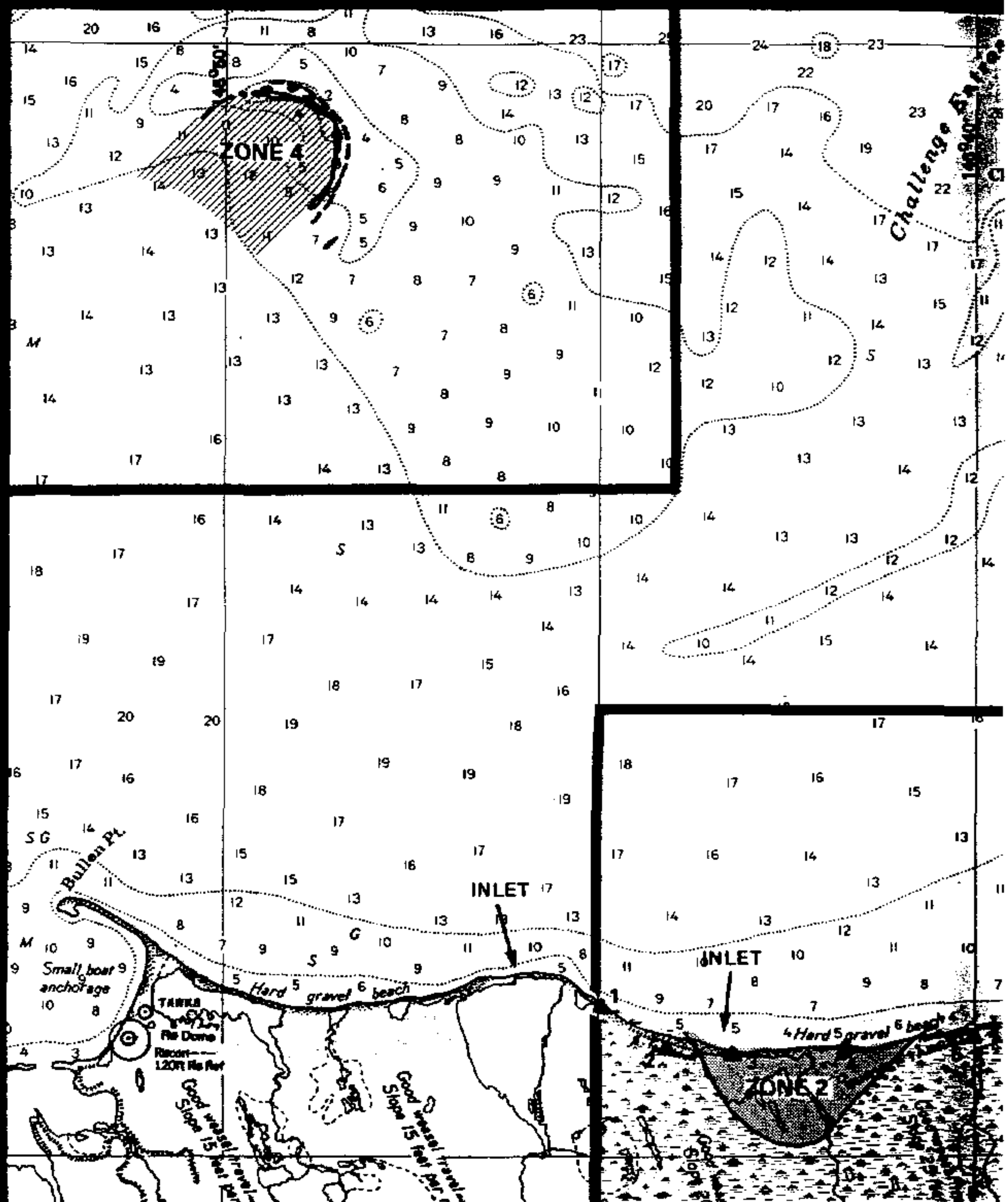


FIGURE 6.5

COASTAL CONSTRUCTION ZONES

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

DRAWN
[signature]

APPROVED
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NOTES:
BASEMAP FT
ORIGINAL S
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SOUNDINGS
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NORTH PAC
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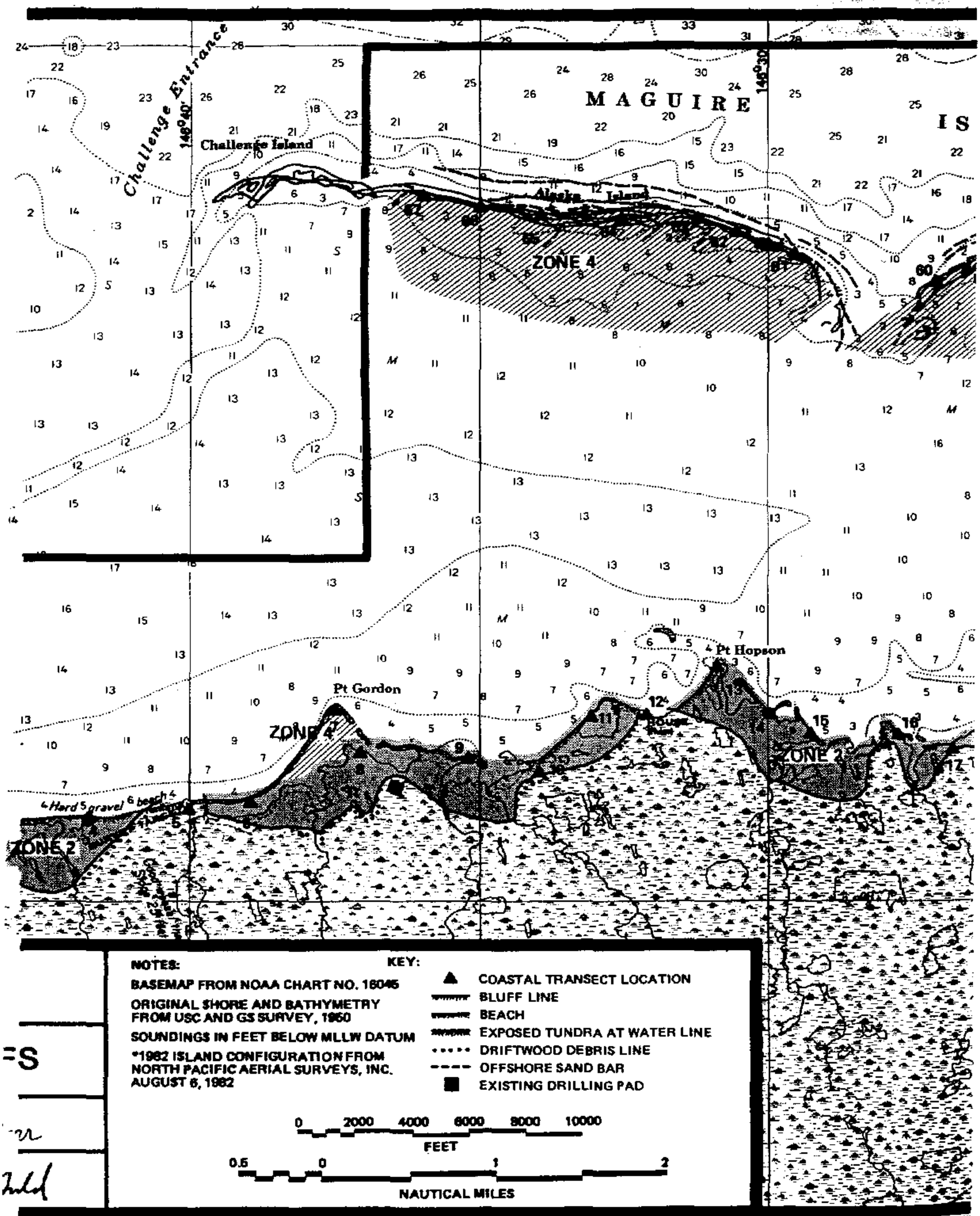
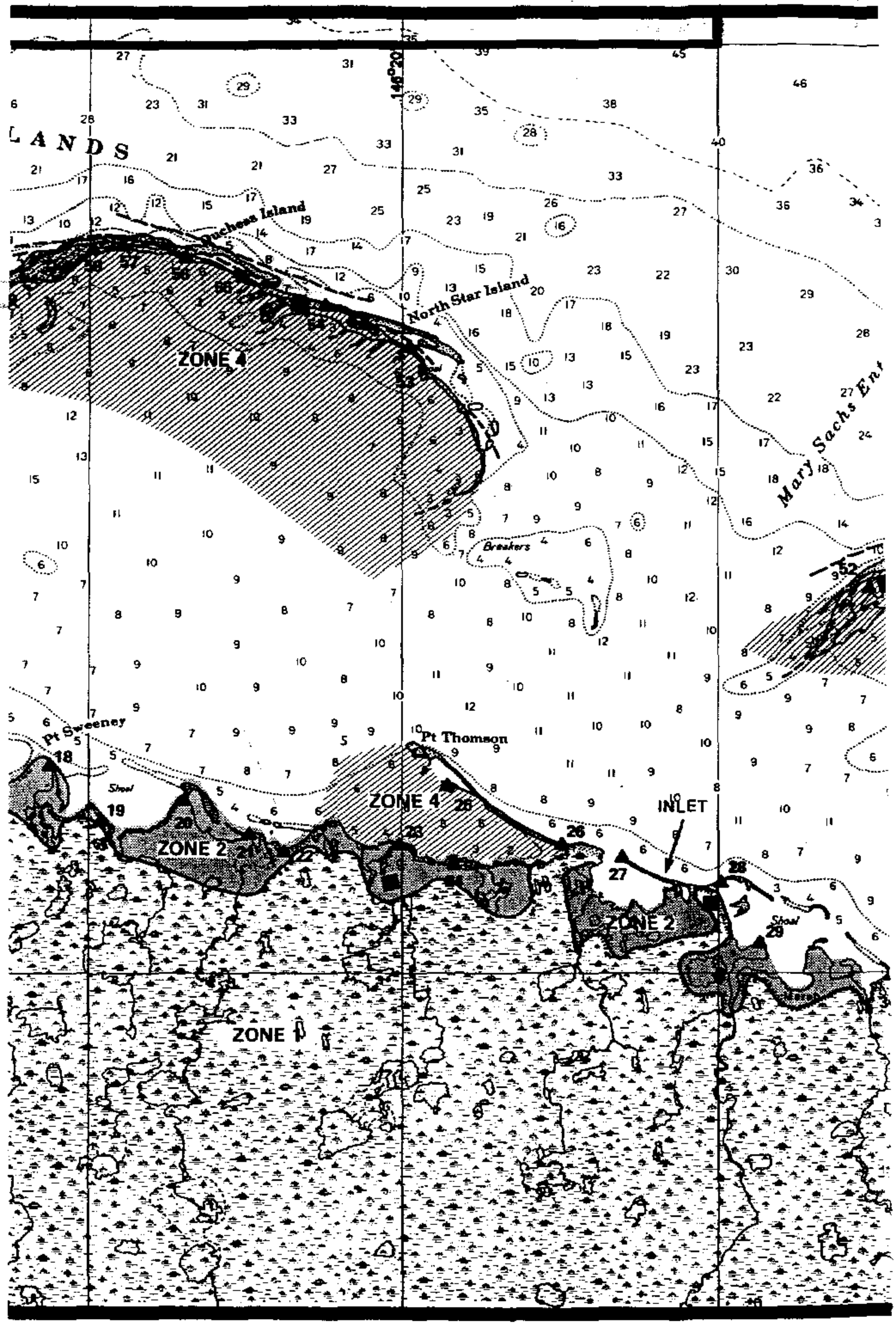
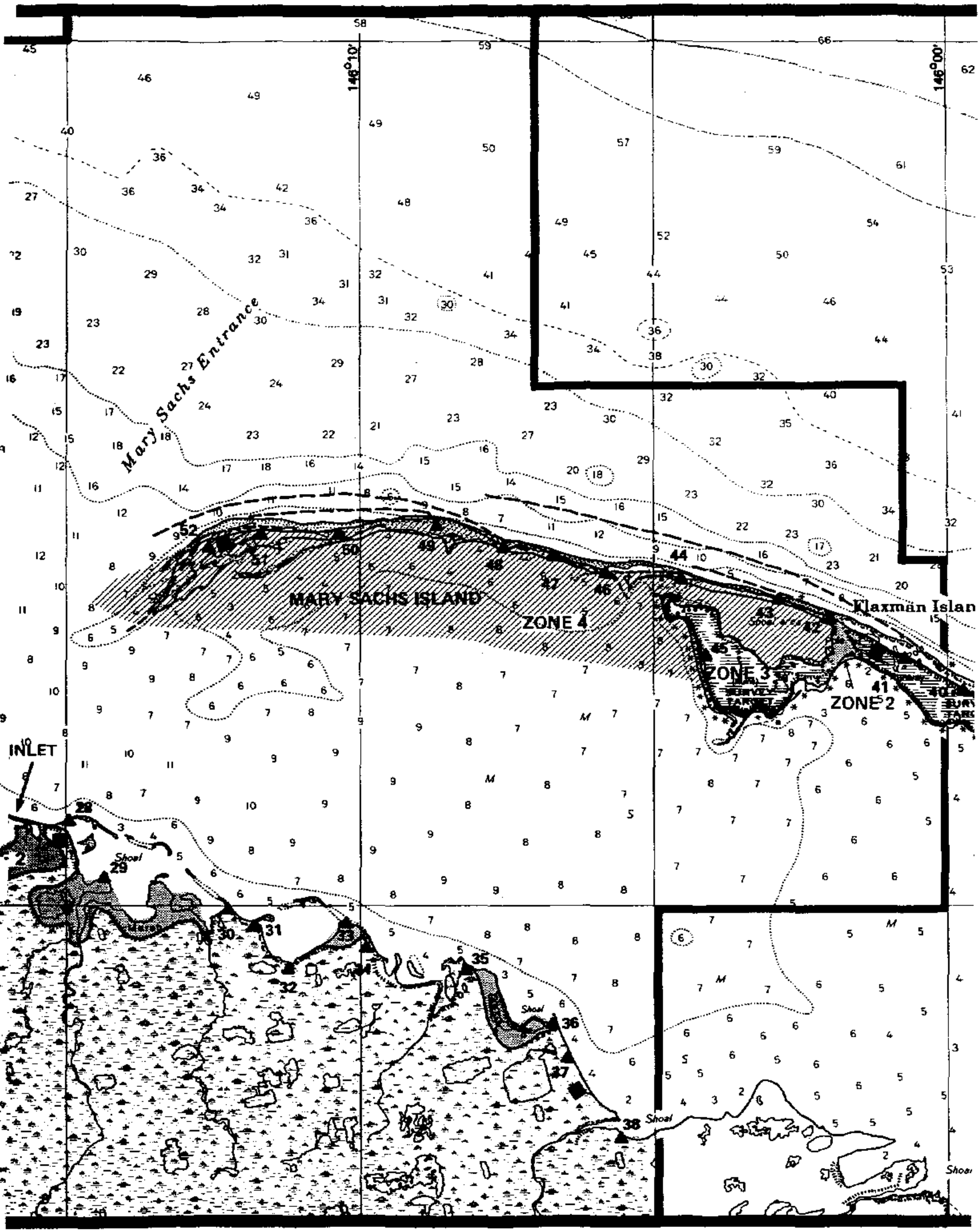
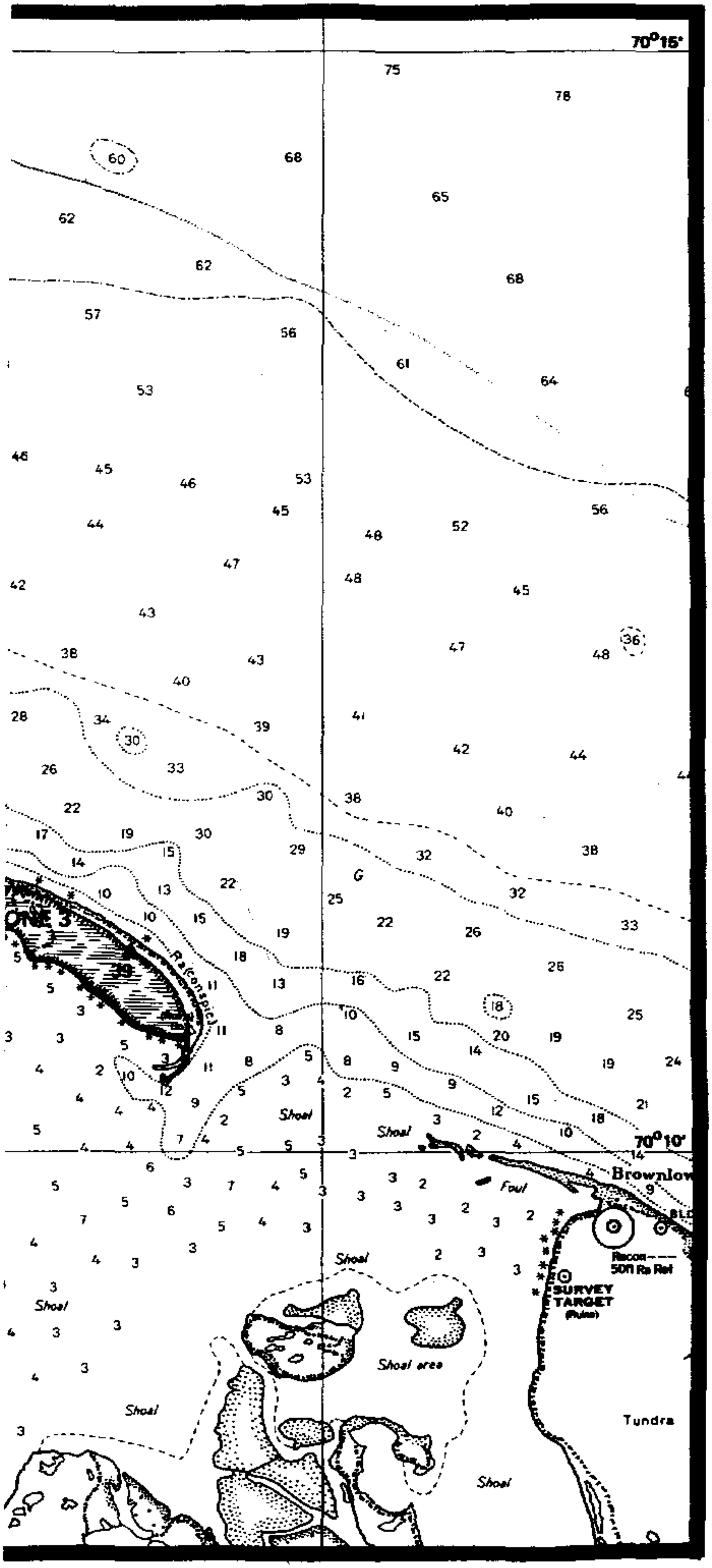


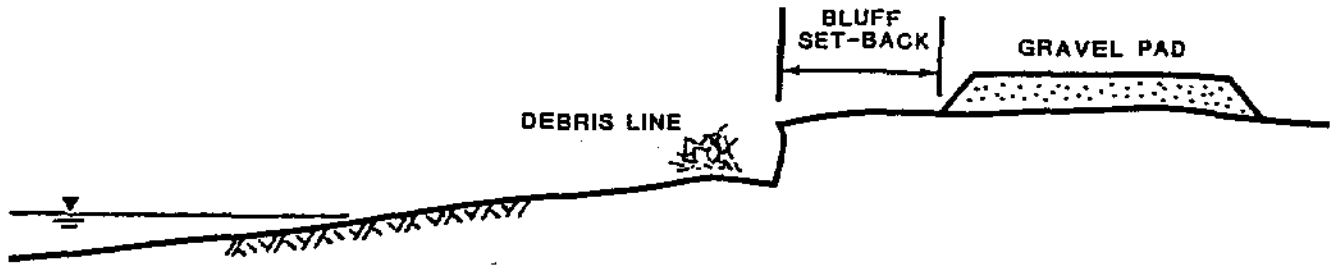
MAGUIRE
IS
Challenge Entrance
146°40'
146°30'
Challenge Island
Alaska Island
ZONE 4
ZONE 4
Pt Gordon
Pt Hopson
ZONE 2
ZONE 2
Hard gravel beach
NOTES:
BASEMAP FROM NOAA CHART NO. 16045
ORIGINAL SHORE AND BATHYMETRY FROM USC AND GS SURVEY, 1950
SOUNDINGS IN FEET BELOW MLLW DATUM
*1982 ISLAND CONFIGURATION 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
146°20'
ZONE 4
Mary Sachs Ent
Breakers
Pt Sweeney
Pt Thomson
Shoal
ZONE 4
ZONE 2
INLET
ZONE 2
ZONE 1

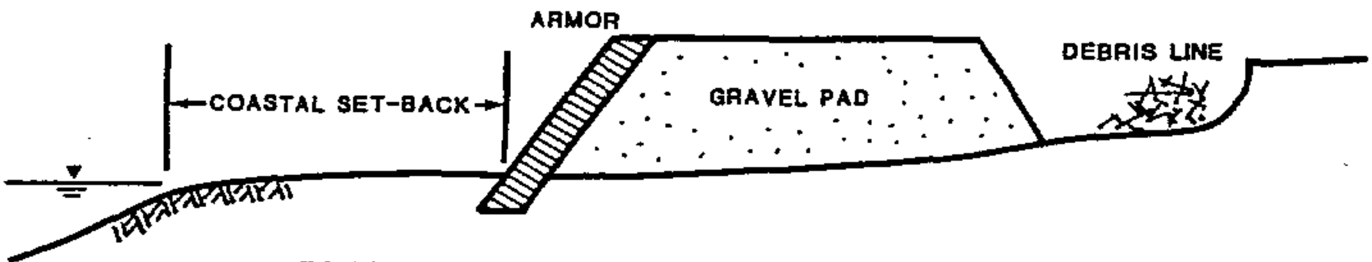

146°10'
146°00'
Mary Sachs Entrance
MARY SACHS ISLAND
ZONE 4
ZONE 3
ZONE 2
Flaxman Islan
INLET
Shoal



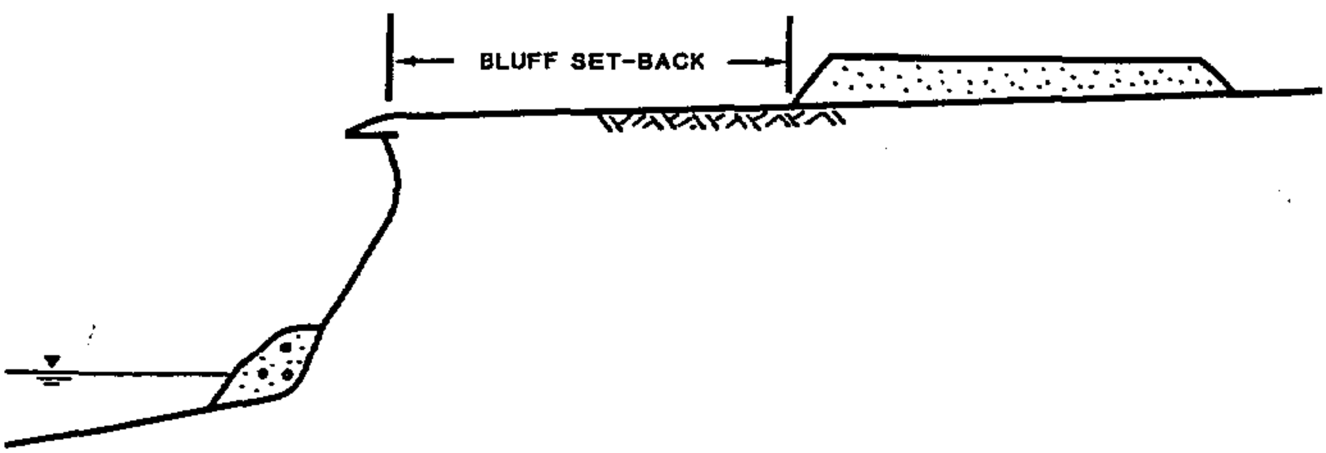
70°15'
Shoal
Shoal area
Foul
70°10'
Brownlow
Recon
50ft Ra Ref
SURVEY
TARGET
Tundra



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.

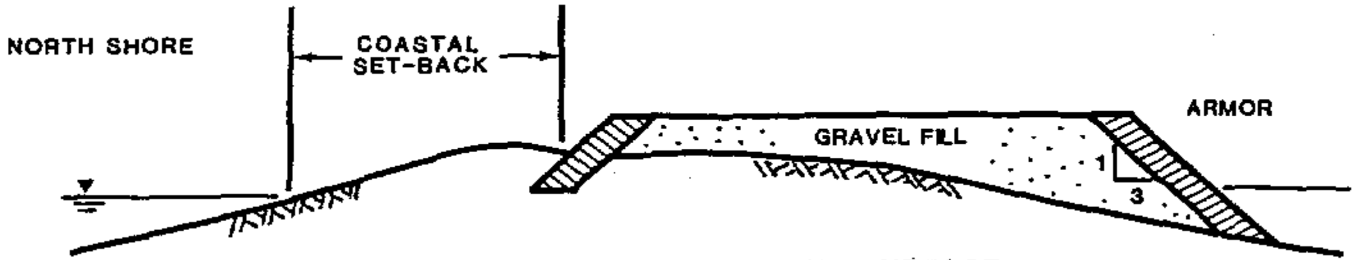
Previous experience is available for slope protection alternatives on Arctic barrier islands. For a one-year exploration pad on No Name Island, Amoco Production Company constructed an unprotected, elevated gravel pad similar to the previously decribed design for Zone 1 (Gadd, et al, 1982). In the Pt. 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).

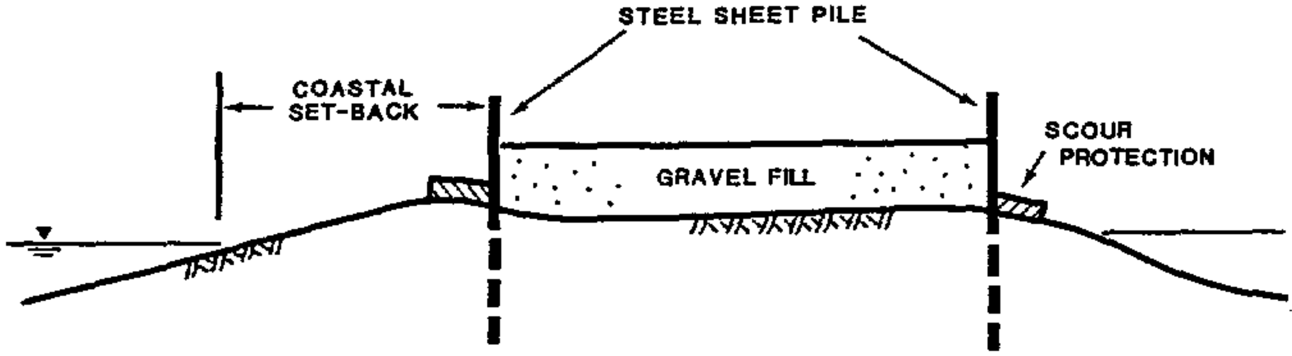
For the gravel pad option, the work surface elevation and slope armor are dictated by the environmental conditions and the design life of the structure. A set-back distance from the north shore must be respected. Note that the slope armor is buried at the structure toe to allow some measure of protection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

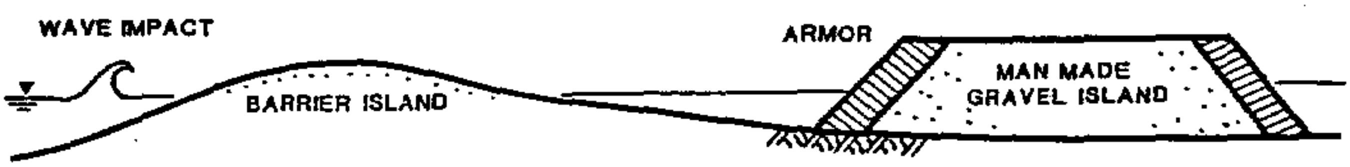
The protected waters of Zone 4 require island construction in water depths of from two to eight feet. Wave and ice impacts in this area are expected to be mild to moderate, due to the protection afforded by the barrier islands. For this alternative, the work surface elevation



A. GRAVEL PAD, BARRIER ISLAND SURFACE



B. SHEET PILE ENCLOSED PAD, BARRIER ISLAND SURFACE



C. MAN-MADE GRAVEL ISLAND IN LEE OF BARRIER ISLAND

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.

o 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)

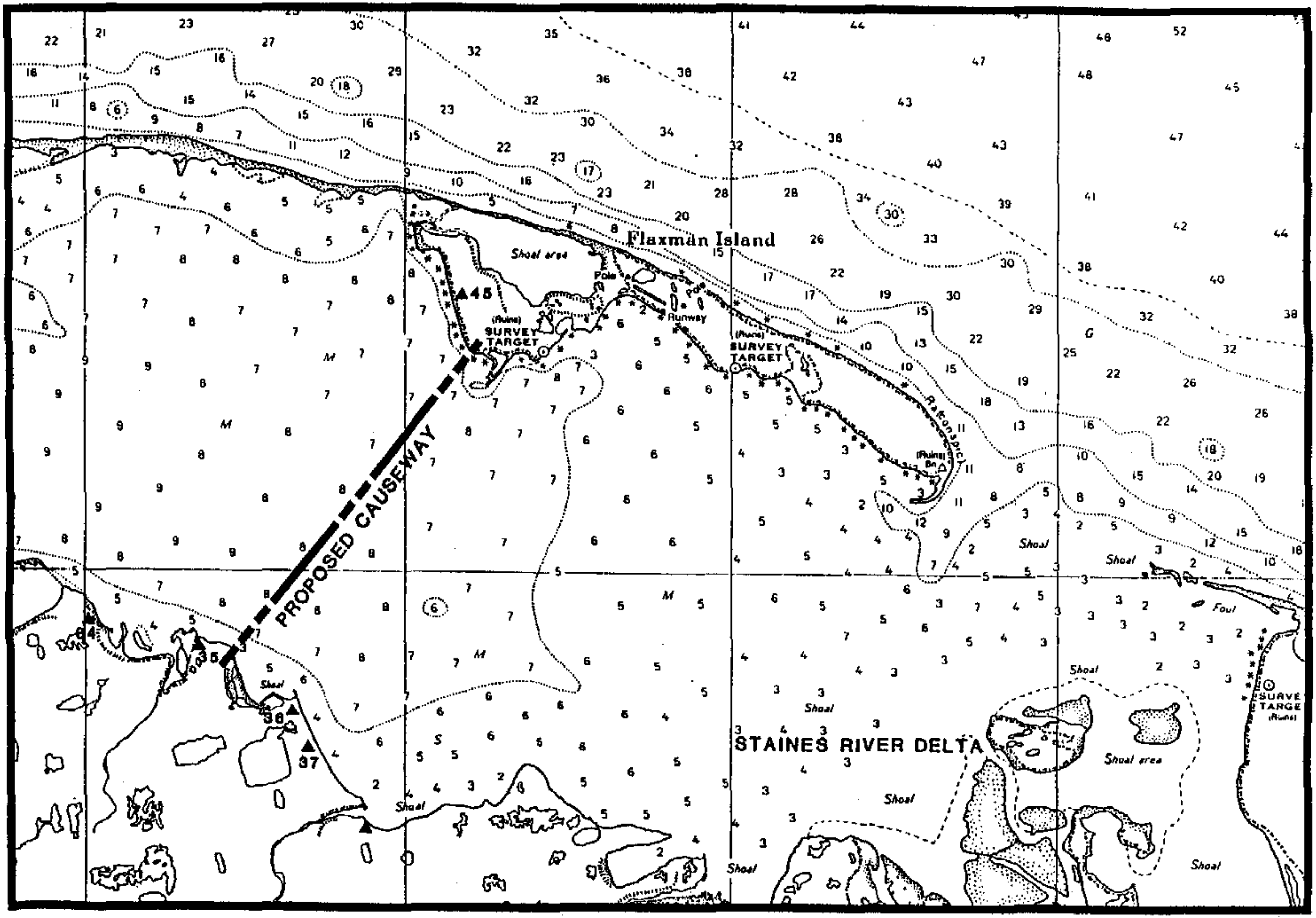


FIGURE 6.8 :PROPOSED CAUSEWAY LOCATION

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.

- 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

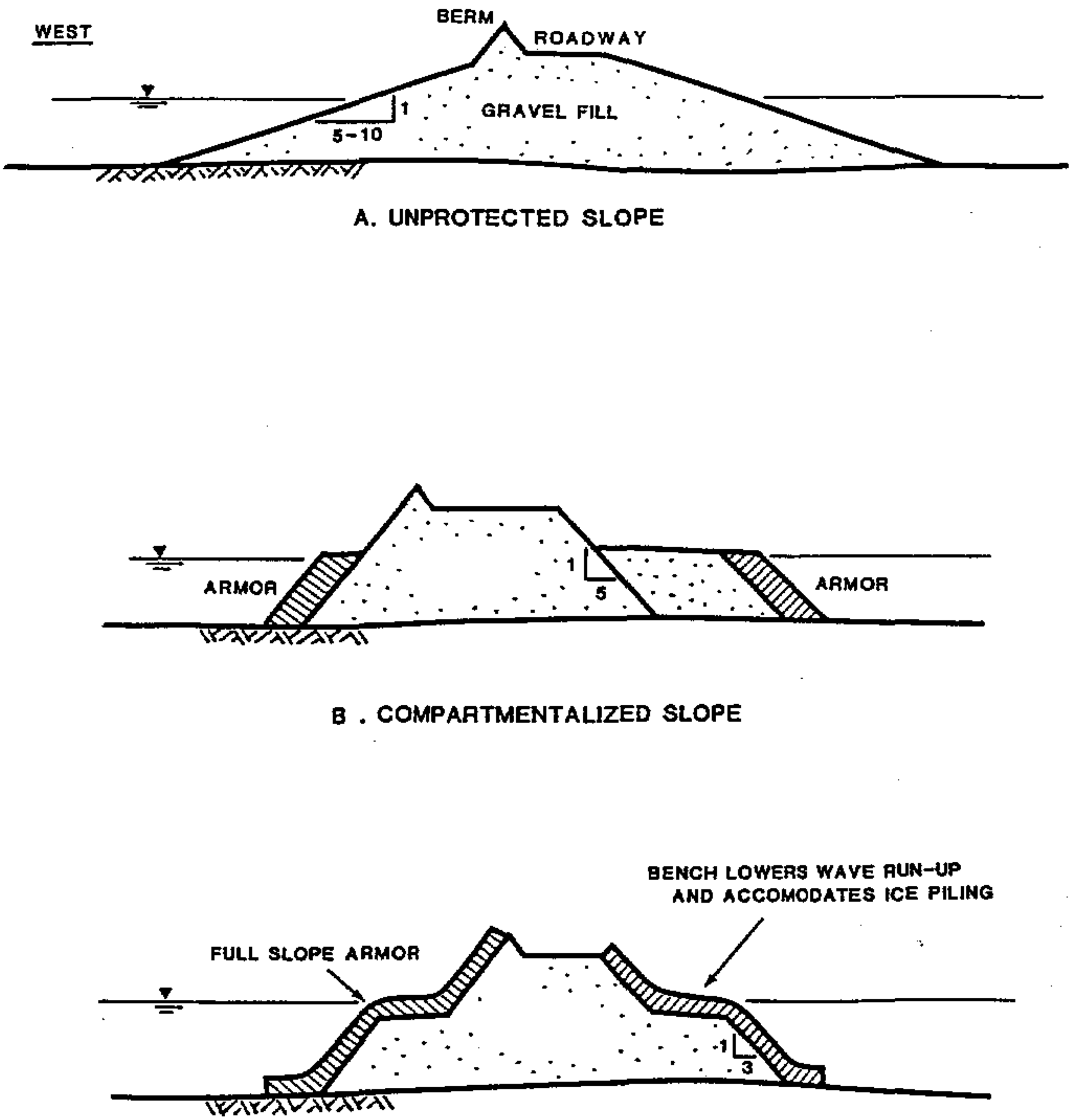


FIGURE 6.9 : CONCEPTUAL SLOPE PROTECTION, COASTAL CAUSEWAY

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.

<u>Coastal Processes:</u> 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:

- Topographic Mapping: 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.

- Offshore Bathymetric Survey: 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.

- <u>Historical Nearshore Bathymetric Comparison:</u> 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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