Attachment F

Sedimentation in the vicinty of a causeway groin - Beaufort Sea, Alaska

by Peter Barnes and Peter Minkler

Introduction

In 1980-81; 1.6 x 10^6 yds^3 of gravel were used to extend the "West Dock" causeway northwest of Prudhoe Bay, Alaska (Alaskan Construction and Oil, December 1981). Causeways and artificial gravel, sand, and mud structures are a proven, desired, and apparently economical technique used by industry in the U.S. and Canadian Arctic for offshore exploration and development activities. Concern has been expressed over the effect these artifical features may have on pre-existing circulation, faunal migration routes, and sediment transport pathways. Sediment pathways are affected by both the introduction of a new sediment source and by the alteration of the original transport pathways. In this report we document additional observed changes in bathymetry, and present further evidence indicating sediment accumulation in the vicinity of a 4.0 km solid-fill causeway extending from the northern Alaska coastline (Fig. 1). We feel that such documentation will provide insight needed to assess natural versus man-related changes. Gravel causeways and gravel islands promise to be more prevalent in coming years in the shallow nearshore waters of the Alaskan Beaufort Sea shelf. The effects of these artificial features on longshore sediment transport studies is poorly known and may adversely affect coastal and nearshore erosion and deposition patterns.

The causeway (also known as "West Dock") consists of 3 segments each about 1500 m long. The innermost segment was built during the winter of 1974-75. The middle segment was built during the following winter (1975-76), and the outermost segment was built during the summer of 1981. Thus the inner segment has influenced the coastal environment for about 7 years, the middle segment for 6 years, and the outer segment for less than 1 year.

Methods and Observations

Precision bathymetry from 1950, 1976, and 1981 was used to study changes in seabed topography. The data for 1950 was obtained from Coast and Geodetic Survey smooth sheet #7857. In both 1976 and 1981, a skiff was used to survey the shallow area between the entrance to Simpson Lagoon and the West Dock (Barnes et al., 1977 and Fig. 2). Additional bathymetric data were gathered using the R/V KARLUK. Water depth was acoustically measured to a precision of 0.2 ft. and is believed to be accurate to ±.5 ft. Navigation for 1976 and 1981 was controlled utilizing a precision range/range system and positions are believed to be accurate to 10 m. Sea level for all data was adjusted to Mean Lower Low Water (MLLW) using NOAA tide station #979-7649 located at the West Dock. Bathymetric data are given in feet as the 1950 and part of the 1976

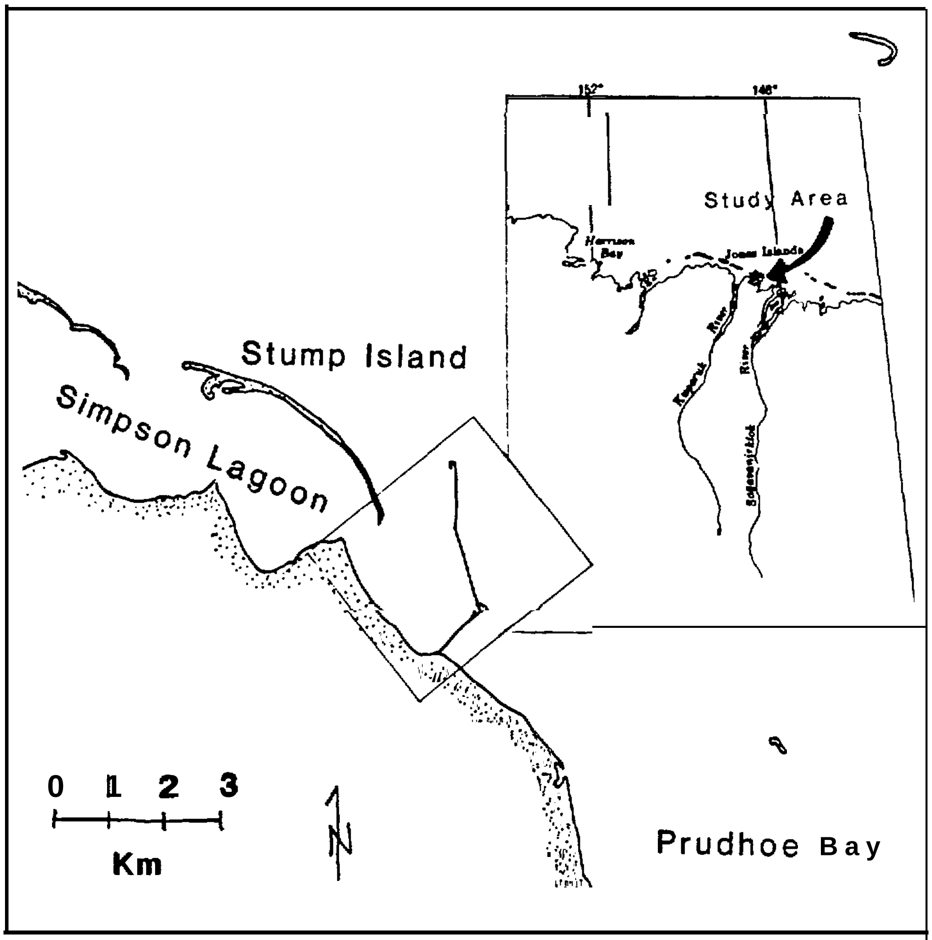

Figure 1. Location of causeway and study area, northwest of Prudhoe Bay, Alaska region.

surveys were measured in feet and we felt additional interpolation to metric units would significantly add error. The contoured bathymetry is shown in Figures 3,4 and 5.

Isopachs of the differences in observed water depth were made from surveys run between 1950 and 1976 and between 1976 and 1981 where overlapping bathymetric data exists (>4' water depth). For volume calculations, the mean value between isopach contours was used for the area between those contours. Considering navigation errors, line spacing, contouring subjectivity, and tidal differences, we believe the isopach map could be in error by a factor of as much as 2. The isopach map of bathymetric changes shown for the 26 years from 1950 to 1976 (Fig. 6) shows the net effect is change of 1 foot or less dominated by erosion, minor erosion (-.4 cm/yr) for the area west of the causeway, and minor net deposition (+.04 cm/yr) for the area to the east of the causeway (Table I). The data of Barnes and Minkler (1981) are not strictly comparable as different areas are considered.

For a common survey area, the isopach map shows that during the 5 years from 1976 to 1981, depth has generally decreased, suggesting deposition of up to 2.5 ft of sediment (Fig. 7). In the area west of the causeway the average sedimentation rate is 8.5 cm/yr, and for the area east of the causeway the average sedimentation rate is 7.6 cm/yr (Table I). Bathymetric data for 1976 and 1981 overlap in a larger area than the 1950 data primarily in water depths less than4 ft. (Figs. 4 and 5).

For this extended area an isopach of changes between 1976 and 1981 was drawn (Fig. 8). The results indicate deposition of up to 2 ft of sediments extends inshore during the 5-year period between surveys (Fig. 8). The west side shows 6.8 cm/yr average sedimentation, the east side shows 7.6 cm/yr average sedimentation.

Table I - Areas, volumes and rates of seabed change

	Common Area (1950-1981)			Extended Survey (1976-1981)		
	West	East	Total (Avg.)	West	East	Tota 1 (Avg.)
Area 1950-1976 ($x10^5 m^2$)	24.1	11.9	36.0	43.3	4.5	47.8
Net gain (+), loss (-) ($x10^5 m^3$)	-2.5	+0.1	-2.4	---	---	
Rate ($x10^5 m^3$/yr) of gain or loss	-0.1	+0.004	-0.1	---	---	
Average sedimentation rate-cm/yr	-.4	+.04	(-,25)	---	---	
Area 1967-1981 ($x10^5 m^3$)						
Net gain (+) loss (-)	+10.4	+4.5	+14.9	+14.8	+4.5	+19 .3
Rate ($x10^5 m^3$/yr) of gain or loss	+2.1	+0.9	+3.0	+2.96	+0.9	+3.86
Average sedimentation rate-cm/yr	+8.5	+7,6	(+8.2)	+6.8	+7.6	(+6.9)

The volumes represented by the change in bathymetry were computed from the isopach maps. The areas between the isopach contours were multiplied by the mean value of the two contours. Between 1950 and 1976 the survey area lost about 10,000m^3/yr. While between 1976 and 1981 the survey shows the area to have gained sediment at a rate of 300,000 m^3/yr.(Peter, pls note I had to condense the table to fit on sheet).

A 37.5-cm-core sample was obtained in water 2 m deep 100 m west of the causeway (see Fig. 2). The core consisted of 35 cm of mud underlain by 2.5 cm of gravel. We interpret the gravel base as materials spilled during the time the causeway was being built (1975-1976). The accumulation of mud above the gravels would indicate an average sedimentation rate of 6 cm/yr.

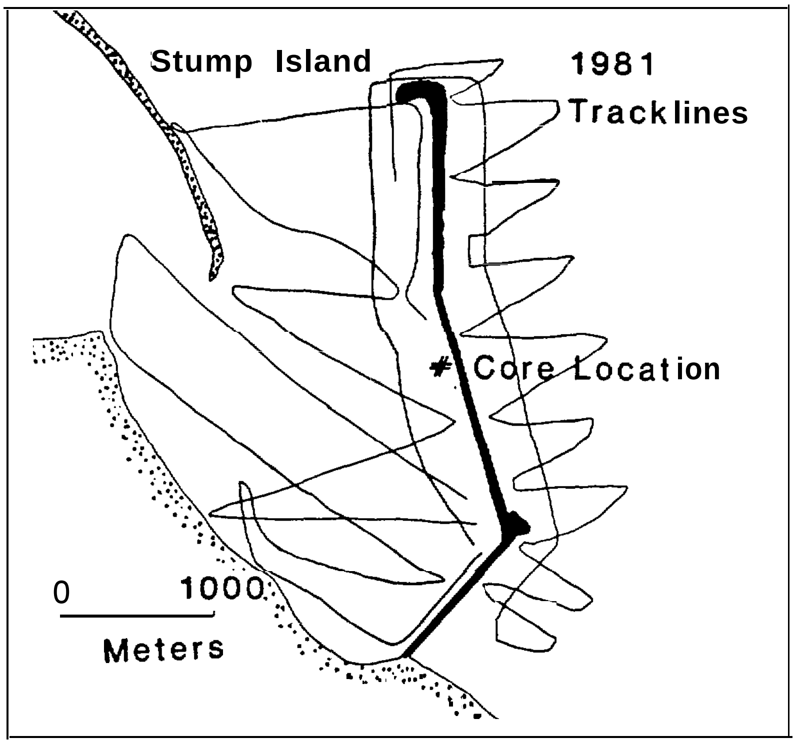

Figure 2. 1981 Bathymetric tracklines used to construct contour map of figure 5.

Discussion

Earlier papers (Barnes and Minkler, 1980, 1981) discussed the effect of the causeway on the geological environment. The 1981 survey extends the coverage and further confirms that the causeway has greatly influenced local sedimentation patterns. Sedimentation has occurred on both sides and offshore of the causeway (Figs. 7 and 8).

Prior to causeway construction sediments in this study area would have been vigorously transported through the study area by intensified currents entering the narrow entrance to Simpson Lagoon and by waves developed over long fetches in Stefansson Sound (Fig. 1). These observations are in keeping with the general coastal and island erosion and retreat noted by Barnes et al. (1977) and by other workers along the coast (Lewellen 1977; Cannon 1979; and Reimnitz, 1980).

Reimnitz and Kempema (1982) observed infill of a natural sediment trap (a strudel scour) on the Sagavanirktok River delta 18 km east of the West Dock. They calculated a volume of bedload sediment moving over the delta platform of 9 $m^3m^{-1}yr^{-1}$. If the two inner causeway segments act as a 2500-m groin perpendicular to the shore, they could form a barrier to 22,oo0 m^3 per 30,000 m of sediment per year. This number is an order of magnitude less than the sediment actually accumulating around the causeway (300,000 m^3/yr, Table I). Thus the causeway apparently traps the equivalent of 10 times the bedload traveling in the nearshore. As bedloads are much less than the total sediments in transit--in streams suspended loads are 10 times beload--the causeway is apparently trapping much of this sediment also.

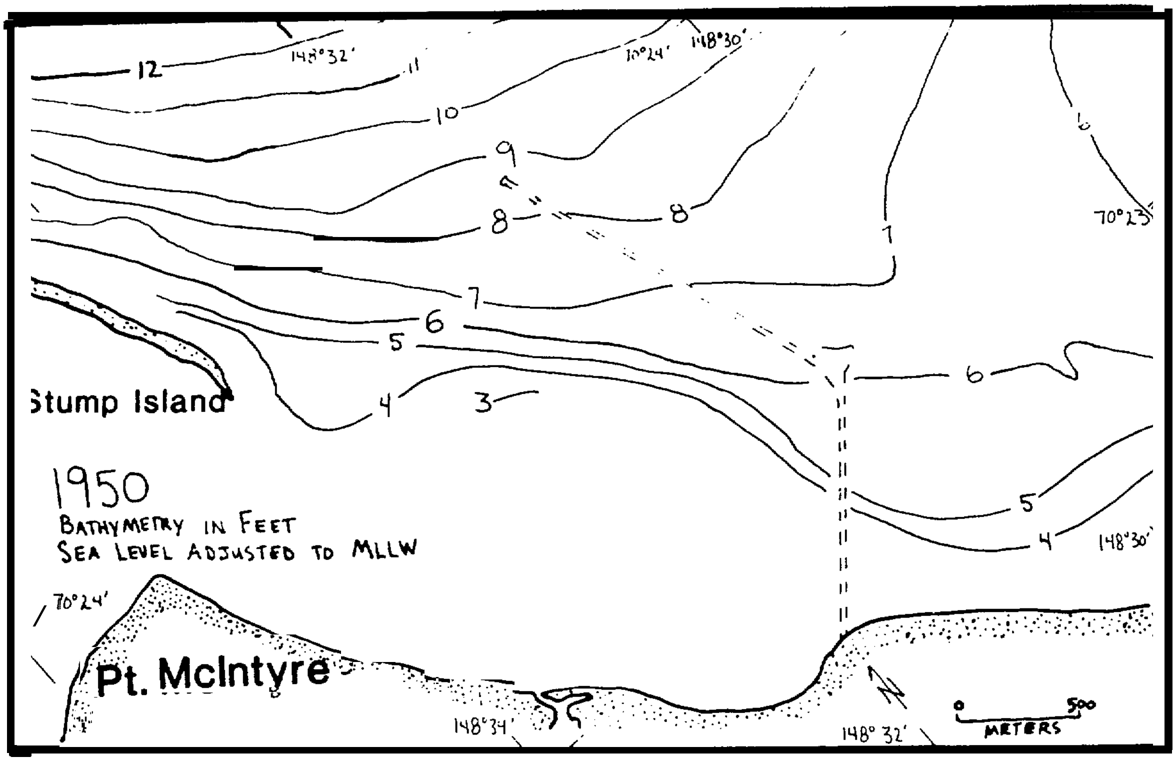

Figure 3. 1950 bathymetry (in feet) from Coast and Geodetic Smooth Sheets. Future location of causeway is shown (see Fig. 1).

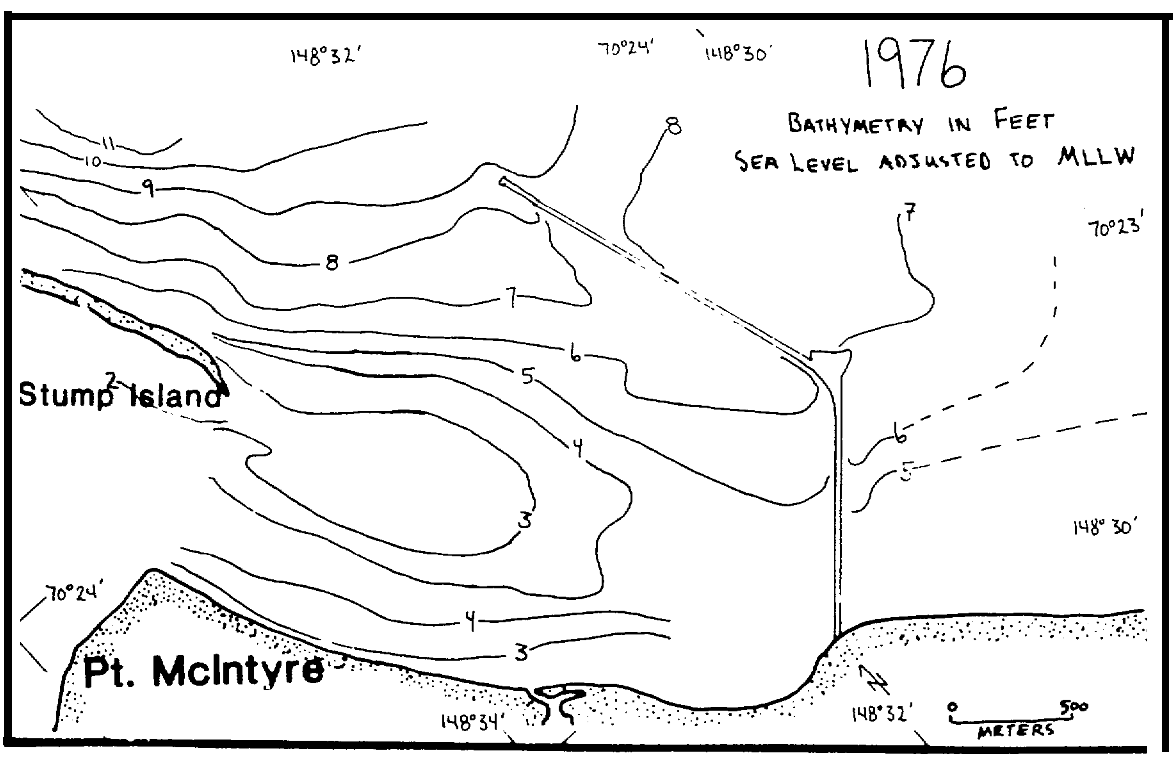

Figure 4. Summer **1976 bathymetry** (in feet). Causeway was finished early in 1976.

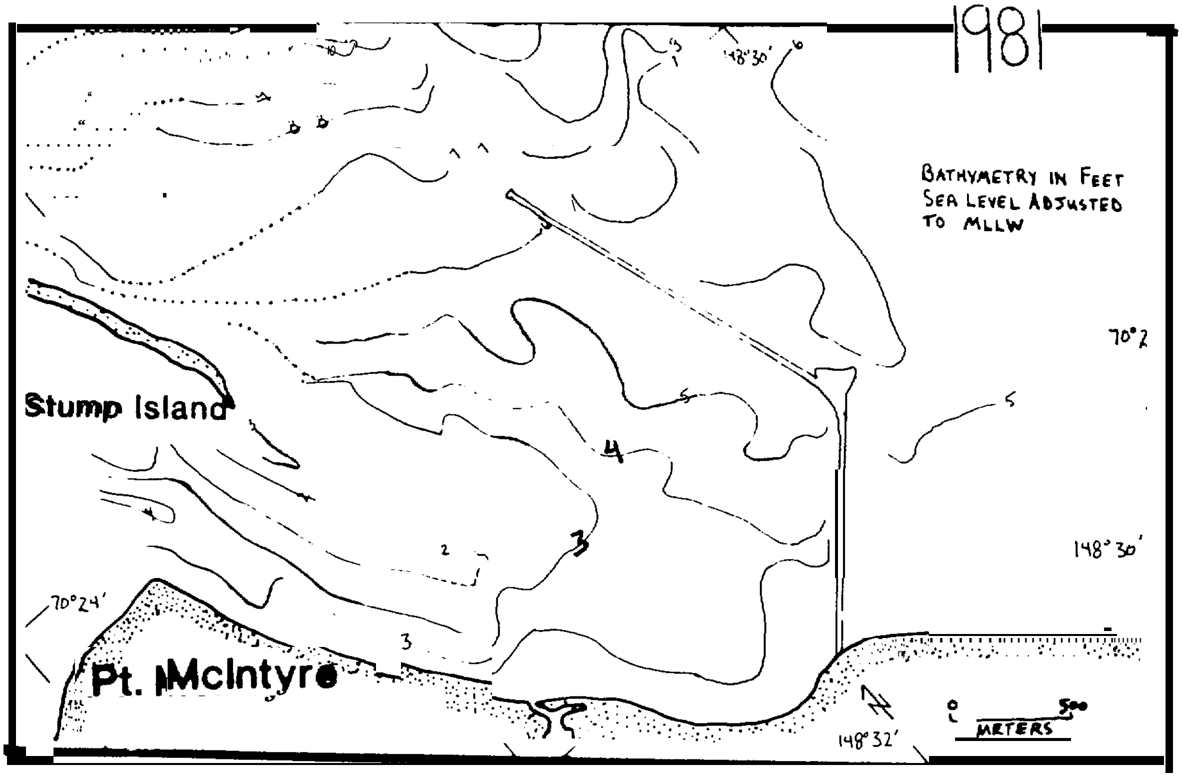

Figure 5. Summer 1981 bathymetry (in feet).

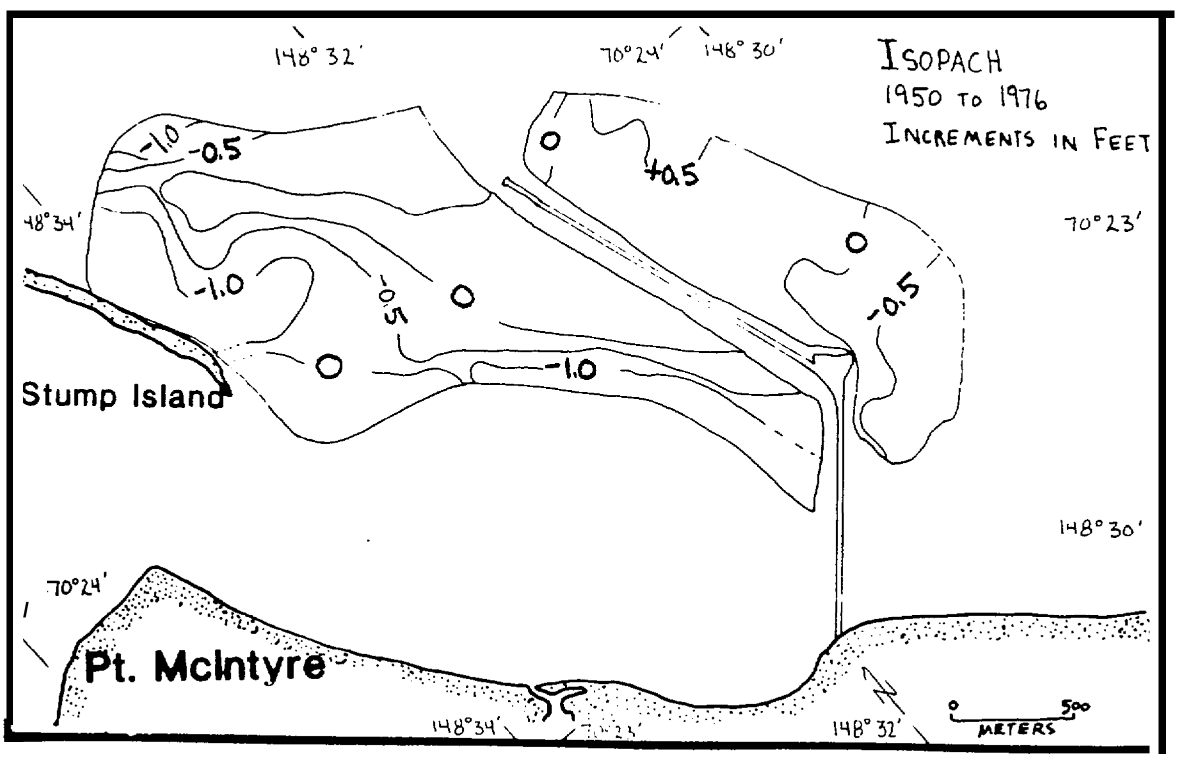

Figure 6. Isopach map (in feet) showing bathymetric changes from 1950 to 1976. Limit of isopach map is determined by the limit of overlapping data 1950 and 1976. (See Figs. 3 and 4).

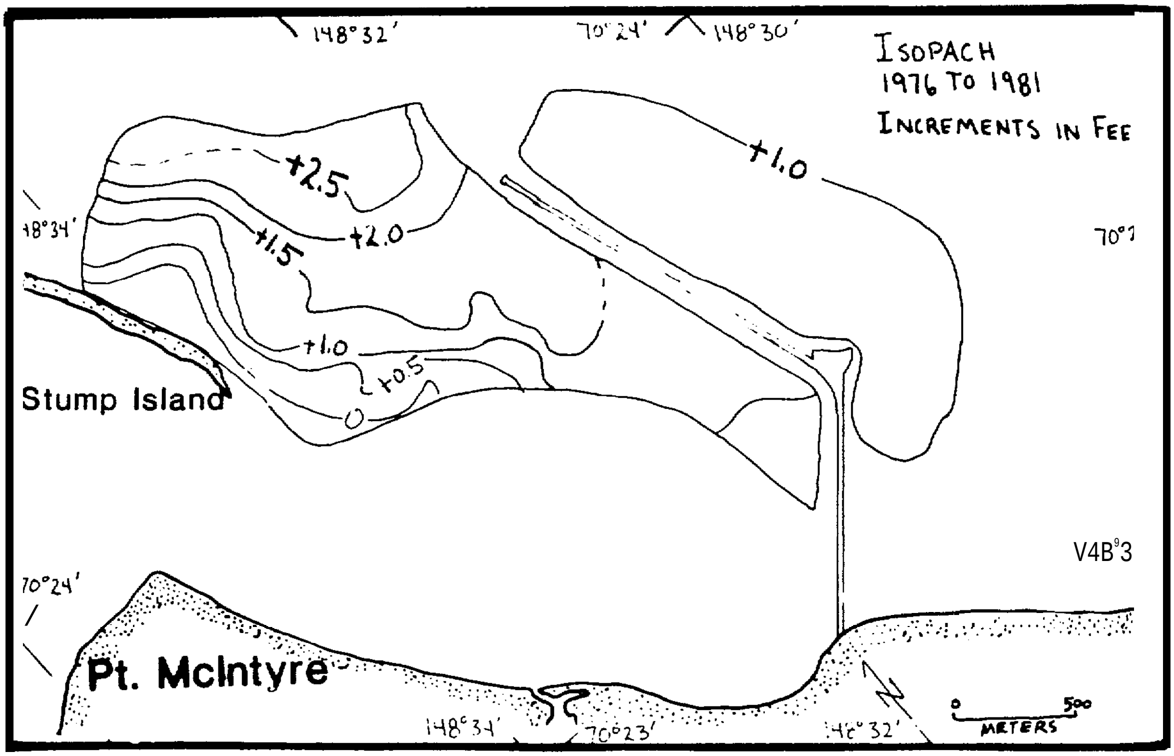

Figure 7. Isopach map (in feet) showing bathymetric changes from 1976 to 1981. Area isopached is same as Figure 6.

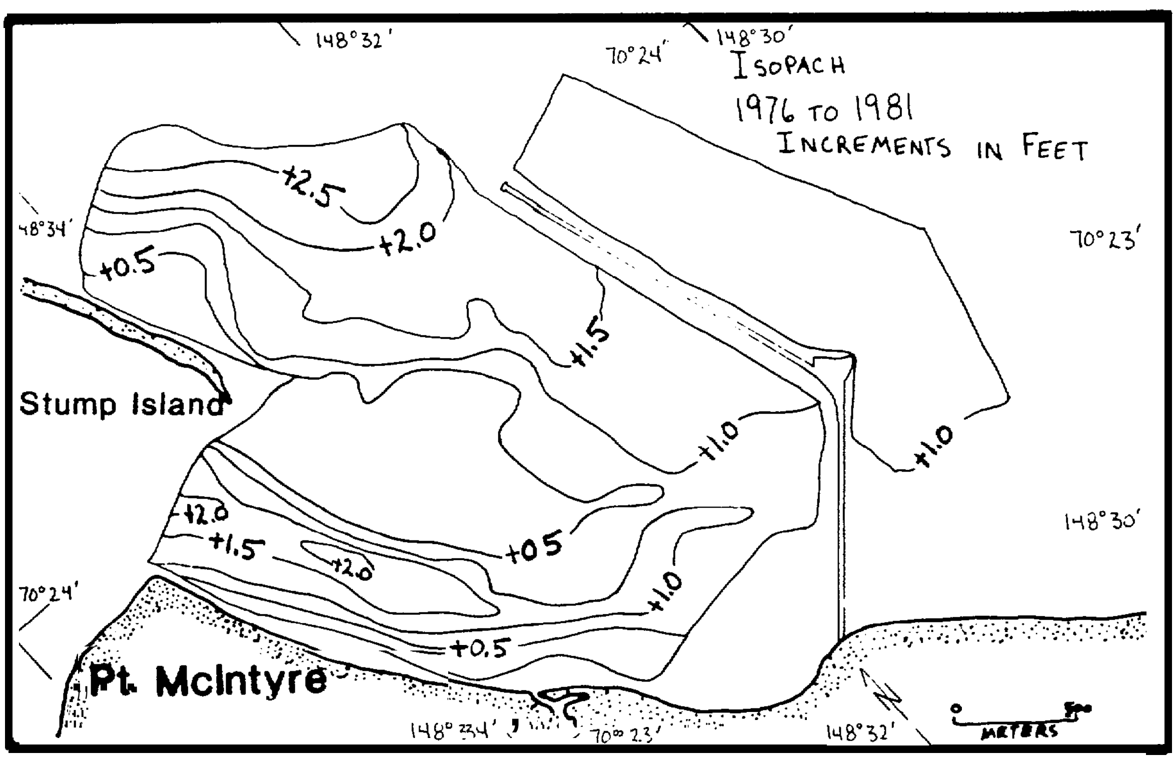

Figure 8. Extended isopach map (in feet) showing bathymetric changes overlapping data sets obtained in 1976 to 1981. (See Figs. 4 and 5.)

Harper (1982) studied changes in the mud content of surficial sediment near the causeway from 1977 to 1981. These two studies showed that during the 4-year period surface sediment on the east side of the dock became coarser while sediment on the west side became finer (Fig. 9). During the open-water season currents flow westerly due to the predominant northeast winds (Mangerella et al., 1982). The causeway then acts as a groin to divert and intensify currents on the east side (Fig. 10). The more intense currents are believed responsible for the deposition of coarser sediment. The quiet backwater created to the west of the causeway under the prevailing northeast wind would enhance the deposition of finer materials. Furthermore, during periods of northeast winds (Fig. 11) the area to the west of the causeway is an area of reduced wave energy that further enhances deposition of fine-grained sediment.

Sediment sources for the area could be coastal erosion, input from the Sagavanirktok and Kuparuk Rivers, the causeway itself, reworked sediment from the seabed, and combimtions of these. We believe reworking of the sea floor in the coastal area to the east of the causeway is the most likely source of the deposited materials. The Kuparuk river is downstream from the sites of deposition during periods of northeasterly winds. The Sagavanirktok River is about 15 km to the east; too far to be an immediate sediment source. Coastal erosion of the 1- to 2-m-high coastal bluffs near the causeway is abut 1 m per year (Barnes et al., 1977) and again too small a source to be the immediate provider of sediment. The causeway itself is composed predominantly of sandy gravel with less than 5 percent fines and again is an insufficient source; especially since *only* **the** surface of the causeway deposits are reworked.

The ***seabed*** in the vicinity is composed of variable amounts of sand, silt, and clay (Barnes, 1974; Barnes et al., 1980) probably derived over time from the three sources discussed above: rivers, coastal erosion, and the causeway. As this sediment becomes resuspended during summer and fall storms, its transport and deposition are controlled by the wave and current regime in the vicinity of the causeway. This means that coarser sediment will be depositing on the eastern side of the causeway with its higher wave and current energy and that finer-grained sediment will be deposited in the lee of the causeway to the west where lower wave and current energies are encountered.

If breaks or openings in the causeway had been incorporated during 1974 and 1975 construction, they may have maintained the original sediment transport regime. The present bridged opening between the middle and outer segments may affect sediment transport pathways. The frequent infilling with gravel during the summer of 1981 suggests nearhsore sediments are initially attracted to the opening. The island chain bordering Simpson Lagoon (Fig. 1) could be considered as a long causeway. The fact that sedimentation rates in this lagoon **are** known to be low even with the Kuparuk River dumping into the eastern end (Fig. 1), suggests that the lagoon is well flushed. The openings between the islands form about 10 percent of the barrier (causeway) length. This suggests that breaks on the order of 10 percent of the length of the causeway would be sufficient to alter the rate of siltation in the vicinity of the causeway. The present opening is only 1 to 2% of the causeway length and thus may be inadequate to influence sedimentation.

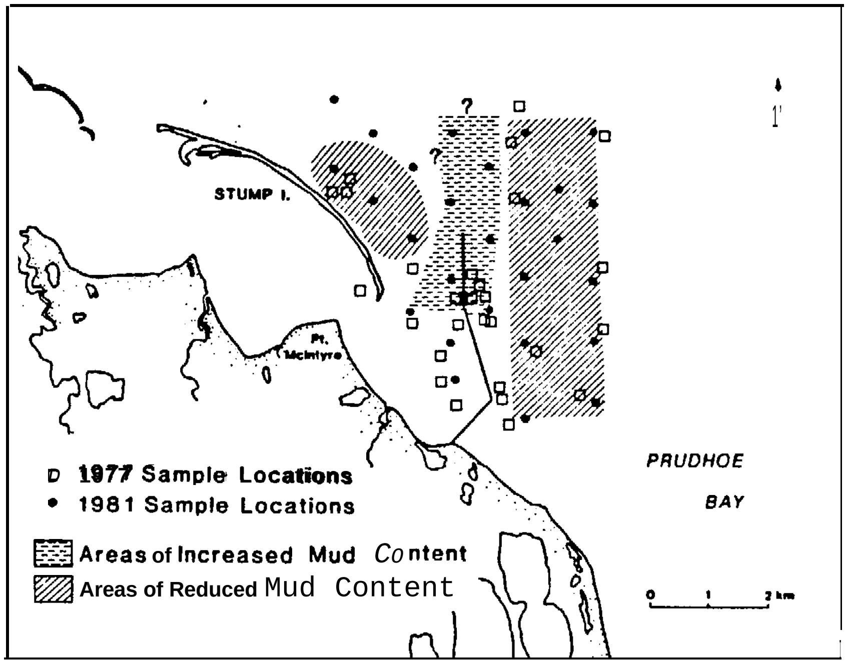

Figure 9. Changes in surficial mud percentages between 1977 and 1981 (from Harper, 1982) .

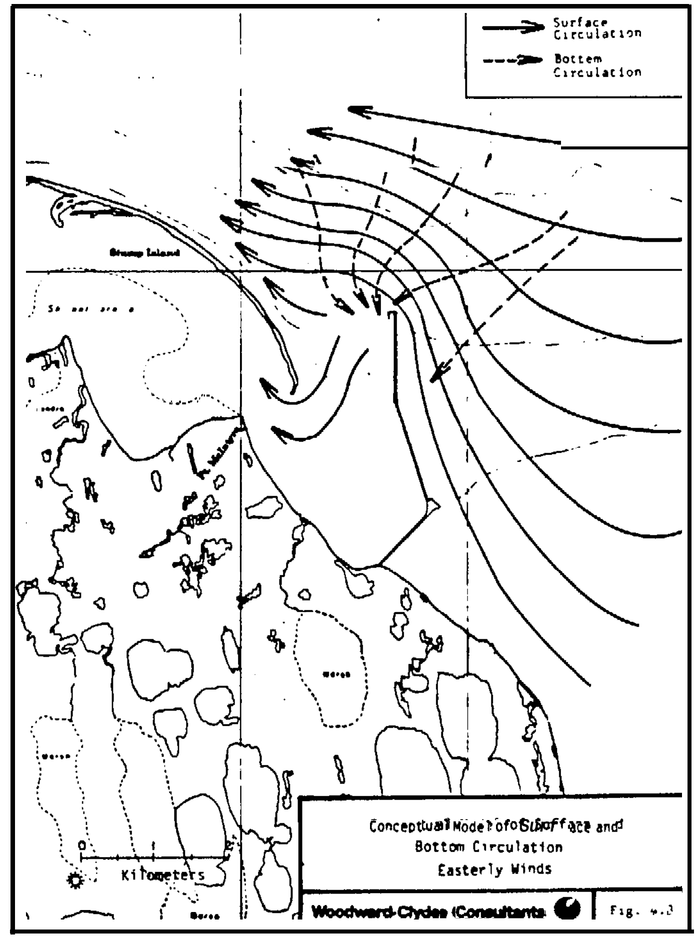

Figure 10. Conceptual model of surface and bottom circulation with easterly winds from Mangarella et. al. , 1981

Data from inshore (Figs. 4,5, and 8) suggest that the shoal extending from the east tip of Stump Island has built up 1-2 feet since 1976. In 1976 a 4-foot channel ran along the coast from Stump Island toward the causeway. This channel is about 1 foot shallower now (Fig. 6) and suggests a less effective flushing of the eastern end of Simpson Lagoon.

Summary

Repetitive bathymetric surveys and subjective observations indicate that sediment deposition is occurring in the vicinity of an artificial-fill causeway. Previously the area had been one of seabed erosion. The change in environment is related to the change in wave and current regime brought about by the causeway construction. The combination of obstruction to shore-parallel transport and the deflection of flow offshore results in sedimentation in the vicinity of the causeway; the dominant winds from the northeast favor fine-grain sedimentation in the lee. Thus the causeway acts as a groin to decrease currents and to allow sediment to be deposited. Extension of the causeway from the water flood project will extend the area of quiet waters and deflected currents and will extend the area of sedimentation seaward. Providing openings, similar to those in the existing barrier island chains, might maintain the present sediment transport regime.

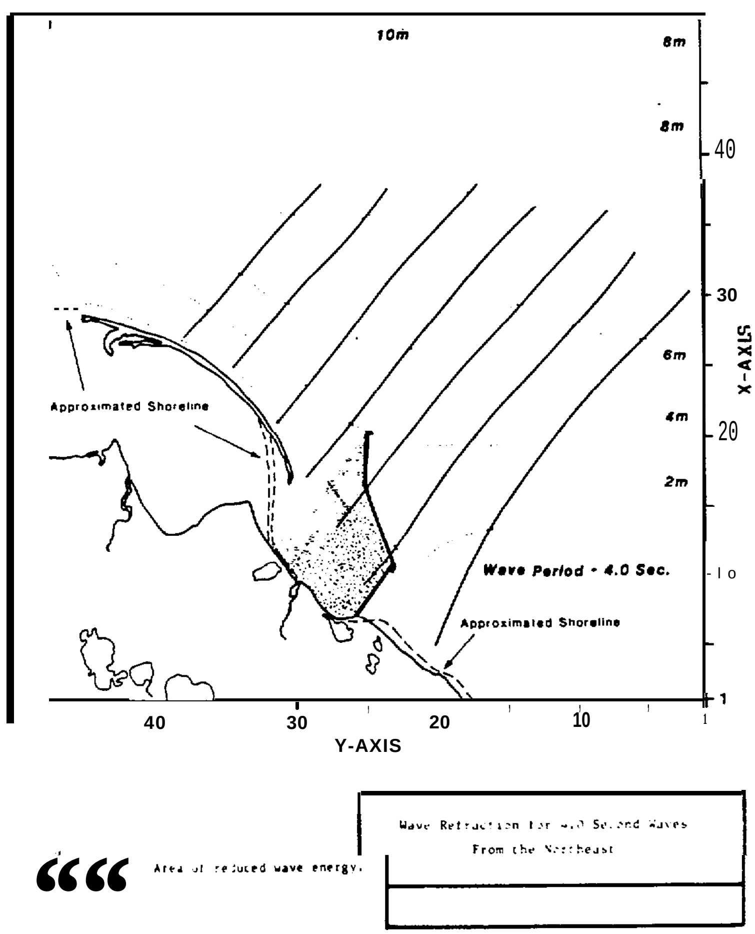

Figure 11. Area of reduced wave energy in the quiet "backwater" of the West Dock (from Harper, 1982).

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