Barrow Alaska Coastal Erosion Feasibility Study

Appendix I: Barrow, AK Coastal Storm Damage Reduction Technical Report

Barrow, Alaska

US Army Corps
of Engineers
Alaska District

**U.S. Army Corps
of Engineers**
Alaska District

Barrow, Alaska

Coastal Storm Damage Reduction
Technical Report

July 2010

Technical Report
Coastal Storm Damage Reduction, Barrow, Alaska

Summary: The City of Barrow (Barrow) is in the North Slope Borough (NSB) on the Chukchi Sea coast about 750 miles north of Anchorage, Alaska. Barrow is the largest community on the North Slope and functions as a regional transportation center for fuel and other materials to communities on the Arctic Slope of Alaska. Although the borough, state, and federal governments are the largest employers, other businesses provide support services to oil field operations and tourism.

The NSB participated with the U.S. Army Corps of Engineers in this feasibility study to find solutions to flooding and erosion problems in Barrow. This report and its appendices contain the information developed during the feasibility study. Barrow has experienced storm damage and erosion problems for decades. Several storm damage reduction measures have been tried with varying degrees of success. Coastal flooding and erosion continue to threaten residential and commercial structures and community infrastructure.

The study determined that Barrow suffers damages from coastal storms that total $1,178,300 in average annual damages. Of these, $1,021,000 are erosion damages to land, structures, roads/protective berms, and utilities, and $157,300 are flooding damages to building structures and contents, utilities, and the water supply dam.

This Technical Report (TR) presents a range of alternatives that could meet both local needs and contribute to meeting National Economic Development (NED) objectives. The study considered ten structural measures and five non-structural measures to reduce erosion and flood damages. These measures were screened down to five basic alternatives with variations based on scale: rock revetments, beach nourishment, joining the National Flood Insurance Program, elevating/relocating buildings, and lagoon filling. Sixteen specific cost estimates were prepared for alternatives involving some construction and were compared with the estimated reductions in storm damages. The first cost of the alternatives ranged from $22 million to $807 million. In all cases, the estimated costs of implementing each alternative exceeded its estimated NED benefits, resulting in negative net NED benefits. The alternative that had the least negative net NED benefits was "Lagoon Filling," with a first cost of $29 million and $744,000 NED benefits, which result in negative net benefits of $879,000 and a benefit-to-cost ratio of 0.46 to 1.0. There is no economically justified solution under the General Investigations authority and potential projects can not be pursued through the normal process for projects specifically authorized by Congress.

Lead Agency: U.S. Army Corps of Engineers, Alaska District is the lead Federal agency. Persons or governmental agencies wishing to comment on this TR may direct their comments to the address below.

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Technical Report
Barrow, Alaska, Storm Damage Reduction

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1.0 INTRODUCTION

1.1 Study Authority

The Barrow, Alaska, Coastal Storm Damage Reduction Interim Feasibility Study (IFS) is being conducted under authority provided by the "Rivers and Harbors in Alaska" study resolution adopted by the U.S. House of Representatives Committee on Public Works on December 2, 1970, which reads in part:

> "Resolved by the Committee on Public Works of the House of Representatives, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the reports of the Chief of Engineers on Rivers and Harbors in Alaska, published as House Document Numbered 414, 83rd Congress, 2nd Session;… Northwestern Alaska, published as House Document Numbered 99, 86th Congress, 1st Session; ... and other pertinent reports, with a view to determining whether any modifications of the recommendations contained therein are advisable at the present time."

1.2 Study Purpose

The purpose of this IFS is to investigate damages caused by coastal storms in the vicinity of Barrow, Alaska, with their associated erosion and flooding, and determine whether a Federal interest exists for financial participation in the future development of a coastal storm damage reduction project. The main purpose of a possible project is to reduce the effect of damaging storms on the community of Barrow, which serves as the economic and social center for the North Slope Borough (NSB), a county-like area of more than 95,000 square miles (about the size of the State of Oregon).

1.3 Study Location

Barrow is the northern most community in the United States, located north of 71 degrees north latitude, and is the economic, social, and cultural center for the NSB. It is on the Chukchi Sea (Arctic Ocean) about 750 miles north of Anchorage, Alaska. The City of Barrow, incorporated in 1958, is the largest community in the NSB, which includes almost all of Alaska north of the 68th Parallel. Outlying communities that rely on Barrow as a hub are shown in figure 1. Barrow encompasses 18.4 square miles of land and 2.9 square miles of water. The majority of the 4,200 residents are Inupiat Eskimos. Barrow is on the coastline of the Chukchi Sea about 10 miles southwest of Point Barrow (figure 2), the northernmost point of land in Alaska. Point Barrow is on a spit fronting Elson Lagoon and marks the boundary between the Chukchi Sea on the west and the Beaufort Sea on the east, both considered part of the Arctic Ocean.

1.4 Study Background and Participants

In 1999 the Corps conducted a study for a Section 14 project for Barrow. This effort was stopped when it became apparent that all measures under consideration would

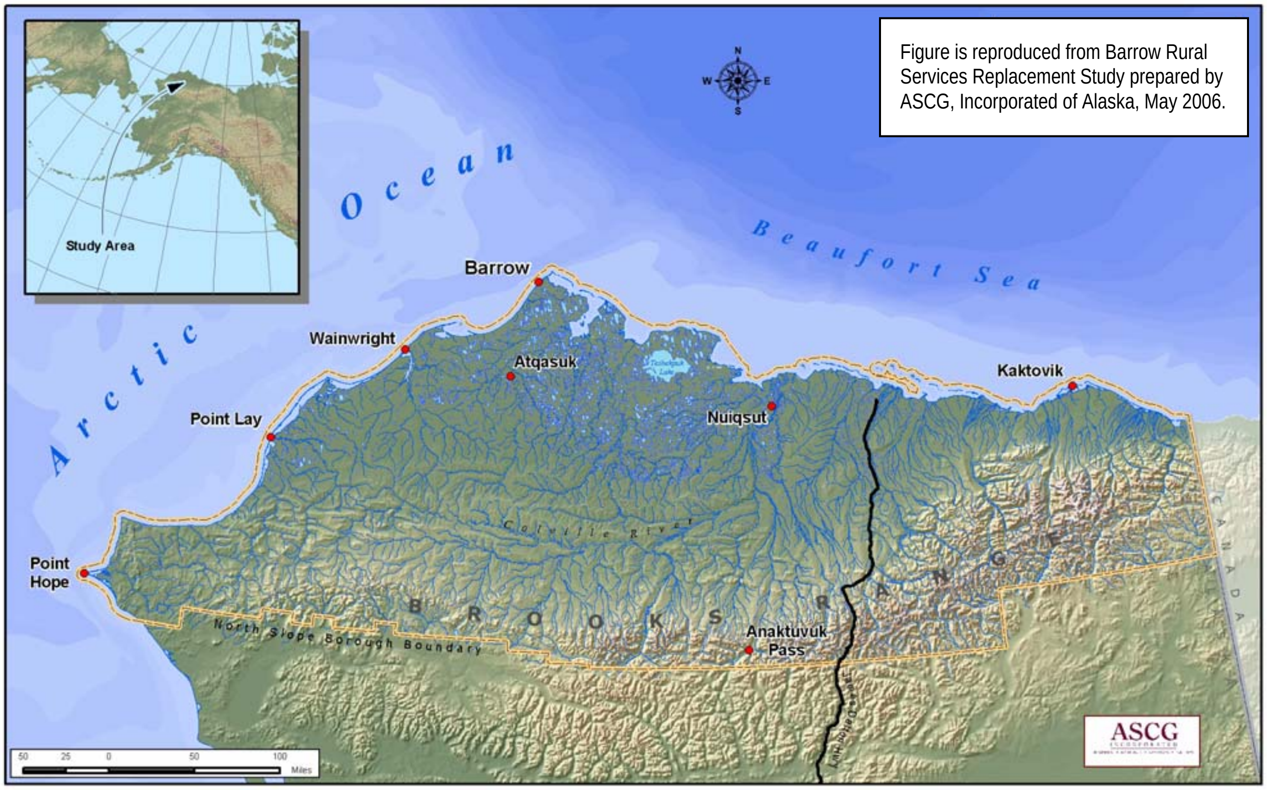


Figure is reproduced from Barrow Rural Services Replacement Study prepared by ASCG, Incorporated of Alaska, May 2006.

Figure 1. Location Map for Barrow

cost substantially more than the Federal cost limit of $1 million for a Section 14 project. After the NSB’s dredge was damaged in 2000, the NSB became interested in working with the Corps of Engineers on a feasibility study of Barrow’s shoreline problems. The Barrow, Alaska, Section 905(b) (WRDA 86) analysis was completed in June 2001 and approved in August 2001 by Corps Headquarters. The Project Management Plan (PMP) was then developed and the Feasibility Cost Sharing Agreement was signed on February 13, 2003.

The local sponsor for this study is the NSB, the county-like, civil government for the northern-most part of Alaska. Personnel from the Alaska District and the local sponsor were the primary participants in the study. As part of their required contributions to the study, the NSB provided cash and a substantial amount of in-kind engineering, economic, environmental, and GIS services through their own forces and a group of consultants. Other Project Delivery Team (PDT) members included personnel from other offices of the Corps, other Federal agencies, and a number of consultants. Assisting the Alaska District directly was the Corps’ Coastal Hydraulics Laboratory (CHL) in Vicksburg MS, the Cold Regions Research and Engineering Laboratory (CRREL) in Hanover NH, the Institute for Water Resources at Ft. Belvoir VA, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service. Corps’ contractors included: Tetra Tech of Seattle WA/Sacramento CA, Oceanweather, Inc. of Cos Cob CT, Tryck Nyman & Hayes of Anchorage, AK (using Hydraulic Consultants of Sherwood, OR), RMM, Inc. of Cummings, GA., and the University of Alaska Anchorage. The NSB participated along with their consultants, who included: ASCG and Ukpeagvik Inupiat Corporation (UIC) of Barrow AK, and the Native Village of Barrow. The Independent Technical Review Team for this document included personnel from Los Angeles District (as part of the Corps' Storm Damage Reduction Planning Center of Expertise in North Atlantic Division), Walla Walla, Alaska, and Omaha Districts, and University of Florida in Tallahassee, FL.

1.5 Scope of Technical Report

The Alaska District, U.S. Army Corps of Engineers and the NSB conducted the Barrow Storm Damage Reduction study as a pre-authorization study. This Technical Report (TR) documents the results of the study and addresses the engineering and planning elements of a feasibility study and social and environmental resources issues. However, the subjects in this report have been summarized because a Recommended Plan for implementation was not selected. Detailed information generated by the feasibility studies is in the appendices.

1.6 Previous Corps Studies and Related Reports

1.6.1 Prior Corps Reports

There are no authorized and completed Corps of Engineers civil works projects in the Barrow area. The Corps of Engineers has conducted a number of studies considering water resources needs of northern Alaska, including Barrow. A major state-wide, watershed by watershed study was conducted from 1947 to 1962 and produced 10 interim reports, including one for northern and western Alaska. Other Corps studies covering Barrow include studies of beach erosion in 1969 and 1991 (under authority of Section 103 of the 1962 River and Harbor Act) and in 1999 (under Section 14 of the 1946 Flood Control Act) and small boat harbors in 1979 and 1993 (under Section 107 of the 1960 River and Harbor Act). Summaries of the recommendations of the previous Corps reports and past authorization texts are provided in Appendix I.

1.6.2 Prior Related Reports by Others

The NSB and others have prepared a number of reports over the last couple of decades that directly or indirectly addressed the storm damage problems facing Barrow and made various recommendations. Summaries of the conclusions of these previous reports are in Appendix I.

1.7 Plan Formulation Process

During the study, a range of alternative measures were identified and initially screened. Alternatives were then more fully developed, compared, and evaluated. This process was conducted in three sequential phases.

Phase 1 concentrated on Steps 1 and 2 of the planning process (identifying problems and opportunities, and inventorying and forecasting conditions). Section 2 describes existing conditions in the Barrow area and a without-project condition is determined. In Section 3, planning objectives are developed and constraints identified. In Section 4, possible measures to achieve the planning objectives are developed, compared, evaluated, and screened. Section 4 also presents summary environmental information for use in alternative evaluation.

Phase 2 concentrated on Steps 3 through 6 of the planning process (formulating, evaluating, and comparing alternative plans and selecting a plan). Alternatives were developed and evaluated by appropriate criteria, and compared with each other. Alternatives that did not meet the planning objectives or clearly failed evaluation criteria were screened out, leading to a group of alternatives to be considered. Five of these preliminary alternatives were then evaluated using the planning objectives and the evaluation criteria. This analysis identified a potential NED Plan. The phase was completed with Independent Technical Review (ITR) of a draft report and the holding of an Alternative Formulation Briefing (AFB) with representatives of the Pacific Ocean Division and Corps Headquarters. The AFB addressed problems and concerns with the study analyses and the draft report that had been identified by the ITR. As a result, the District was requested to review and revise both the hydraulic and economic analyses.

Phase 3 concentrated on revising the hydraulic and economic analyses, completing the ITR, and producing a TR. The revised analyses resulted in no alternative having NED benefits that exceeded its costs. Remaining work documented the study process, the revised analyses and study results in the TR, which contains all the completed detailed studies for potential future use by local governments and others.

1.8 Current and Future Projects of Other Agencies

In recent years, a number of Barrow stakeholders have been actively involved in planning, designing, and/or constructing major new facilities. One characteristic common to the facilities being replaced or upgraded is that they are relatively close to the shoreline and would or could suffer significant damages during future extreme storm events. Local entities have taken seriously the erosion and flooding threat and generally employed the non-structural choice of retreat and relocation farther from danger for their vulnerable facilities. These include the landfill, the wastewater treatment plant, the hospital replacement, the Barrow Global Climate Change Research Facility, the new Barrow Arctic Science Consortium (BASC) access road, and the dam renovation. A detailed discussion of each is in Appendix I. These new projects will reduce future erosion and flood damages. Even though these projects reduced possible NED benefits for a new Corps project, the local community chose to move out of harm's way what they can, when they can. These sites are shown on figure 3. Although millions are being spent on these projects, portions of existing commercial, residential, and public land and structures remain susceptible to erosion and flooding from extreme storm events. The current study provides an opportunity to address these smaller buildings and facilities that are critical to the long-term economic and social well-being of Barrow and the NSB.

1.9 Summary of Public Involvement and Scoping Meetings

Public involvement activities, described in more detail in Appendix I, were related to developing public information on the study and obtaining public comments during the study process. The public involvement strategy consisted of (1) an initial study scoping meeting; and (2) periodic public meetings, radio show, news releases and information pamphlets. The study included review throughout the process by agencies at the federal, state, local and Tribal governmental level, special interest groups, and the general public.

A Notice of Intent (NOI) to prepare an EIS on storm damage reduction improvements at Barrow and an announcement of public scoping meetings appeared in the Federal Register on April 17, 2003. A meeting notice describing the project, requesting comments, and announcing the dates, times, and locations of the public scoping meetings was mailed to interested individuals, groups, agencies, and tribes. A press release announcing the public meetings was sent to local media.

The Corps held the first scoping meeting in Barrow on June 12, 2003. At the meeting the Corps listened to the interested individuals who attended and the concerns they had regarding possible developments at Barrow, the studies that should be done, and the questions that should be answered. The primary concern expressed centered on potential alternative impacts to the natural resources of the area and any subsequent impact to continued subsistence harvesting of those resources by residents. Graves and cultural resources were cited as a concern along the beach. Residents encouraged the Corps to consider elder knowledge of conditions and to consider climatic events beyond the 50- or 100-year events. Comments regarding possible gravel borrow on Cooper Island indicated concerns with cultural resources, traditional use areas, and bird habitat. The process of economic justification was discussed. People wanted to know how a cost/benefit analysis was done. Residents have become accustomed to modern services in Barrow, such as the utilidor, which contains water, sewer, and power. There are fears that quality of life issues may not be captured as benefits.

In November 2004, the study team mailed a study progress report to Post Office box holders in Barrow. This updated residents on activities undertaken since the initial scoping meeting. Major items discussed were deployment of instruments offshore of Barrow to measure waves and currents, accomplishment of the drilling program looking for gravel borrow areas, performance of environmental field studies, review of cultural resources properties, performance of economic baseline studies, and surveys of potential flood damages.

On April 6, 2005, a study progress meeting was held in Barrow, but public attendance was sparse due to conflicts with local whaling events that night. The Corps presented and explained the study progress information provided in the November 2004 pamphlet. Measures to address the erosion and flooding problems were discussed as well as the planned summer field activities. Local residents identified possible impacts caused by various measures and suggested other measures for consideration. Major concerns were expressed about environmental and cultural impacts associated with opening new borrow areas and potential dike alignments.

On August 23, 2006, a study progress meeting was held in Barrow and was well attended by more than 60 local residents. The meeting was held in both English and Inupiaq. The Corps presented the major results of studies to date: the beach appears stable and beach erosion is not a problem; bluff erosion is still a problem along with flooding; beach nourishment is no longer being considered due to economic, environmental, and cultural concerns; the prime measures under consideration are revetment protecting the bluffs and a coastal dike preventing flooding. In addition, the Corps was going to look at non-structural measures, such as raising or relocating buildings. The public was informed that as part of any Corps project, the community would have to participate in the National Flood Insurance Program (NFIP). Meeting participants identified impacts associated with measures being proposed and were concerned whether any project would perform as designed, particularly in resisting the severe ice forces any project along the Barrow shoreline would encounter. As a result of public comments, the study team added physical model tests of the proposed dike/revetment section to the study plan. Earlier in the day of the meeting, Corps study-team members participated in a bi-lingual radio call-in show discussing the study and possible project alternatives on KBRW, the local AM radio station.

2.0 PROBLEM IDENTIFICATION

2.1 Summary of Study Area Conditions

2.1.1 Study Area

Barrow is located just west of a long, inverted v-shaped spit that juts into the Arctic Ocean (figure 2). Elson Lagoon is to the southeast of the spit. Point Barrow, which lies at the north point of the inverted v spit, marks the boundary between the Chukchi Sea and the Beaufort Sea of the Arctic Ocean. Plover Point is at the eastern end of the spit, about 4 miles southeast of Point Barrow. Approximately 12 miles of the Chukchi Sea coastline near Barrow is shown in figure 3. The City of Barrow's municipal limits cover most of the area shown, including "neighborhood" areas referred to in this report as Barrow, Browerville, NARL, Nixeruk (primarily a fish camp), and Nuvok (an archaeological site near Point Barrow). The Barrow Storm Damage Reduction study area is a 4.7-mile-long reach centered along the Barrow and Browerville neighborhoods. This shoreline fronts active, developed properties, while the remainder of the shoreline consists of the undeveloped bluff line southwest of Barrow and lake/tundra lowlands to the northeast. Figure 3 locates other local features discussed throughout this document. These features include, from southwest to northeast: the old gravel pit, the Utqiagvik Village archaeological site, the Wally Post-Will Rogers Airport, Tasigrook Lagoon (between the water supply dam and the shoreline), Isatkoak Lagoon (Barrow's fresh water supply), the lagoons used for sewage treatment, the old landfill, and the former Naval Arctic Research Laboratory (NARL), which is now used by the Barrow Arctic Science Consortium (BASC), the new Barrow Global Climate Change Research Facility (BGCCRF), and Ilisagvik College (IC). The developed portion of Barrow and Browerville neighborhoods contains single and multi-family residences, commercial buildings, city and NSB shops, and the water supply lagoon system. The existing development in the Barrow and the Browerville neighborhoods is shown in figures 4 and 5, respectively. The beach fronting the City of Barrow is composed of sand and gravel, with an average median diameter of 3.0 mm, poorly sorted, with significant size fractions between 0.3 and 20 mm. The bluff and low-lying area backing the beach is composed of silt and fine sand. The up to 30-foot-high bluff, shaped by the combined effects of: occasional storms, water run-off, and degradation of permafrost (figure 6), occurs along the beach in the Barrow neighborhood. As one travels to the northeast, the bluff decreases in height (figure 7) until it disappears near Tasigrook Lagoon. Northeast of the lagoon, the back edge of the beach rises to an elevation of approximately 8 feet, where it grades into fairly level tundra.

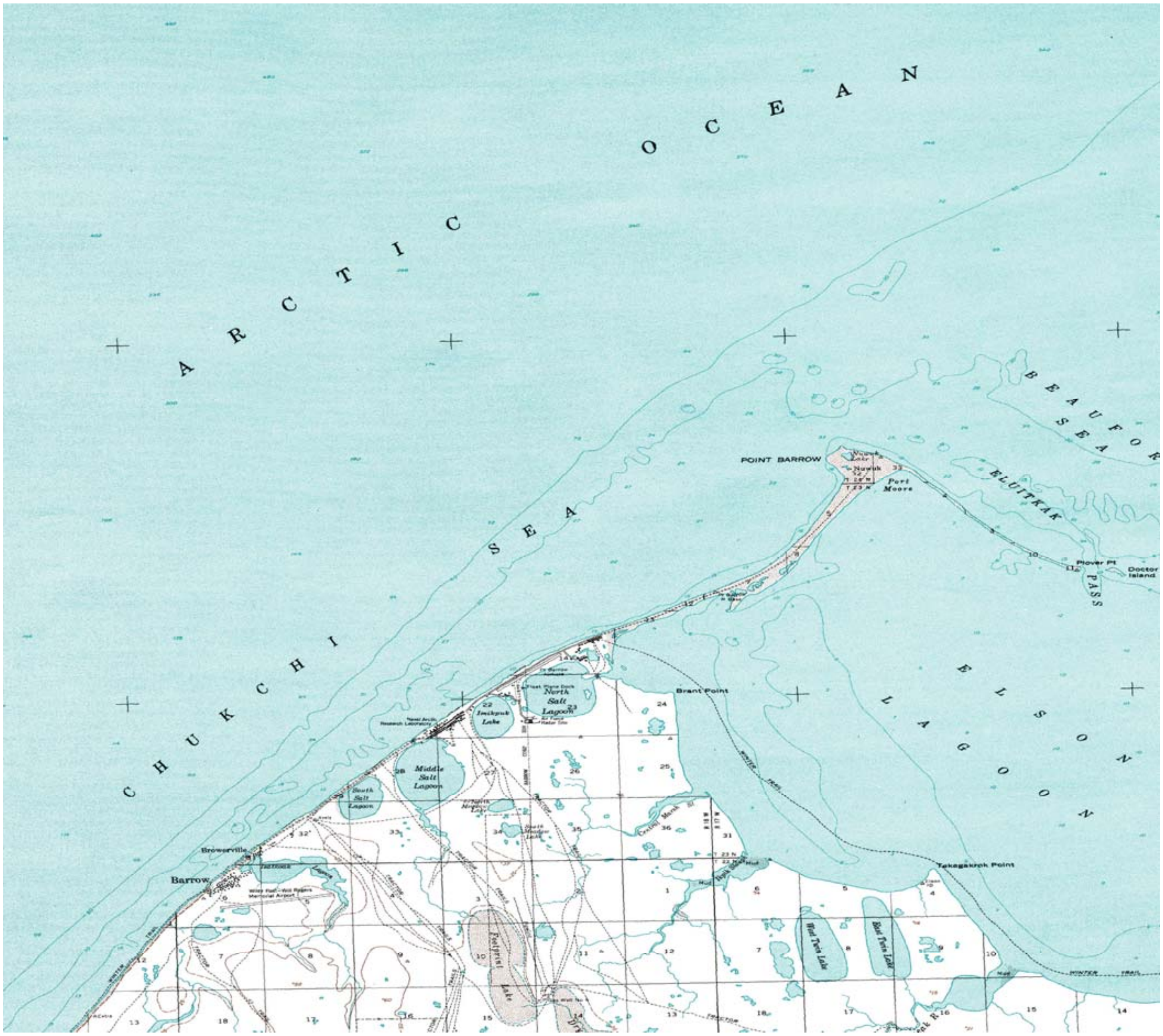


Figure 2. Barrow and immediate surrounding area.

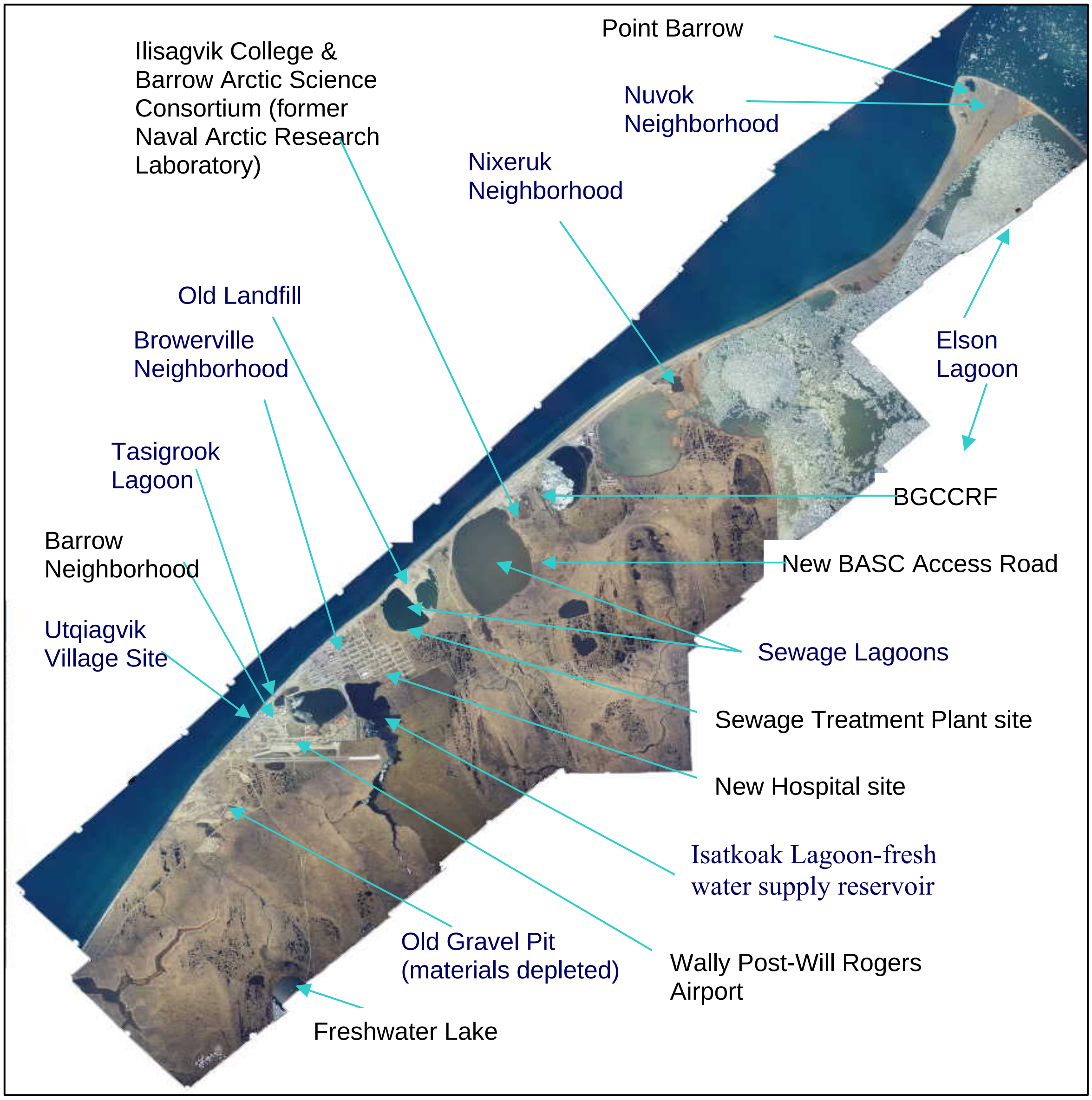


Figure 3. Barrow and local features.

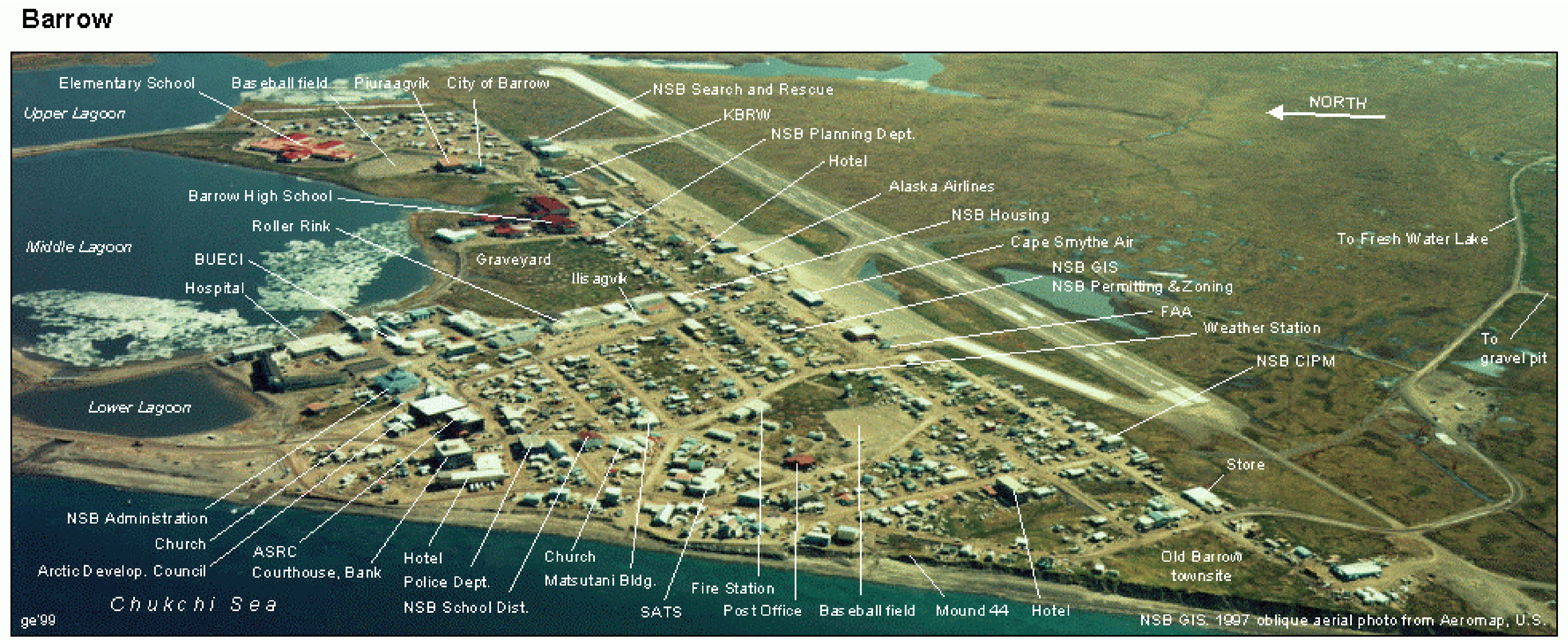


Figure 4. Barrow Neighborhood

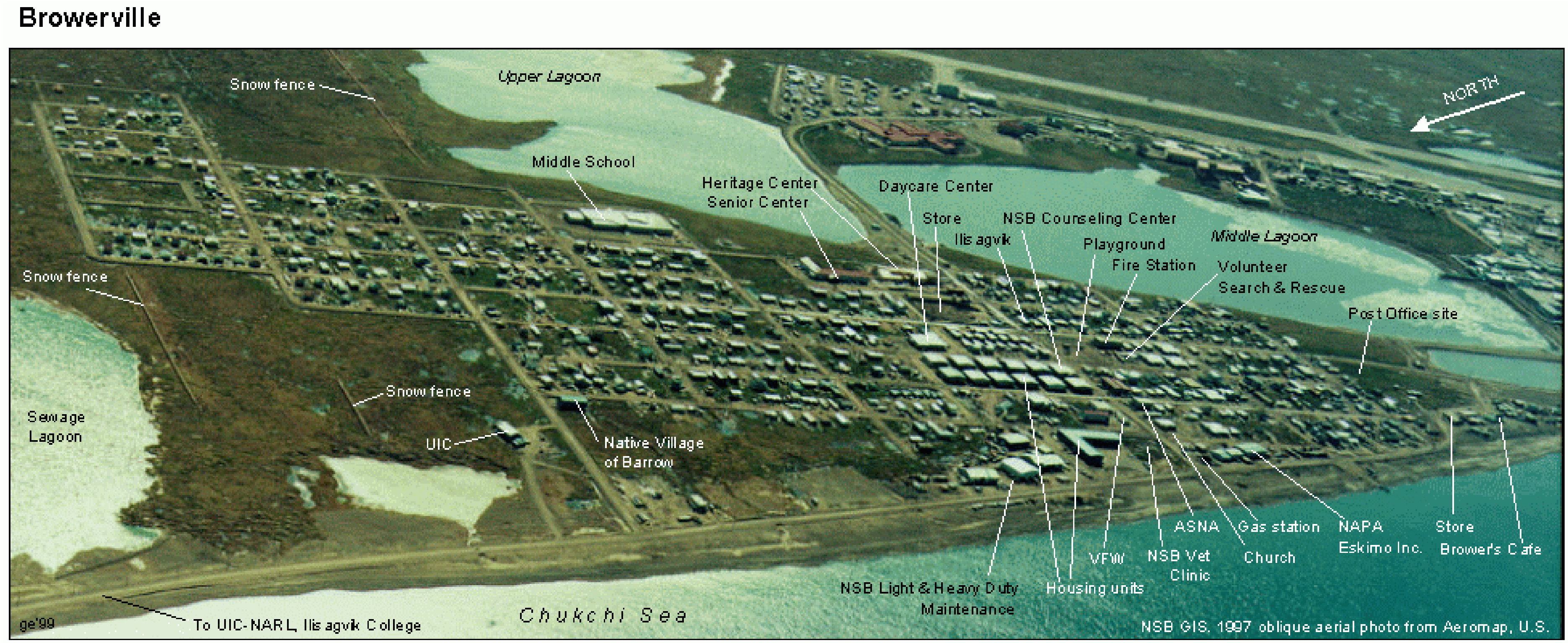


Figure 5. Browerville Neighborhood

Figure 6. Bluffs adjacent to the Utqiagvik Village Archaeological Site.

Figure 7. Decreasing bluff height along Egasak Street in Barrow Neighborhood.

2.1.2 Temperature

Barrow exists in an arctic environment with average annual precipitation (rain and melted snow water) averaging 5 inches and average annual snowfall of 29 inches. Temperature extremes range from -56 to 78 degrees Fahrenheit, with average summer temperatures ranging around 40 degrees Fahrenheit. The daily minimum temperature is below freezing 324 days of the year. The sun does not set between May 10 and August 2 every year, nor does it rise between November 18 and January 24.

2.1.3 Ice Conditions

The Chukchi Sea is typically ice-free from early July at Barrow. Freeze up typically occurs in November, but the formation of stable shorefast ice may be delayed. Stability is achieved after one or more significant pack ice “shoves” deform and ground the ice. Grounding can take place as late as January, or not at all. Once grounded and stabilized, the shorefast ice cover remains in place until the start of breakup in late spring and early summer. The beaches near Barrow show normal profiles fully shaped by waves during the summer, open-water season. However, when sea ice is present, the beaches near Barrow are subject to the pushing action of ice more than most arctic regions. The ice sheet may glide over the beach, striating it much like a miniature glacier and pushing a small pile of debris ahead of it. After the ice melts, the striations show the passage of the ice and the ridge-like pile of debris marks the terminus of flow, much like an end moraine. The ice may dig its leading edge into the beach and buckle up into piles of ice blocks as high as 30 feet, known locally as “ivu.” Representative sea ice covers at Barrow are on the order of 4.9 feet thick and have a flexural strength of 90 pounds per square inch.

2.1.4 Tides

Barrow is in an area of semi-diurnal tides with two high waters and two low waters each lunar day. Mean Sea Level is +0.25 feet Mean Lower Low Water (MLLW) and Mean Higher High Water is +0.50 feet MLLW. The records do no report highest observed water level or lowest observed water level.

2.1.5 Wind

The Alaska Climate Research Center at the Geophysical Institute, University of Alaska Fairbanks compiled wind data from 1971 to 2000 for Barrow. The prevailing winds are easterly and average 12 miles per hour (mph). The maximum wind speed recorded was 48 mph.

2.1.6 Wave Climate

Because of its location, Barrow remains relatively protected from growing wave conditions in the Beaufort Sea to the east, and swells south of Cape Lisburne in the Chukchi Sea. Barrow’s wave climate is dictated by storms in the Arctic Ocean limited in extent by the pack ice. Wind and wave hindcasts for 1982-2003, supplemented with data from 27 pre-1982 storms and mean weekly ice maps, were used to transform the waves from a deepwater wave hindcast boundary output point to the nearshore at Barrow. The largest storm of record in the extremal wave analysis occurred in September 1986 with a storm from the west-northwest. The peak significant wave height was 17 feet with a 10.5-second period. The return period predicted for this storm by the extremal analysis is 30.3 years. The deep-water waves were transformed to near-shore waves using the Steady-State Spectral Wave (STWAVE) model, which was validated using near-shore wave measurements acquired during the summer and fall of 2003 using Acoustic Doppler Current Profilers. A second season of data collection was attempted in 2004, but was unsuccessful because one gage was destroyed by an ice keel and the other was lost due to ice formation at the end of the open-water season.

2.1.7 Water Levels

Historic water-surface elevations (including tide and surge) and currents for storm events were computed by CHL using the **AD**vanced **CIRC**ulation (ADCIRC) hydrodynamic circulation model. The effect of wave set up and run up on the total water level previously computed by ADCIRC was computed by CHL using the **S**torm-induced

BEAch **CH**ange (SBEACH) Model. Table 1 provides the surge elevations from the ADCIRC analysis for various tidal return periods.

Table 1. Summary of Surge Stage-Frequency Relationship

	Return Period					
	5 yr.	10 yr.	15 yr.	20 yr.	25 yr.	50 yr.
Surge Elevation	2.30 ft.	2.85 ft.	3.05 ft.	3.18 ft.	3.25 ft.	3.58 ft.
Standard Deviation	0.13 ft.	0.16 ft.	0.16 ft.	0.16 ft.	0.16 ft	0.16 ft.

Coastal flooding at Barrow is caused by a combination of tide, surge, wave set up, and wave run up. Only the addition of run up results in flooding along the coast near Barrow. SBEACH does not model wave runup on complex upland areas. To estimate the runup flooding, a modified version of SBEACH was applied to estimate the volume of water that is pumped past the berm/dune crest for each storm simulation. Estimates of volumes of water overtopping the crest were calculated using time histories of profile and hydrodynamic output from SBEACH.

2.1.8 Currents

Tidal fluctuations at Barrow are minimal so the predominant source of currents is wind generation. Current modeling using the ADCIRC model indicated depth averaged currents during storm events range between 1.0 and 1.4 knots. These currents are generally maintained for 12 hours or less and predominantly flow to the northeast along the coast.

2.1.9 Sediment Transport

A set of profile ranges was established to analyze long-term shoreline change. Cross-shore and longshore sediment transport mechanisms were evaluated. The SBEACH model runs indicated beach sediments at Barrow generally do not move in the cross-shore direction. The threshold grain size for movement is 0.8mm, but average grain size is 3 mm. Average horizontal change of the zero elevation (shoreline) over the 15-year period is 13.5 feet of accretion, with individual profiles ranging between 62 feet of erosion to 87 feet of accretion. Longshore sediment transport at the site was estimated at an average net transport rate of 7,300 cubic yards per year to the northeast.

2.1.10 Coastal Storm Effects

The City of Barrow is on a coastline that runs from the northeast to the southwest and is most vulnerable to storms from the north and west in August through October (late summer to fall) when there is open water and the permanent ice pack stays a few hundred miles offshore. From November through July, there is generally enough ice present to restrict wave development. The two coastal problems of greatest concern are storm-induced erosion of the bluffs and flooding. Flooding has occurred several times when summer and fall storms arrive from the west accompanied by large waves and elevated water levels. The October 1963 storm is remembered as being particularly severe and caught many residents unprepared (figures 9 and10).

Figure 8. Flooding damage caused by the October 1963 storm. {Note utility poles in background located along shoreline road}

Figure 9. Flooding at Barrow. {near Transect 31}

2.1.11 Coastal Flooding Analysis

Coastal flooding at Barrow results from wave run up over the beach and into the upland areas. Flooding elevations were estimated with a modified version of the SBEACH model. Fourteen damage reaches (figure 10) were established, and a representative profile was developed for each reach based on measured profile data from 1987 and 2003. Profiles for the Barrow neighborhood on which the storms were simulated in SBEACH are provided, as an example, in figure 11. Profiles for other reaches are shown in Appendix A. Because coastal flooding is caused by wave run up, it is topographically controlled. Storm data from the **WA**ve prediction **M**odel (WAM) and STWAVE combined with surge (ADCIRC) hindcasts for 28 historical events were used as model input. Twelve water level curves were generated for each storm, taking the ADCIRC predicted values and combining with three barometric and four tide curves, giving a total of 336 historically based plausible storms, which, when combined with the 14 profiles, resulted in 4,704 SBEACH simulations.

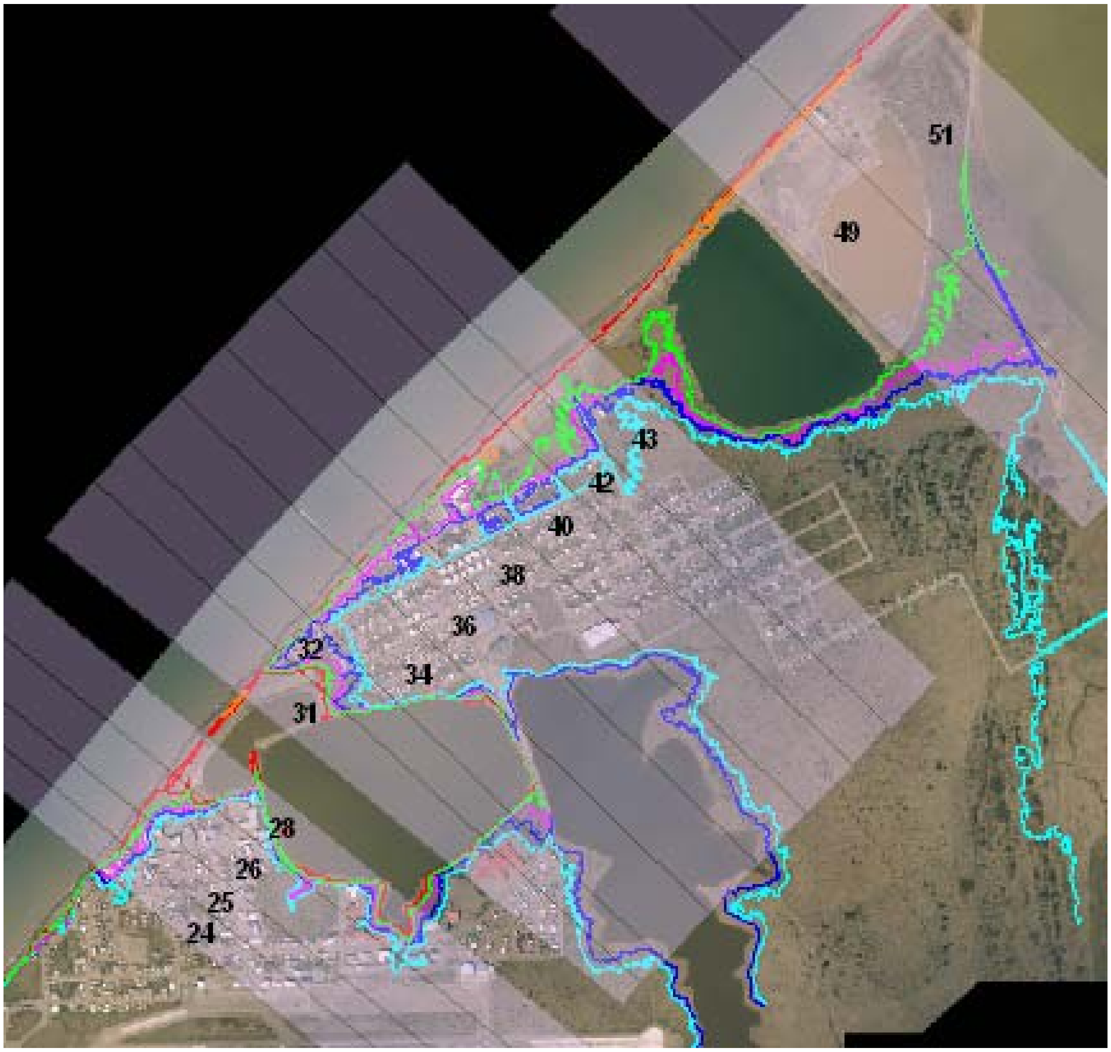


Figure 10. Study area with 14 damage reaches identified and elevation contours (red=8ft, green/orange=10ft, pink=12ft, blue=14ft, cyan=16ft).

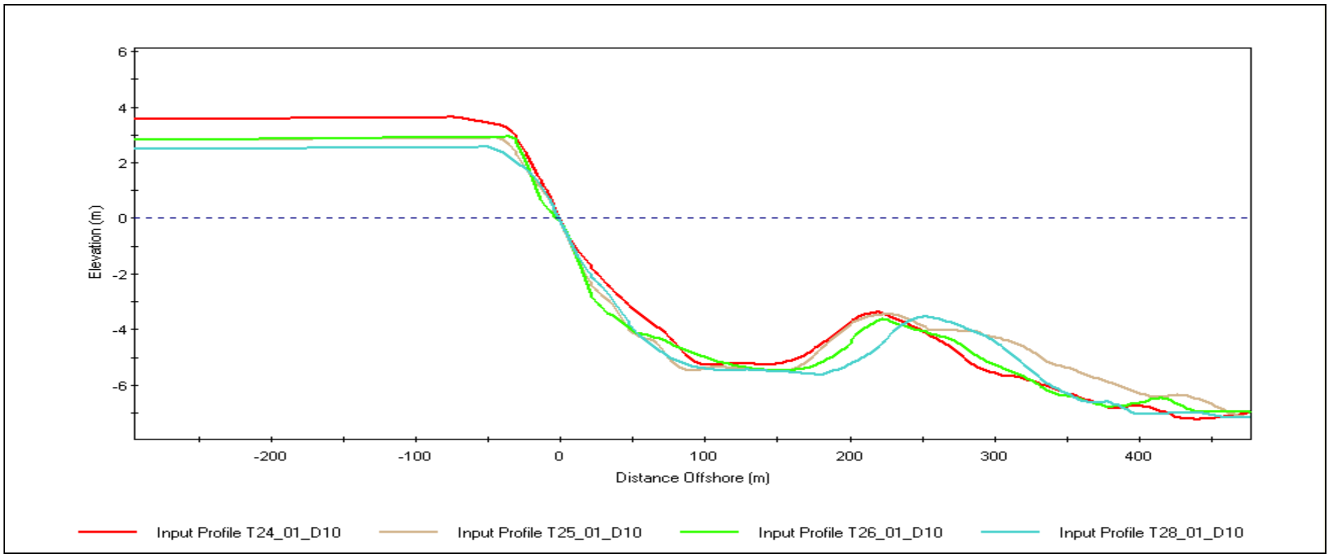


Figure 11. Example Beach profiles for Reaches 24, 25, 26, and 28 at Barrow.

SBEACH does not model wave run up on complex upland areas. To estimate the run up flooding, a modified version of SBEACH was applied to estimate the volume of water that is pumped past the berm/dune crest for each storm simulation. At Barrow, the tide + surge + wave setup never exceeds the berm/dune crest, so only profile overwash is occurring at Barrow. A step function was developed for each reach, which used topographic characteristics and storage capacity calculations for each reach to compute the flooding elevation. Flooding elevations were capped at 0.25 foot above the highest contour in the reach. The calculated flood exceedance probabilities by reach are presented in table 2. The table presents the probability that the flooding level will exceed a given level for each reach. An individual stage-frequency curve was developed with the statistical Empirical Simulation Technique (EST) model for each reach. Separate curves were generated for each reach and are given in Appendix A. The EST results have been capped at the upper end to reflect physical constraints introduced by the topography of each reach. The bottom of each curve coincides with the beach berm crest, and no flooding occurs below this level. On reach 24, for example, flooding is not expected to occur for storms with a return period below approximately 20 years (figure 12). Figure 13 provides an example stage-frequency curve for Reach 26, which is just northeast of the Top of the World Hotel.

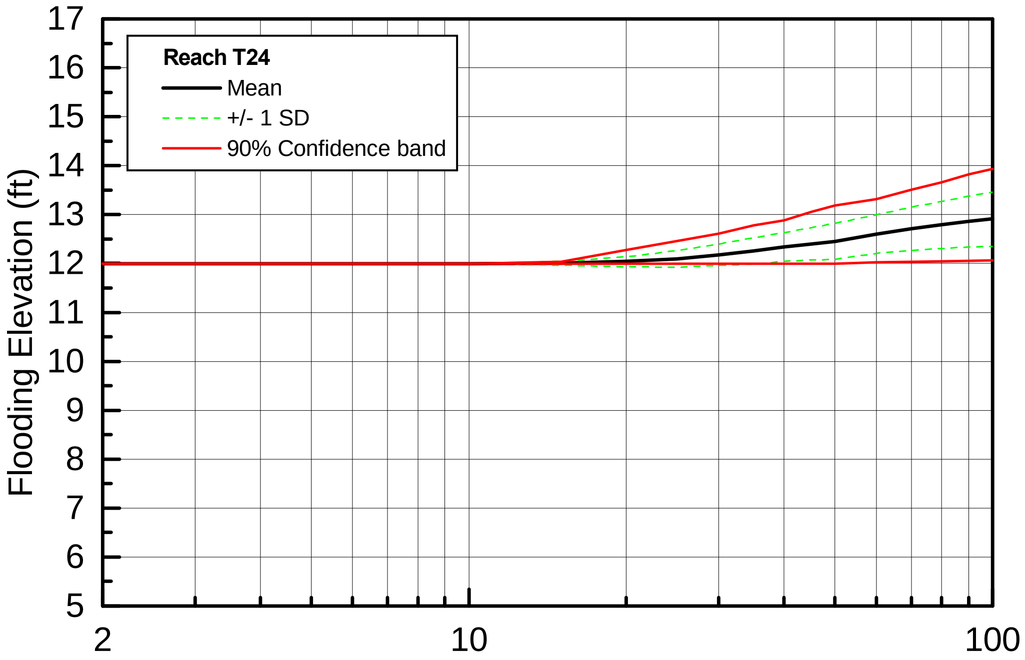


Figure 12. Stage-frequency curve for damage reach 24.

Table 2 . Flood Exceedance Probabilities

Reach	Berm Elev (ft)	Flood Exceedence Probabilities									
		>7ft	>8ft	>9ft	>10ft	>11ft	>12ft	>13ft	>14ft	>15ft	>16ft
24	12.0						0.0357	0.0022			
25	9.5				0.1741	0.0893	0.0513	0.0179	0.0067		
26	9.6				0.1741	0.0982	0.067	0.0513	0.0223	0.0089	0.0067
28	8.5			0.0826	0.0089						
31	7.9		0.0938	0.0938	0.0714	0.0647	0.0625	0.0603	0.0402		
32	9.3				0.0938	0.0714	0.0625	0.0536	0.0179		
34	9.7				0.0558	0.0179	0.0067				
36	7.9		0.0558	0.0558	0.0402	0.0179	0.0156				
38	8.1			0.0558	0.0201	0.0112					
40	7.0	0.0446	0.0313	0.0268	0.0246	0.0156	0.0089	0.0067	0.0022		
42	6.0	0.0313	0.0268	0.0268	0.0246	0.0201	0.0134	0.0112	0.0089	0.0067	0.0045
43	8.0		0.1607	0.0848	0.0491	0.0268	0.0246	0.0179	0.0179	0.0045	
49	8.7			0.2946	0.0938	0.0357					
51	8.3			0.096	0.0268						

For reaches evaluated southwest of the sewage lagoon in the Barrow and Browerville neighborhoods, a storm with a return period of 5 to 20 years, depending on the reach, is required to produce flooding. For reaches near the sewage lagoon, model results indicate a 3-year storm will produce some flooding. The calculated 50-year flooding elevation across the study area varies between elevations 10 and 14.5 feet. These calculation estimates do not include consideration of any flood protection berm features, such as the temporary ones that the city puts in place before and during a storm or any proposed structure. Papers written on the effects of the 1963 storm that impacted the coast cite debris lines measured at the 12-foot elevation at the former Naval Arctic Research Laboratory site north of Barrow. This debris line is outside the project area, but the topography is similar to that in the Browerville neighborhood. The stage-frequency curves indicate that a flood elevation of 12 feet is possible during an extreme storm event.

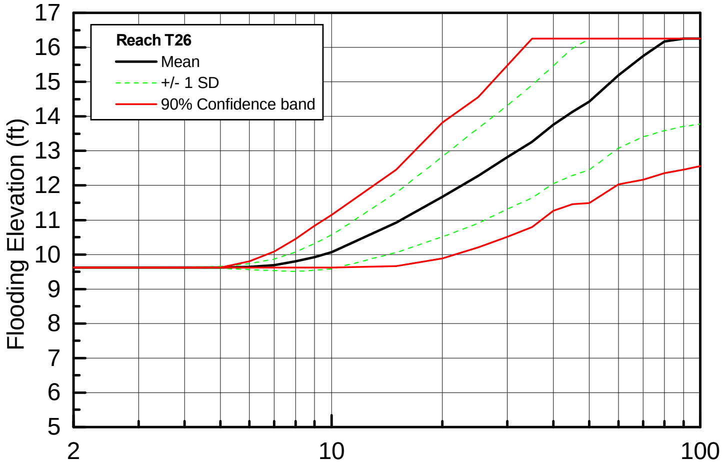


Figure 13. Example Stage-frequency Curve for Damage Reach 26.

2.1.12 Coastal Erosion Analysis

Shoreline analysis at Barrow indicates there has been a significant change in the shoreline. Aerial photographs from 1948 through 2003 were analyzed. Differences in the shoreline movement were plotted in time increments to determine if erosion along the coast was episodic or consistent through the years. The plot between 1948 and 1955 appeared to be typical shoreline behavior, with areas of erosion and accretion occurring. Between 1955 and 1974, a large amount of shoreline erosion occurred along the entire study area. The 1974 and 1984 plot comparison shows a predominance of accretion along the coast, and the 1984 and 1997 plot comparison shows the shoreline beginning to return to a typical beach pattern with pockets of erosion and accretion. A comparison of available aerial photography (1948 and 2003) indicates the coast mostly eroded during that time.

The greatest erosion appears to have occurred between 1955 and 1974, when the highest storm water levels occurred and there were a number of major construction projects. The 1963 storm is reported to have transported a large amount of beach and bluff material—as much as 200,000 cubic yards. In addition to being the year of the biggest storm event, a great deal of material was borrowed from the beach to facilitate construction associated with the rapid growth in Barrow. Because Barrow's permafrost soils were far from ideal for supporting large structures, the beach was heavily mined to supply gravel for the runway, building foundations, and roads. A 1963 photograph shows trucks moving material along the beach in front of the City of Barrow and a haul road that leads to the new airport under construction (figures 14 and 15). During this period, the Wiley Post-Will Rogers Memorial Airport and the Samuel Simmonds Memorial Hospital were built. A head of the Naval Arctic Research Laboratory, Dr. Max Brewer, estimated that the beach mining operation removed 1.1 million cubic yards of material. Also, local residents took beach gravel for use on personal property until this practice was banned by the Bureau of Indian Affairs and the NSB. The combination of mining of the beach for gravel and the record storm resulted in extreme retreat of the shoreline between 1955 and 1974. Due to the relatively small volume of annual sediment transport that typically occurs, the beach has been slow to recover. After 1974, Barrow was left with a narrow beach backed by bluffs placed in the precarious position of bearing the brunt of storm waves without the dissipative effects of a wide beach. The effects of shoreline retreat are still being experienced today through bluff erosion and flooding during storms.

Figure 14. Road leading to the airport runway construction from the beach.

Figure 15. Enlargement of Shoreline Portion of Figure 14.

In addition to chronic erosion, locations that are “hot spots” in the city of Barrow were identified at transects 18-20, 23-27, and 29-30. Of these “hot spots,” the coast between transects 23 and 27 was identified as the most critical because it covers the most shoreline and fronts the most densely populated portion of the coast (figure 16). The coast in this area has not yet stabilized and reached equilibrium from the material loss between 1955 and 1974. Isolating the erosion along that section of coast for the years 1984 to 2003 shows a net shoreline erosion rate of 2.2 feet per year, which is less than the erosion rate of 4 feet per year experienced between 1984 and 1997, but slightly higher than the overall rate of 1.5 feet per year for 1948 to 2003. If allowed to erode unchecked at the lower rate of 2.2 feet per year, and assuming the bluff/dunes will try to maintain the existing beach width, structures along this section of coast would be impacted within the 50-year period of analysis for this study. The predicted retreat of the beach line is shown in figure 17.

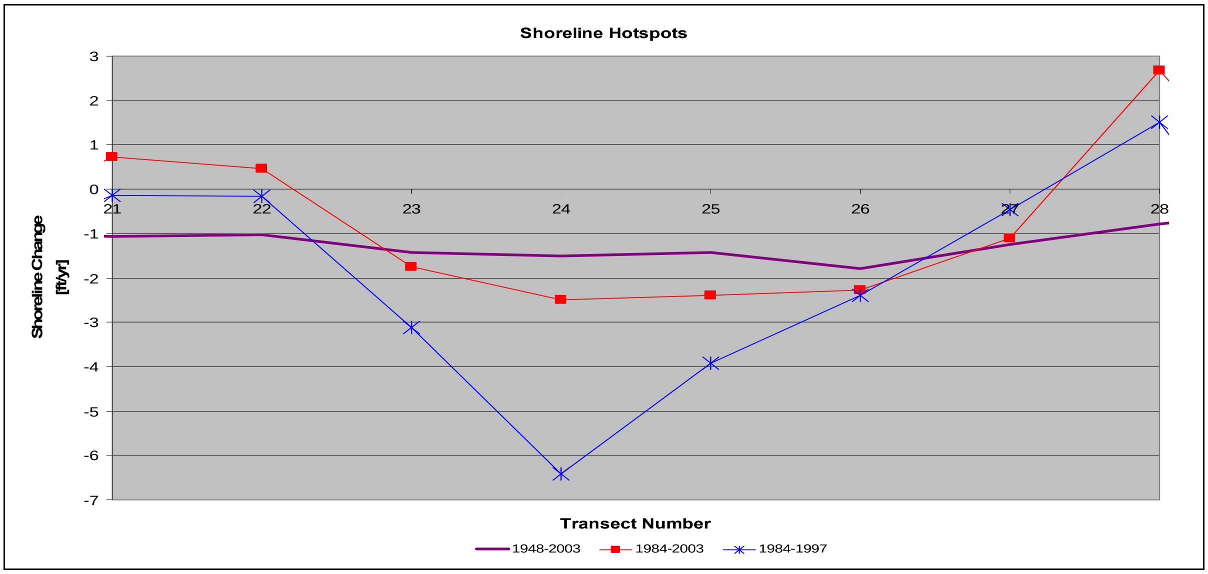


Figure 16. Plot of area of "hotspot" area of persistent erosion.

Figure 17. Aerial photograph of "hotspot" in Barrow Neighborhood

2.1.13 Regional Emergency Services

As the political and economic hub of the NSB, Barrow provides important regional emergency services to the other seven communities in the Borough (Anaktuvuk Pass, Atqasuk, Kaktovik, Nuiqsut, Point Hope, Point Lay and Wainwright (figure 1)). Emergency infrastructure systems in Barrow that currently support operations in the other communities include: search and rescue, law enforcement, fire suppression, health care, communication, and cargo delivery. Each outer NSB community was analyzed to determine its capacity to respond to emergencies. While the communities have their own Search and Rescue building, police station, public works building, fire station and village health clinic, they are equipped to handle only limited emergency needs. Four alternate service centers (Anchorage, Fairbanks, Kotzebue, and Nome) were analyzed for providing emergency support services to NSB communities if Barrow was unable to provide such support. The distance between Barrow and each community is less than the distances between the communities and the alternate service centers with the exception that Nome and Kotzebue are closer to Point Hope than is Barrow. Distance is critical when delivering emergency services, particularly in the extremely adverse arctic environment of the North Slope. While each of the alternate service centers could provide all or most of the critical services, the practicality and response time to deliver these services were determined to be problematic due to a number of factors including distance and inability to respond in a timely manner, potential for response personnel and aircraft to be unavailable when needed in emergency situations because of needs in the areas that they regularly serve, inability of available aircraft to land at many of the NSB's small airstrips, and unfamiliarity with the area, which would impede response in poor weather conditions. The other NSB communities are highly dependant on service providers in Barrow to deliver both critical and non-critical services. Alternate service centers in Anchorage, Fairbanks, Nome, and Kotzebue would be unable to approximate this same level of service. Significant storm damages in Barrow affecting its infrastructure could severely impact timely aid to these communities, particularly since some or all could be experiencing the same or worse storm conditions as Barrow.

2.1.14 Local Government Past Damage Reduction Measures

The NSB and others have made numerous attempts to curb the storm-caused erosion and flooding that impact the coast in front of Barrow and its associated facilities. Past coastal erosion and flooding mitigation measures include pushing beach material into berms during storm events, placing sacrificial berms along the shoreline road, offshore dredging for beach nourishment, geotextile sack revetment, filled utilidor seawall, laid-back tar barrels, geotextile tubes, and HESCO Concertainers. A discussion of the performance these measures is contained in Appendix I.

2.2 Without-Project Flooding and Erosion Damages

2.2.1 Historic Flooding and Erosion Damages

Storms that impact the coast during the open water season are typically fast moving from the north and northwest and last from 24 to 48 hours, but can extend up to 96 hours. In October 1963, a strong cyclonic storm passed near Barrow and caused extensive damage; primarily from flooding. The 1963 storm blew gusts up to 73 knots over an ice-free ocean (figure 18). Seawater was reported to have moved 400 feet inland in parts of Barrow. The reported damages totaled $25,090,000 in 2007 dollars, including extensive erosion, damages to 32 homes, flooded roads, loss of fuel oil, damage to a radio tower, contamination of the water supply for several months, and interruption of utility service.

The reported water elevation was 11 to 12 feet and the event generated the equivalent of 20 years of sediment transport and erosion according to NARL scientists. Fifteen homes were destroyed and 17 more were damaged. About 70 percent of the airstrip at NARL was destroyed along with four aircraft, six buildings, and many supplies, stores, and

Figure 18. 1963 Flood Damage Example

scientific equipment. The foundations of the NARL buildings were eroded causing structural damage. The city's power lines and power plant were down, fuel was lost, and water supply was contaminated with salt water. Furthermore, roads were flooded and badly eroded, and a timber bridge floated away. Descriptions of damage from other notable storms follow:

- September 1954: Water elevation 9-10 feet MLLW, water washed over beach, helium tank moved from community nearly to Point Barrow.
- October 1954: Water elevation 9.5 feet, minor damage.
- September 1968: Water elevation 8.5 feet, $50,000 in damages (not inflation adjusted), shoreline road severely eroded and bridge damaged.
- September 1970: Water elevation unknown, minor damage.
- December 1977: Water elevation only 3.5 feet, but persistent winds drove ice 30 yards inland and flooded gas-well runway 6-18 inches deep through a crack in the ice.
- September 1978: Water elevation 5 feet, $5,000-$50,000 in damages (not inflation adjusted) to shoreline road.
- September 1986: Two separate storms, not much data, Leavitt House had to be moved due to erosion, large bluff segments with archaeological remains eroded.
- August 2000: Second most devastating recorded storm due to heightened effects from the lack of sea ice, $7.7 million (not inflation adjusted) in damages mainly to the dredging barge, 36 private homes and 4 NSB housing units sustained roof and siding damages, 6 miles of shoreline road flooded and damaged.
- October 2002: Water elevation peaked at 14 feet, widespread flooding due to dynamics of sustained winds and heavy surf. During storm, heavy equipment rebuilt existing berms to protect fresh water lagoon, some roads damaged, and power outage occurred.
- July 2003: Two storm events, both minor damages, some to shoreline road, but limited as berms were reinforced to reduce flooding and erosion.

2.2.2 Categories of Potential Damages

The primary categories of potential damages in Barrow are erosion damages to the bluff, erosion damages to the beach flood protection berm and shoreline roadways, and flood damages from coastal storms in the eastern portion of the Barrow neighborhood and in the western Browerville neighborhood. Erosion damages include land, structures, archeological site (Utqiagvik Village), and the beach berm and shoreline roadway. Flooding damages occurred to structures and contents, water supply, spillway and its associated utilities and the utilidor and associated utility services. These are discussed in following sections.

2.2.3 Future Without-Project Coastal Erosion Damages

Results of engineering studies and review of historic damages identified two primary sources of erosion damages in the study area. These are damages from wind and waves to the bluff in the Barrow area and costs associated with ongoing repair of the beach berms and beach frontage road (Stevenson Street) in the northeastern part of the Barrow neighborhood and in the Browerville neighborhood.

2.2.3.1 Bluff Erosion Damages

Historic erosion along the bluff in Barrow can be divided into two zones (figure 19). Erosion Zone 1, extending southwestward from the beach in front of the western end of Tasigrook Lagoon to Okoksik Street, was estimated to have a future erosion rate of 2.2 feet per year, resulting in inland movement of the bluff line by 110 feet over the 50-year period of analysis. Erosion Zone 2, extending southwestward from Okoksik Street to the bluff in front of the northeastern end of the airport runway, was estimated to have a future without project landward erosion rate of 1.0 feet per year, resulting in moving the bluff line inland by 50 feet over the 50-year period of analysis. The result of the erosion in both zones would be damages associated with the loss of land, structures, and cultural and historic resources. Figures 19 and 20 show the expected zone of bluff retreat (erosion) over the 50-year period of analysis. The extent of lost land over the 50-year period of analysis is estimated at 7.4 acres. Estimated land damages from erosion over the 50-year period of analysis, based upon a value of $100,000 per acre, have a total present value of $283,000 (equivalent average annual damage is $15,000). As a result of continued bluff erosion, it is estimated 31 structures in the Barrow Neighborhood would be condemned or otherwise removed. Valuation of erosion damages to structures was based upon the estimated depreciated replacement cost of each structure, assuming all contents of value would be removed and no future development would occur in the identified erosion zone. Estimated structural damages from erosion over the 50-year period of analysis have a total present value of $4,735,000 (equivalent average annual damage is $254,000).

Figure 19. Expected 50-year erosion in the vicinity of Barrow.

Figure 20. Expected 50-year erosion in the vicinity of Barrow.

The Utqiagvik Village Site falls in part within the 50-year erosion zone. The site is periodically impacted by bluff erosion that can result in exposure and damage/loss of artifacts, the remains of semi-subterranean houses and occasional human remains being uncovered. UIC annually monitors the Utqiagvik village site by gathering artifacts and human remains from the beach below the site and occasionally archaeologically excavating eroding or threatened features. This cost is not included in the NED analysis. The non-monetary cultural value associated with the archeological site is likewise not included.

2.2.3.2 Annual Storm Protection and Road Repairs

During the 2000 storm, water flooded and overtopped Stevenson Street. Four sections of the roadway were lost (approximately 200 yards in length), costing approximately $330,000 (2007 prices) to repair. It is estimated the road needs to be repaired every 3 years due to storm damages, at a cost of $110,000 annually (2007 prices). Under existing conditions, the estimated annual cost for repairs to beach berms and the shoreline roadway is $677,200 (2007 prices). In the without-project condition, this cost will continue until a project is constructed that controls wave activity and protects the roads from erosive forces during storm events. Over the 50-year period of analysis, this annual cost has a total present value of $12.6 million.

2.2.3.3 Expected Utilidor Damages

The Barrow utilidor is a heated underground utility corridor that provides utility service to parts of the study area. The system became operational in 1984 and currently includes 3.3 miles of utilidors in both the Barrow and Browerville neighborhoods. It contains 11 miles of water, sewer, and force mains, as well as electrical conduit and communications cable. Erosion is expected to result in failure of the utilidor at the west end of Agvik Street within 25 years. The resultant damage is estimated to have a present value of $1.4 million and an average annual value of $75,000.

2.2.3.4 Summary of Expected Coastal Erosion Damages

Table 3 summarizes the present values of erosion damages for each category over the period of analysis and their average annual equivalent values.

Table 3. Summary of Expected Erosion Damages

Erosion Caused Damages	Present Value	Average Annual Value
Land Loss	$283,000	$15,000
Structure Condemnation	$4,735,000	$254,000
Beach Berm Construction/Repairs and Roadway Repairs	$12,604,000	$677,000
Utilidor Damages	$1,399,000	$75,000
Total	$19,021,000	$1,021,000

2.2.4 Future Without Project Coastal Storm Flooding Damages

Coastal flooding in Barrow’s neighborhoods of eastern Barrow and Browerville is expected to continue under without-project conditions. To evaluate without-project flood damages, the Corps’ Beach-*fx* risk-based economic model was applied. Beach-*fx* is a

Monte Carlo-based, event-driven coastal storm damage assessment model. This event approach uses a database of plausible storms in a Monte Carlo-based model to evaluate the economic consequences of storm driven impacts on upland development.

2.2.4.1 Expected Damages to Structures and Contents

A typical new-built structure in Barrow is shown in figure 21. Because of the need to avoid heating the ground under buildings and melting the permafrost, almost all recent structures have either been elevated on piles or placed on gravel mounds. In this design, the lowest damageable item is the utilities box that is usually located several feet below the first floor elevation (as shown to the left of the house in the figure). The utilities box contains both water (constantly circulating) and sewer connections. Most older buildings in Barrow were built with the first floor on or very near the ground surface with similar utility connections.

Figure 21. Typical New-Built Barrow Home.

A structural database was developed by ASCG, Inc. for the NSB and the Alaska District that included 1,000 structures either near or below the 20-foot elevation contour line. In 2006, a supplemental field inspection was performed on a sample of 112 of these structures to include both residential and nonresidential structures in both Barrow and Browerville neighborhoods. Structures were assigned values as a function of the estimated first floor square footage and estimated value per square foot by use, class, and type. Field survey observations were used to apply depreciation adjustments to estimated structure replacement values. Damages to both structures and contents are a function of depth of water relative to the first floor elevations. While a large number of structures are within the 20-foot contour line, many are elevated above the ground level and would be at risk from only the rarest storm events. Estimated damages were determined based on flood depth relative to first floor elevation. The depth damage functions applied in the study for estimation of flood damages to structures and contents can be found in Appendix D.

As noted above, the Beach-*fx* model was used to estimate future storm damages with uncertainty. The Beach-*fx* model uses Monte Carlo simulation to generate probability-distributed data that integrates both engineering and economic relationships to determine the impacts and damages of a storm passing a shoreline. Water surface elevations were modeled by CHL using the SBEACH model and converted to Beach-*fx* storm-response database files for use in the damage assessment. Economic damage elements were spatially developed representing structure and content value, first floor elevations, and type categorizations with uncertainties for structural analysis. Figure 10 shows the delineation of the study reaches for the coastal storm damage analysis. The Beach-*fx* model reports damages by reach in terms of mean, standard deviation, and maximum and minimum values based on a summary of individual simulations for the number of iterations run in the model. For Barrow, 150 iterations were run to create a sample of storm damages over a 50-year analysis period. Table 4 presents the estimated average annual equivalent coastal storm damages to structures and contents for all reaches as derived in the Beach-*fx* model. The total estimated annual damages to structures and contents has a mean expected value of $58,900.

Table 4. Without Project Expected Annual Coastal Storm Damage to Structures and Contents.

REACH	AVERAGE ANNUAL EQUIVALENT DAMAGES			
	MEAN	STANDARD DEVIATION	MAXIMUM	MINIMUM
24	$7,630	$9,000	$53,990	$0
25	$7,390	$5,170	$33,410	$0
26	$19,590	$12,170	$69,460	$0
31	$4,540	$4,130	$21,670	$0
32	$2,780	$2,780	$14,350	$0
34	$40	$100	$920	$0
36	$3,430	$5,770	$43,130	$0
38	$240	$690	$6,920	$0
40	$4,340	$9,190	$56,250	$0
42	$8,230	$12,950	$68,180	$0
43	$690	$420	$2,050	$0
TOTALS	**$58,900**	**$62,370**	**$370,330**	**$0**

2.2.4.2 Expected Damages to Utilities and Infrastructure

ASCG, Inc. prepared a report in September 2005 for the North Slope Borough and the Alaska District that documented their analysis of the monetary impacts resulting from loss or damage to utility infrastructure in the study area, including water supply, Itasigrook Dam Spillway and utilities that cross the spillway, and utilidor/buried utilities.

The Barrow Utilities and Electric Cooperative provides Barrow with water, sewer, and electric service. The city's water source is the upper portion of Isatquaq Lagoon. Water is taken from the lagoon, run through the treatment plant's nanomicrofiltration process and distributed to residents. The ASCG Study identified the damage initiating elevation for the water supply to be at 10 feet mean sea level (MSL) at the outflow pipes from Isatkoak Reservoir at Ahkovak Street. The feasibility study's engineering analyses found that the potential range of water surface elevations, as simulated by the study's SBEACH model, are not expected to result in damages to the city's water supply system.

The spillway will undergo damage when water surfaces in the area exceed 8 feet. The Beach-*fx* model predicts that water surfaces can exceed 8 feet in the spillway reach, although only under low frequency storms. The damage function applied for estimating damages was based upon 5 percent damage between 8 and 9 feet, 50 percent damage between 9 and 10 feet, and 100 percent damages with an 11-foot or higher water surface elevation. The total estimated damages to the spillway are estimated to have a mean expected value of $67,400.

The utilidor would undergo damage when water surfaces in the area exceed 10 feet. SBEACH predicts that water surfaces can exceed 10 feet, although only under low frequency storm events. Maximum utilidor damages from any flood event were identified at $4.5 million. The damage function applied for estimating damages was based upon 6 percent of the maximum damage at 12 feet water surface elevation, 40 percent damage at 14.5 feet, and 62 percent damage at 16 feet. The total damages to the utilidor over the 50-year period of analysis were estimated to have a mean expected value of $31,000. No flood damages were included for any periods after year 25, where the erosion analysis predicts failure of the utilidor to avoid double counting.

2.2.5 Summary of Annual Coastal Flooding Damages

Table 5 summarizes the present values of flooding damages for each category over the period of analysis and their average annual equivalent values.

Table 5. Summary of Expected Coastal Flooding Damages

Flooding Caused Damages	**Present Value**	**Average Annual Value**
Structures and Contents	$1,096,300	$58,900
Water Supply	$0	$0
Spillway and Utilities	$1,254,000	$67,400
Utilidor	$577,900	$31,000
Total	$2,928,200	$157,300

2.2.6 Summary of Future Without Project NED Coastal Damages

Table 6 provides a summary of the expected annual without project damages from coastal flooding and erosion in the study area.

Table 6. Summary of Expected Annual Coastal Storm Damages

DAMAGE CATEGORY	**ESTIMATED DAMAGE %**	**OF TOTAL**
Average Annual Coastal Erosion Damages	$1,021,000	87%
Average Annual coastal Flooding Damages	$157,300	13%
Total Expected Annual Coastal Storm Damages	$1,178,300	100%

2.3 Natural Resources and Social Issues and Concerns

2.3.1 Natural Resources

Extensive environmental studies were undergone as part of the IFS. The results of these studies are provided in Appendix H – Affected Environment. The following paragraphs provide a very short summary of the major natural resources in the Barrow area with issues/concerns that any potential project would need to address.

Marine Mammals. Arctic climate warming is affecting ice pack formation, and consequently the polar bear is now listed and the spotted seal may be a candidate species under the Endangered Species Act. Pacific walrus and other species of seal are also in the area and are affected by the shrinking ice pack. Whale species, notably the endangered bowhead whale, frequent the Barrow area.

Birds. Steller's and Spectacled Eider sea ducks, known to nest in the Barrow area, are listed as threatened under the Endangered Species Act. A large variety of shore birds and terrestrial birds forage on the beaches and nest in the nearby tundra habitat. Seabirds are abundant in near-shore waters.

Fish. The near-shore zone in Barrow provides habitat for several species of fish important to subsistence and as forage fish in the food chain. Local people fish for Arctic cod, and it is an important food source for marine mammals, seabirds, and fish. Other important forage fish are capelin, Pacific sand lance and fourhorn sculpin. The near-shore zone is important rearing habitat for juvenile Arctic cod and fourhorn sculpin. Capelin spawn on Barrow beaches.

2.3.2 Social

Consideration of the social and cultural conditions in Barrow was undertaken as part of the IFS. The results of these studies are provided in Appendices D and H. The following paragraphs provide a very short summary of the major social and cultural conditions in the Barrow area with issues/concerns that any potential project would need to address.

Bluff Erosion. Coastal storms cause beach and bluff erosion and flooding. Erosion of the beach increases flooding in the lower elevation areas. Delayed ice pack formation caused by arctic warming makes the beach and bluff more vulnerable to storms.

Beach Access. The people of Barrow are concerned by the narrowing of the beaches and shoreline road erosion, which limits access to Point Barrow fish camps, boat launching sites, whale harvesting, and recreation activities.

Whaling Culture. Barrow's cultural and social way of life is tied to the northern sea coast, with a long history of whaling. The community has an interdependent social network of families and traditions. The private and public infrastructure is at risk with the increased frequency and severity of coastal storms threatening the cohesion of the community. People of Barrow have the view that the city should be able to have modern infrastructure and have it protected like any other modern city, and still maintain their traditions.

Historical and Archeological Sites. People have lived in the Barrow area for more than 4,000 years as evidenced by numerous archeological sites along the coast, notably the Nuvuk site at Point Barrow and the Utqiagvik Village site in the Barrow neighborhood within the project area. Active erosion along the bluff has been exposing and washing away portions of the site, which is eligible for the National Register of Historic Places. The NSB is currently evaluating a sod house built around 1880 for eligibility for the National Register. The NSB and Ukpeagvik Inupiat Corporation are nominating a portion of the Browerville neighborhood as a National Historic District. The potential for undiscovered cultural and historic sites along the coast is high. The former Point Barrow whaling station is the oldest frame building in the arctic and is on the National Register of Historic Places. Archeological surveys conducted at the potential gravel source areas found cultural materials. The gravel borrow sites considered at the BIA site and at Cooper Island, where bird biologist George Divorky runs a research station, may be eligible for the National Register of Historic Places.

3.0 PLAN FORMULATION

3.1 Need for Action

Representatives of Barrow have expressed concern regarding coastline erosion since the 1960's. Over the years, Barrow has tried a variety of methods to curtail the erosion. The largest scale attempt was a beach nourishment project, discussed in Appendix I, which operated from 1996 intermittently through 2000, when the dredge was heavily damaged in a storm and later sold. No formal appraisal of the uncompleted beach nourishment program was ever made. Informal appraisals by officials and citizens in Barrow indicated the program provided temporary protection from the August 2000 storm, which removed most of the nourished material from the beach, but the program was too expensive to continue. Public perception remains that Barrow is experiencing severe erosion of the bluffs and flooding driven primarily by summer and fall storms. Section 2 provided results of technical analyses undertaken as part of this feasibility study to identify the actual problems, which forms the basis for the need for action to resolve those problems.

The erosion problem previously perceived as acute is really an ongoing, chronic problem with isolated “hot spots” caused by the normal erosive power of the ocean against a permafrost bluff with development immediately adjacent. The Barrow bluffs are composed of fine sand, silt, and organic material bound by permafrost. Wave action on the face and base of the bluffs causes localized melting of the permafrost and niching at the toe of the bluffs, leading to both material slumping and block failure. Both mechanisms move material to the toe of the bluff, where it is eroded by high water events. This action continues annually during the open-water season of mid-June through October and could grow worse if climate change raises the level of the Arctic Ocean and/or increases the severity or frequency of summer and fall storms. The problem is aggravated by lingering effects of past beach mining (particularly from 1955 to 1974), which have not yet been fully rectified. To reduce/eliminate this erosion, measures are necessary that would protect the bluff from this constant annual wave attack without significantly affecting the current longshore transport of beach materials. Total expected annual erosion damages in the study area are estimated at $1,021,000, including value of land loss, structures (contents assumed to be removed), and costs of beach berm construction, shoreline roadway repairs, and utilidor damages.

The Barrow/lagoon/Browerville flooding problem was defined by analyzing the effects of tides, winds, waves, ice, surge, wave set up, and wave run up. The shoreline was divided into reaches, and the expected flooding in each was analyzed separately. For reaches evaluated southwest of the sewage lagoon in the Barrow and Browerville neighborhoods, a storm with a return period of 5 to 20 years, depending on the reach, is required to produce flooding. For the reaches near the sewage lagoon, model results indicate a 3-year storm will produce some flooding. The calculated 50-year flooding elevation across the study area varies between elevations 10 and 14.5 feet. Total expected annual flooding damages in the study area are estimated at $157,300 including damages to structures and contents, spillway and utilities, and the utilidor.

Aside from direct damages to Barrow, a severe coastal storm could affect the Barrow infrastructure and make it difficult or impossible for Barrow personnel to respond to emergency conditions occurring in other NSB communities. This could greatly impair rescue and recovery activities, making the potential disaster in the smaller communities even worse, such as the fire in Kaktovik that destroyed its power system in the middle of winter several years ago. Had resources not been readily available in Barrow and provided to Kaktovik in a timely manner, the village might have quickly "frozen up" due to the below-freezing temperatures, with loss of life and damage to other infrastructure, residential, commercial, and public facilities.

3.2 Problems and Opportunities

3.2.1 Problems

The NSB has been dealing with storm damage and erosion problems at Barrow for decades. Erosion and flood damages from storms impact the shoreline and potentially threaten the community's way of life. Traditionally, when the city or nearby NARL needed foundation materials for buildings or infrastructure improvements, those materials would be obtained from the beach or a gravel pit area, updrift (southwest) a mile from Barrow. The effect of removing millions of cubic yards of beach and pit materials for infrastructure improvements over the decades is an unstable shoreline area starved for material. The natural feeding of the downdrift beach from the pit area stopped. In fact, when the current airport runway/taxiway project is completed, the long-used gravel pit at Barrow will be substantially exhausted. The loss of natural nourishment coupled with increased storm frequency and decreased ice cover left the Barrow coastline vulnerable to the erosional effects of storms. The NSB currently engages in construction of temporary beach berms, by bulldozing up beach sand into a berm supplemented with borrow materials from upland areas. These ongoing activities and associated costs could be replaced by a permanent project.

To guide the study and identify appropriate analyses to be undertaken, the Barrow PDT developed a Problem Statement that summarizes the specific problems evident along the Barrow shoreline. It reads:

> **Problem Statement:** **Barrow's way of life is intrinsic to its location. Changing coastal and climatic conditions have caused Barrow to experience increased frequency and severity of coastal storms. These storms produce hazardous conditions due to flooding and erosion that result in monetary and non-monetary damages. They pose a threat to public and private infrastructure, which is essential for maintaining the cohesion of Barrow as a community, commercial center, emergency support center, and regional seat of government in northern Alaska. The people of Barrow, bound by common traditions, a long history of whaling and mutual reliance, have integrated families from around the world to form the interdependent social network that makes Barrow a unique and distinctive North American town.**

3.2.2 Opportunities

Water projects are formulated to alleviate problems and take advantage of opportunities in ways that contribute to the accomplishment of the two Federal objectives of National Economic Development (NED) and Environmental Quality (EQ), while addressing, as appropriate, the other two national accounts, Regional Economic Development (RED) and Other Social Effects (OSE). Opportunities are goals that the potential Federal project may contribute towards achievement. The PDT discussed with the sponsor possible items that might become opportunities for fulfillment as part of a Corps project. The only one the community expressed significant interest in was to have a navigation element that would provide a boat harbor for commercial and subsistence use and possible recreational purposes. Early in the IFS, improving barge navigation was included as a planning objective, if it could be realized as an incidental output, along with developing ecosystem restoration opportunities, if any, as appropriate. Phase I studies determined potential gravel borrow sites are not located in Elson Lagoon. Therefore, barge related navigation improvements that would be incidental to development of borrow sites for beach measures were ruled out. Also, a review of environmental conditions in the area did not identify ecosystem restoration measures in Barrow that could improve nationally significant resources and meet appropriate criteria. In general, the planning objectives utilize an integrated approach to the solution of erosion and flooding along the Chukchi Sea (Arctic Ocean) coastline in the vicinity of Barrow, Alaska. No other opportunities were identified for consideration by the study.

3.2.3 Collaborative Planning

The Barrow area is an example of a location where collaborative planning, even without direct Corps participation, has brought dividends to the community. Other State and Federal Agencies have been and will be funding a number of infrastructure improvements in and near Barrow. These include the new, $28 million primary sewage treatment plant and disposal system (located between the South Salt Lagoon and the Middle Salt Lagoon), the new Regional Hospital by the Indian Health Service (located just northeast of the Upper Isatquaq (water supply) Lagoon), the new 100,000-sq.-ft. Barrow Regional Climate Change Research Facility of the Barrow Area Science Consortium (located 1,000 feet southeast of NARL near Imikpuk Lake), and a new 2.6-mile-long, $7 million road (Uivaqsaagiaq Road) to the new BASC research facility from inland off Cake Eater Road. In planning the local government agencies involved have actively tried to move critical facilities away from harm along the shoreline. In addition, every year the NSB expends about $700,000 on emergency operations during storm and flooding events by placing sacrificial beach berms along the shore. This coastal storm damage study provides the opportunity to generate information on existing and possible future erosion and flood damages that can impact much of the existing infrastructure. Also, the information, if properly applied in the design of future community facilities, could significantly reduce damages in the future that might have occurred without such information. The current large local annual expenditures could be reduced in the future by implementing appropriate measures.

3.3 Planning Objectives

The IFS focused on meeting the project objectives listed below, primarily through analyzing alternative plans identified in the Barrow 905(b) Analysis and others developed through the study process. The study formulated and optimized the alternatives for implementation based on costs, benefits, and other related assessments. The provisions of EC 1105-2-409, “Planning in a Collaborative Environment,” guided development and screening of potential alternative plans. Normally, the plan that maximizes net NED benefits is identified as the NED plan. Should there be a locally preferred plan, engineering and economic analyses for that plan are conducted to the same level of detail as the NED Plan. Other plans may be identified, as appropriate.

3.3.1 NED Planning Objective

The NED planning objectives of the study are:

- Reduce damages caused by shoreline erosion resulting from wave and/or ice attack in Barrow during coastal storms for at least 50 years.
- Reduce damages caused by flooding to residences, commercial structures, and critical community infrastructure in Barrow resulting from coastal storms for at least 50 years.

3.3.2 EQ Planning Objective

The EQ planning objective is:

- Preserve the sensitive arctic environment surrounding Barrow through the life of any project.

3.3.3 RED Planning Objectives

The RED planning objective is:

- Promote opportunities for employment and income gain for NSB residents and businesses due to direct and secondary activities during the construction period.
- Promote long-term growth and stability in Barrow employment, income, and tax revenues that would be adversely affected by coastal storm damage effects.

3.3.4 OSE Planning Objectives

The OSE planning objectives are:

- Preserve through the life of a project the social and cultural values of the Barrow community.
- Preserve through the life of a project the life, health, and safety of smaller communities in NSB that depend upon Barrow to provide both normal and emergency health care, public safety, fire suppression, search and rescue, and other essential services.
- Preserve through the life of a project the Utqiagvik Village Archaeological Site (eligible for the National Register of Historic Places) from coastal storm damage and detrimental construction activities.
- Preserve through the life of a project the existing views of the Chukchi Sea from Barrow and Browerville for the enjoyment of residents and visitors and for their use in sustaining subsistence activities.

3.4 Planning Constraints

Barrow is one of the areas in Alaska where the threatened Steller's eider and spectacled eider sea ducks are known to nest and the polar bear visits. Any action in Barrow would require consultation under Section 7 of the Endangered Species Act with the USFWS. Elson Lagoon is highly productive for fish and waterfowl. Other marine mammals such as seals, walruses, and beluga and bowhead whales are found in near-shore waters at different times of the year. Care must be taken in the design of the project such that the project does not significantly interfere with subsistence activities critical to the community.

The several archeological sites, historic buildings, and a historic district in the Barrow area are discussed in Appendix H. Many sites are eligible for or listed in the National Register of Historic Places. The impact of the project alternatives on cultural resources and archaeological sites will be examined and evaluated as required under the National Historic Preservation Act. Any project construction and maintenance near the Utqiagvik Village Archaeological Site should be from the water side off the beach to ensure no negative impacts to the site occur.

Some technical constraints also need to be considered in plan formulation. Federal participation in the cost of restoration of beaches is limited to restoration only to the historical shoreline of record, unless needed for structural design. Both Corps of Engineers and Federal Emergency Management Agency criteria regarding the design and analysis of coastal flooding, coastal structures, and flood plain mapping need to be considered to provide the best product for the local community. In addition, the final project design must take into account not only structural stability against water/wave attack, but also problems the structure would encounter from ice movement and attack and interior drainage.

3.5 Evaluation Criteria

Evaluation criteria listed below were used to screen and evaluate alternative plans and to measure each plan's contributions. The alternative plan shown to maximize net NED benefits normally is identified as the NED Plan.

Completeness. The extent to which an alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of all planned effects. (Does the plan include all the elements needed to achieve the identified benefits?)

Effectiveness. The extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities, as established in the planning objectives. (To what extent does the plan provide the desired outputs?)

Efficiency. The extent to which an alternative plan is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities as established in the planning objectives, consistent with protecting the Nation's environment. (Does the plan provide the maximum net NED benefits?)

Acceptability. The workability and viability of the alternative plan with respect to acceptance by state and local entities, and the public, and compatibility with existing laws, regulations, and public policies. (Is the plan feasible [in technical, environmental, economic, and social senses] and doable [in political, legal, institutional senses]? To what extent is the plan, while maybe not ideal, satisfactory?)

4.0 RISK MANAGEMENT MEASURES AND ALTERNATIVES

4.1 Identification of Initial Risk Management Measures

A wide array of structural and non-structural risk management measures was considered to address identified coastal storm damage problems and opportunities. Structural measures are those that reduce the risk by modifying the characteristics of the flood or erosion problem. Non-structural measures are those that reduce risk by modifying the characteristics of the buildings and structures subject to flood and erosion damages and/or modifying the behavior of persons that live in the risk area. Barrow experiences two separate but related overlapping problems: erosion (primarily of the bluff area during storms and melting permafrost) and storm driven flood damages. Many of the risk management measures that are commonly used elsewhere to deal with coastal erosion and flood damage do not apply under arctic conditions. Some measures could potentially address both problems, but for this discussion of initial risk management measures, the problems are discussed separately in three major categories:

- Structural measures that reduce flood damages(Transects 24 thru 43),
- Structural measures that reduce bluff erosion (Transects 17 thru 27), and
- Non-Structural measures that move susceptible structures/facilities away from danger, reduce the damage in place, or change local policies, procedures, rules, etc. to reduce damage susceptibility of improvements.

4.1.1 Structural Bluff (Bank) Erosion Risk Reduction

The bluffs at Barrow are composed of silt and organic material bound by permafrost. Wave action on the face and at the base of the bluffs causes localized melting of the permafrost and niching at the toe of the bluffs. Once the permafrost melts, the bluff material has no inherent strength, which leaves the bluff susceptible to two potential failure modes: slumping or block failure. Slumping occurs when the permafrost is exposed and the subsequent melting produces localized mud flows of unstable material down the face of the bluff. This material is then washed away during high water events. Block failure occurs when the base of the bluff has eroded out to the point where the ice is no longer capable of supporting the weight of the bluff and a large block of bluff collapses and is washed away by high water events. Block failure can be quite large if the failure plane is along the ice wedge of a polygon. Structural bluff protection measures considered were revetment, beach nourishment, sea wall, offshore breakwater, and groins.

4.1.1.1 Revetment

Use of a revetment to protect the bluffs would allow the bluffs to be protected from the major erosion sources of slumping and niching. A revetment to protect eroding bluffs has been successfully used in many locations throughout Alaska. Limiting factors when considering a revetment along the bluffs at Barrow are cost of the revetment material, the resistance of the revetment material to ice forces, and the ease of construction and maintenance. Material options considered for the revetment included rock, supersacks, and articulated concrete mats. This measure would protect the bluff toe and not harm the existing beach. It was retained for further consideration in developing alternatives.

4.1.1.2 Beach Nourishment

This measure combined with raising the road along the shoreline formed both the potential solutions identified in the Section 905 (b) Analysis. Use of beach nourishment to protect eroding bluffs has not been used widely in Alaska. The key to successful beach nourishment is the use of material as coarse as or coarser than the material in the area to be nourished. This option would protect the toe of the bluffs from niching, but would not address the slumping issues associated with melting permafrost.

The NSB began a beach nourishment program in the 1990's, using a dredge to place material from the nearby sea bottom on Barrow beaches. However, the dredge used to perform the beach nourishment was heavily damaged during a storm event in 2000, prior to the completion of the nourishment project. During dredging, the NSB had been unable to obtain material that was as coarse as or coarser than the existing beach material. Subsequent storms washed away the comparatively fine-grained material that had been placed on the beach. The beach nourishment program was terminated before completion after the damage to the dredge, when the NSB determined that the meager results were not worth the costs of the program.

The Corps considered reinitiating beach nourishment to protect bluffs and to reduce flooding. Past results at Barrow and experience at other beach nourishment projects has shown that long-term results would be achieved only if coarser material (gravel) could be used. Reconnaissance studies indicated beach nourishment was a measure to be considered during feasibility studies and that between one-quarter million and one-and-a-half million cubic yards of gravel might be required for a successful beach nourishment project. There is no economically viable site with gravel of such size near the affected coastline. The closest developed site is the UIC gravel pit 6 miles inland from the protected beach. Cost estimates for another measure indicate relatively small quantities of gravel from the UIC commercial source would cost $33.50 per cubic yard delivered to the site (appendix C). The UIC borrow pit is the least expensive site that could be identified, but would not produce more than a small part of the 2 million cubic yards required for an extensive beach nourishment project. This led to an extensive search early in the feasibility study for a large, new gravel source near Barrow.

Several undeveloped gravel sources were identified in the Barrow area, and three were evaluated in detail as material sources for beach nourishment (figure 22). These were the BIA site, the Pt. Barrow spit, and Cooper Island. Exploration was also attempted at an old, submerged spit directly north of the current Pt. Barrow, but sea conditions were rough and no viable gravel site was found. The site closest to Barrow, identified as the BIA site, is on the tundra 4 miles south of Barrow. It would be accessible by ice road in the winter and produce gravel adequate in both grain size and quantity. Gravel at the site is under relatively deep, perennially frozen overburden, which would be expensive to remove and store. Cost to develop and transport gravel from this source and restore the site after production was estimated to be $70 per cubic yard. The site is potential nesting habitat, and therefore critical habitat, for two species of endangered sea ducks, Steller's eider and spectacled eider (Appendix E). Ensuring listed eiders and their critical habitat was protected, restored after production, and effects mitigated would be expensive and would present significant risks to a project's viability.

Barrow Spit, a coastal accretion beach northeast of Barrow, has gravel that is large enough and abundant enough to serve as a source for beach nourishment. There is no overburden on the current spit and the site is relatively accessible from Barrow, so development costs would be comparatively low. Cost to develop and transport gravel from this source and to restore the site after production was estimated to be $48 per cubic yard**.** The spit is used by a variety of birds, but is not nesting habitat for endangered species. Developing and extracting gravel from this site could impact known archeological and historical sites that are particularly important to the historic record as the northern-most habitations in the United States and to the people of Barrow and surrounding communities as representative of their ancestral roots. Recovery of archeological materials directly affected by gravel removal and indirectly affected by induced erosion would be expensive, contentious, and time consuming in the short construction season. There is substantial risk human remains and unanticipated archeological discoveries would halt work for substantial periods. Archiving archeological material would be expensive, as would mitigation for unavoidable effects.

Cooper Island is a low-lying barrier island 25 miles east of Barrow with gravel suitable in size and quantity for beach nourishment. Barrier islands closer to Barrow, which were evaluated as gravel sources, did not have economically extractable amounts of gravel. Gravel could be excavated from the surface of Cooper Island and barged to Barrow for beach nourishment. Gravel also could be excavated after Elson Lagoon was frozen in the autumn and trucked to Barrow over an ice road. Transportation costs and environmental timing constraints would make this the most expensive of the three potential new gravel sources evaluated in detail. Cost to develop and transport gravel from this source and to restore the site after production was estimated to be $75 per cubic yard. Cooper Island is used intensively by migrating shorebirds each spring, is nesting habitat for a variety of shore and seabirds, and is adjacent to marine waters that are extremely productive for invertebrates that, in turn, are eaten by great numbers of fish and by bowhead whales. The island also is the site of a migratory bird research program spanning two decades and has produced data important for understanding long-term changes in populations of migratory shorebirds in the far north. Mitigation measures to avoid or minimize impacts to coastal resources, including migratory birds, bowhead whales, and the ability of Native people to harvest those whales would add appreciably to costs for gravel from this site.

Evaluation of potential gravel sources in the far north of Alaska shows developing a local material source for beach nourishment would be very expensive, largely because any type of construction in the frozen soils on land or in the shallow coastal waters is expensive. The high value of the Chukchi Sea coastline for both cultural and biological resources imposes timing and other constraints that would further increase costs, but that are difficult to quantify. As an alternative to expensive gravel extraction near Barrow, gravel could be barged to Barrow from sources farther south. The total cost would depend upon the specific source selected, primarily whether it was an existing commercial site or a new borrow area. There is no assured, already-developed, large-volume gravel source at Nome. However, there are large volumes of gravel in the area, residue from the placer barge, gold mining days. Nome gravel could relatively easily be developed, extracted, and barged to Barrow. Costs were developed for alternative comparison that assumed the gravel and rock materials required for a project would come from the vicinity of Nome.

All the potential sites except for the submerged spit had sand and gravel that was comparable in size to the beach material at Barrow and Browerville. The success of a beach nourishment alternative at Barrow is the ability to constantly renourish the beach if beach material similar to the existing beach is used or less frequent nourishment if material coarser than the existing beach material is used. The beach nourishment option would not address the slumping issues associated with melting permafrost. It would protect the bluff toe and not harm the existing beach, so it was retained for further consideration.

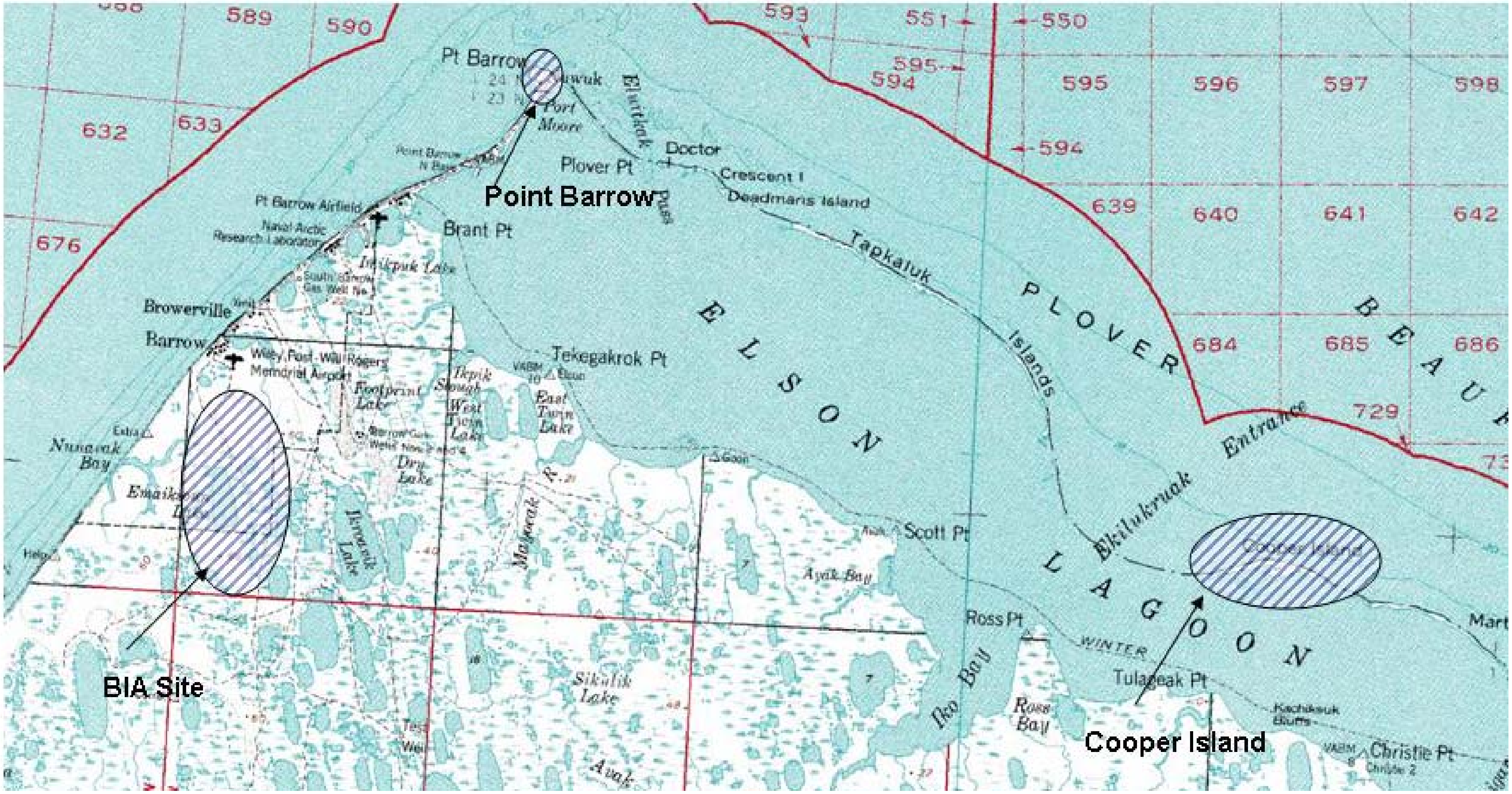


Figure 22. Potential gravel sites from geotechnical investigation.

4.1.1.3 Seawall

Seawalls have been used in Alaska to stem erosion, prevent loss of land, and to protect developments and infrastructure behind them. Materials that could be used in the construction of a seawall include sheet-pile, timber piles, pipe piles, or concrete. The beach at Barrow is important to the way of life in the arctic. Boats are launched on the beach for subsistence activities, and goods and supplies are landed on a barge at the beach, so it is important that the beach be maintained. A number of seawall structures in Alaska have caused scour to develop on the fronting beach. Because this option could harm the coastal environment, it was dropped from further consideration

4.1.1.4 Offshore Breakwater

Intermittent breakwaters could be used to lessen the wave energy impacting the beach and the base of the bluff. This option would need to be designed to withstand ice forces associated with ivu events. Typically, offshore breakwaters provide a quiet area where sediment accumulates and a tombolo forms, giving the shoreline a scalloped appearance. Due to the small amount of sediment transport, the formation of a tombolo would be a very slow process. Materials that could be used in the construction of a breakwater include rock or concrete armor units similar to dolosse. Construction costs of this option would be higher than other options because work would need to be performed from a barge, inspection and maintenance would be more difficult, and it would likely lead to erosion outside the project area due to the interruption of the natural sediment transport system. Consequently, this measure was dropped from further consideration.

4.1.1.5 Groins

Groins are typically placed to limit the movement of longshore sediment to build up a beach. Due to the limited longshore transport of beach material, groins would be marginally effective. Materials that could be used in the construction of a groin system include rock, steel piles, timber piles, and sacrificial supersacks. Groins would take a long time to build up sediment to increase the beach width and would limit the amount of material being transferred outside the project area resulting in erosion outside the project area. This measure was dropped from further consideration.

4.1.1.6 Summary of Structural Bluff Erosion Reduction Measures

Table 7 presents a summary evaluation of the measures considered for bluff erosion reduction.

Table 7. Summary of Structural Bluff Erosion Reduction Measures.

Protection	Good Features	Bad Features
Revetment	Provides protection of the entire bluff face. Easy construction with land based equipment. Easy access to inspect for damages and to repair.	Susceptible to ice damage. Depending on material used, could have high maintenance requirements.
Beach Nourishment	Returns beach material that had been lost during storm events and borrow activities. Would reduce wave impact at the base of the bluff.	Will require periodic maintenance. No nourishment material with significant gravel portion locally available.
Seawall	Provides protection of the entire bluff face.	Will protect the bluff, but possibly erode the fronting beach.
Offshore Breakwater	Will reduce wave climate at the base of the bluff.	Susceptible to ice damage. More complex construction. Needs offshore equipment. More difficult to inspect and maintain. Would produce a sediment deficit downdrift of the groins. Sediment transport is minimal, beach buildup will take a considerable time.
Groins	Would build up sediment and eventually raise beach elevation resulting in milder wave climate at the base of the bluffs.	Susceptible to ice damage. Would produce a sediment deficient downdrift of the groins. Sediment transport is minimal, so beach buildup will take a considerable amount of time.

4.1.2 Structural Flood Risk Reduction

The bluffs at the southwestern end of Barrow provide sufficient elevation to protect that part of the coast from being susceptible to flooding from even severe storm events. The terrain elevation decreases to the northeast along the coast. At Tasigrook and Isatkoak lagoons, no bluff exists and the coast is a low-lying beach. The area of Isatkoak Lagoon and the northeast low-lying beach along the coast are susceptible to flooding during storm events. Flooding occurs during storm events with high wave run up elevations that exceed the berm elevation fronting the coast. Structural flood damage reduction measures that were considered for Barrow were: (1) coastal dike adjacent to shoreline road, (2) coastal dike formed by raising the shoreline road, (3) seawall, (4) beach nourishment, and (5) filling Tasigrook Lagoon.

4.1.2.1 Coastal Dike Adjacent to Shoreline Road

A dike that would dissipate the energy associated with wave run up could be constructed on the seaward side of the coastal road. The dike would be susceptible to damage from ivu events and could be designed to withstand ice forces, but this would require a significant increase in the size of the armor stone, and due to a lack of information on the frequency and severity of these episodes, maintenance due to ivu events would still be assumed. A dike sized to address the wave run up and not ice forces would use considerably smaller armor stone, but would have a higher associated maintenance interval. The NSB currently uses a sacrificial dike system to protect low-lying areas from flooding, which is effective, but susceptible to wave and ice damage. The dike option would protect the low-lying coastal area from flooding and not harm the existing beach, so it is retained for further consideration.

4.1.2.2 Coastal Dike Formed by Raising Shoreline Road

This measure combined with beach nourishment formed both potential solutions identified in the 2001 905(b) Analysis. A dike could be constructed by raising the shoreline road to provide an increased elevation in the low-lying areas that are susceptible to flooding. A dike would need to be designed to protect the structure from wave effects and ice forces. During storm events the NSB constantly places sacrificial dikes along the coastline. Construction and maintenance material for a dike would be a prime concern for this option. The dike option would extend from transect 22 to transect 43. This measure would protect the low-lying coastal area from flooding and not harm the existing beach. However, construction costs would be substantially higher than the coastal dike adjacent to the road measure due to the need to raise the entire road cross section. Additional real estate rights would be required because of the greater project footprint. This measure was dropped from further consideration.

4.1.2.3 Seawall

Seawalls have been used in flood protection in the same manner as a dike. A seawall would require less land for construction because it could have a vertical face. As previously discussed, the concern with seawall systems is waves breaking on the seawall face erode the material in front of the seawall, so if the seawall is not placed deep enough the structure will be undermined and begin to fail. Wave action on the wall face results in narrowing the beach fronting the seawall. Because there was potential damage to the beach, it was dropped from further consideration.

4.1.2.4 Beach Nourishment

The intent of beach nourishment would be to raise the beach elevation and to move the wave run up away from Tasigrook Lagoon and the Browerville neighborhood. The beach fill and bluff fill would be a continuous project, so the preliminary project attributes discussed in the beach nourishment for erosion protection apply for the beach nourishment for flood protection measure. This measure was retained for further consideration.

4.1.2.5 Filling Tasigrook Lagoon.

During a coordination meeting with stakeholders, City of Barrow personnel suggested filling in Tasigrook Lagoon up to elevation +8.0 feet and pumping any required discharge from Istakoak Lagoon to the ocean. This would serve to provide damage reduction for a high-value infrastructure element, the Istakoak Dam and the utilities crossing it. An evaluation of that alternative found it to be the simplest flood reduction plan and least prone to failure. It is estimated 250,000 cubic yards of fill material would be needed to fill to Tasigrook Lagoon. This measure was retained for further consideration.

4.1.2.6 Summary of Structural Flood Damage Reduction Measures

Table 8 presents a summary evaluation of the structural measures considered for flood damage reduction.

Table 8. Summary of Structural Flood Damage Reduction Measures

Measure Type	Advantages	Disadvantages
Coastal Dike	Straightforward construction and maintenance. Proven success in Alaska. Easy access for inspection.	Susceptible to ice damage. Depending on materials used, could have high maintenance requirements.
Road Raised for Coastal Dike	Construction complicated by having to accommodate roadway, local access, and drainage. Easy access for inspection.	Susceptible to ice damage. Depending on materials used, could have high maintenance requirements. Would have real estate requirements greater than the coastal dike to accommodate roadway, local access, and drainage.
Beach Nourishment	Aids in returning the beach to its original state. Would reduce wave run up with increased beach elevation.	Would require periodic maintenance. No nourishment material with significant gravel portion locally available.
Seawall	Provides a large area of flood protection.	Would protect the low lying areas from floods, but erode the fronting beach.
Lagoon Fill	Simplest structural measure. Would require pumping lagoon discharge to ocean.	Pumps might be hard to maintain in arctic environment.

4.1.3 Non-Structural Damage Reduction Measures

Where structural measures try to control or divert the water causing flood damages or erosion, non-structural measures reduce the susceptibility of buildings, structures, utilities, facilities, land, etc. to damages from storm events and abnormal flooding. In Barrow, consideration was given to non-structural measures such as participation in the National Flood Insurance Program (NFIP), wet and dry floodproofing, elevating and/or relocating structures, and buyout/demolition of structures.

4.1.3.1 Participation in the National Flood Insurance Program

Currently, the NSB does not belong to or participate in the NFIP. This measure would provide that the NSB, as the normal planning and regulatory agent under Alaska state law for the Barrow and Browerville neighborhood’s in the City of Barrow, join the emergency program of the NFIP and eventually participate fully in the regular program of the NFIP. Under provisions of Water Resource Development Acts (WRDA), Congress requires non-Federal sponsors of flood damage reduction (Section 402 of WRDA 1986) and hurricane and storm damage reduction projects (Section 14 of WRDA 1988) to participate in the NFIP and comply with its provisions.

The sponsor must prepare a Floodplain Management Plan (FMP) within one year after signing a Project Partnership Agreement and implement the FMP one year after project completion (Section 202C of WRDA 1996). This means that the Corps project local sponsor must adopt local regulations in accordance with requirements and guidelines of the Federal Emergency Management Agency, which generally include updates of local ordinances to preclude new development in the velocity zone or other high hazard area and require new development outside the floodway/hazard area to be constructed with first floor elevations at or above the median 1 percent chance flood level. The FMP would describe conditions in the floodplain after project implementation and identify the residual risks and potential public safety concerns. The FMP would include a plan for emergency flood operations for the community, including an emergency evacuation plan, as appropriate.

No physical work would be performed along the beach. Floods would continue to occur but, damages to structures and contents would be reduced gradually over time. In developing and evaluating possible solutions to water resources problems, the Corps is required by national policy to assume that flooded communities already are active members of the NFIP. For those communities that are not, this policy assumption becomes an additional requirement that is added to and included with all other local sponsor requirements for participation with the Corps of Engineers in a storm damage reduction project. Appendix I provides additional information on the provisions of both the emergency and the regular NFIP that local governments must follow.

4.1.3.2 Floodproofing of Buildings and Structures

Wet and dry floodproofing was considered for the community of Barrow. However, it was not practical for reasons dealing with the climate, foundation, and typical construction methods. Because of problems encountered with snow and ice, many buildings are elevated. This permits the snow to drift under the structure and pass through rather than piling up against the windward side of the structure. Also, building foundations can incur major damage whenever the structure is placed directly on grade due to melting of permafrost causing differential settling. Most structures in Barrow are elevated above the natural ground either on piles or on a thick gravel pad to insulate the soils. An air space is designed to separate the relatively warm building's flooring beams and joists from the ground. Therefore, some normal floodproofing measures are not practical at Barrow, where it is better to consider elevating or relocating buildings. This measure was dropped from further consideration.

4.1.3.3 Relocation of Major Public Facilities

This measure would move public buildings and facilities that currently may be susceptible to various levels of storm and flood damages to safer locations. In recent years, a number of Barrow stakeholders have been actively involved in planning, designing, and constructing new buildings and facilities in cooperation with other Federal and Alaska state agencies. In each case they have considered the dangers posed by storms and flooding and have selected sites farther removed from the shoreline. Examples include:

- Moving the old solid waste landfill from the beach to a site 8 miles inland (new site open).
- Closing out the primary treatment sewage lagoons (South Salt and Middle Salt lagoons) and constructing a Wastewater Treatment Plant on high ground inland of the lagoons.
- Replacing the existing Samuel Simmonds Hospital, on Isatkoak Lagoon next to the dam, with a new facility on high ground 10 blocks from the shoreline (site preparation underway).

- Constructing the new 80,000-square-foot Barrow Global Climate Change Research Facility at the Barrow Arctic Science Consortium (BASC) using a location and design that elevates the structure above potential flood levels (Phase 1 completed).
- Relocating Stevenson Street, the existing primary road along the shoreline from the Browerville neighborhood to BASC, to high ground inland along Laura Madison Street. This provides a safer vehicle route that would not be overtopped and blocked during severe flooding.
- Raising by several feet the existing road that crosses the middle of Isatkoak Lagoon, providing a flood-free route between the Barrow and Browerville neighborhoods.
- Repairing and upgrading the existing 10-foot-high dam that forms Isatkoak Lagoon.

Since all these projects are being actively pursued by local agencies with cooperative funding from non-Corps Federal agencies and/or Alaska state agencies, they have been considered to properly belong in the without-project condition. Thus, their damages and potential project benefits are not available and have not been included in the current Corps study. This measure was dropped from further consideration in the Corps feasibility study, since major local structural/infrastructure improvements are being constructed by local governmental agencies under other Federal, state, and regional programs and do not need Corps participation.

4.1.3.4 Elevating/Relocating Residential and Commercial Buildings

This measure would structurally raise on piles private residential and commercial buildings identified by the flood damage appraisal as receiving flood damages and relocate private residential and commercial buildings identified as suffering damages from erosion during the study period. The sponsor, through its contractor ASCG, conducted a damage survey using sampling techniques to determine the stage-damage relationship for structures and contents unique to Barrow. This measure would raise structures above the flood elevation or move them away from the erosion area, which would reduce their estimated damages. This measure was retained for further consideration.

4.1.3.5 Buyout and Removal of Residential and Commercial Buildings

This measure would buyout and remove residential and commercial structures from the potential flood and erosion areas. The cost of buyout at current market value, demolition, and removal of the structure greatly exceeds the potential value of the benefits that could be realized by eliminating the future risks. This measure was dropped from further consideration.

4.1.3.6 Summary of Non-Structural Damage Reduction Measures

The Congressional requirement for a local government (either the NSB or the City of Barrow) to participate in the NFIP is included with all alternatives except for the No Action Plan. Local stakeholders are relocating a number of major public and private structures and facilities, and these projects are not considered further as part of this feasibility study. Floodproofing of damageable structures is not practical and the buyout costs would exceed the reduction in damages realized. Therefore, these measures will not be considered further. Reducing flood damages by raising or relocating residential and commercial structures is discussed in more detail in Section 4.2.6.

4.1.4 Design Parameters for Structural Measures

4.1.4.1 Run Up For Structural Measures

The run up associated with the natural beach slope was presented earlier as part of the SBEACH analysis for coastal flooding. SBEACH is not able to calculate run up associated with a permeable stone structure, so calculation methods were used as described in the Coastal Engineering Manual (CEM). Since revetment providing shore protection from flooding would be set back from the near-shore environment, the run up calculation was made using shallow water assumptions. Larger waves will have broken by the time they reach the toe of the structure, so the significant wave height used for calculations was the maximum wave height that could be sustained at the toe of the structure with the associated water level described above using the relationship $H_{b/}h_b$=0.78 (where Hb is the breaker height and hb is the water depth below the still water line at the wave crest at incipient breaking). Run up was calculated using methods for a rock armored surface shown in the CEM. The run up elevation was added to the SBEACH water elevation to obtain a minimum structure elevation for the 20, 50, and 100-year flood events. Although the bluff area is not susceptible to flooding because of the natural elevation, wave run up is equally important in the protection of the bluff from erosion. The fine material that comprises the bluff is extremely susceptible to erosion from wave action and run up that could remove the fine material. The revetment elevation at Transect 18 to protect from storm attack was calculated in the same manner as the flood revetment elevation described above. Total water elevation on the revetment in the bluff area is generally higher than total water elevation on the revetted berm in the flood area. The beach is generally narrower in the bluff area, which results in a structure that is closer to the shoreline and more vulnerable to attack from larger waves. The results of the run up analyses are shown in table 9.

Table 9. Total Water Level in the Low Lying Area

(Tide + Surge + Set Up + Run Up)			
	20-Year Wave Run Up [feet]	50-Year Wave Run Up [feet]	100-Year Wave Run Up [feet]
Low area	9.5	12.5	14.0
Bluff area	14.5	18.5	20.0

4.1.4.2 Design for Wave Attack

The armor stone was sized for a depth-limited wave impacting the toe of the structure. To accommodate the uncertainty associated with a decreasing ice season and a potential increase in storm activity, the 95 percent confidence interval associated with the 50-year water level that included the tide + surge + wave set up from SBEACH was used for the water level rather than the mean water level. This elevation was superimposed on the 2003 transect survey elevation to determine the maximum wave height that could impact the structure. The water depth at the toe of the structure yields a maximum potential breaking wave of 8 feet at the toe of the structure. The revetment design for shore protection used a multilayer design with two layers of armor stone and under layers of B stone, core, gravel, and filter fabric. Using Hudson's equation for the largest breaking wave of 8 feet and a Kd of 2 results in armor stone size of 2.7 tons.

4.1.2.3 Design for Ice Attack

In addition to wave forces, any structure placed along the coast at Barrow would be subject to ice forces. The survivability of a rock structure along the coast during an ivu event was studied using a physical model at the Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire. A series of four model tests were conducted in the Test Basin of the Ice Engineering Facility at CRREL to simulate the impact of ice shoves from the Arctic Ocean on the proposed coastal protection structure. The objective of the model tests was to assess the integrity of the proposed structure under the impact of the ice shoves by determining the stability of the stones. A review of available data on ice conditions in the Arctic Ocean off Barrow indicated that representative ice covers are on the order of 5 feet thick. A detailed discussion of the ice tests is in Appendix A.

The last test evaluated 4-ton stone and 8-ton stone on the structure slope with four different toe configurations (8-ton, 13-ton, and 20-ton toe stones). The revetment slope section with the best survivability during the tests was the selectively placed 8-ton stone slope with a 13-ton toe. The 8-ton stone slope with an 8-ton toe sustained damage that would require slope repair. The 8-ton stone slope with the 13-ton toe stone sustained damage to a section of the toe that would need repair, but the bottom layers of the toe stone stayed in place and there was minimal movement on the revetment slope. The entire 4-ton stone slope survived, but experienced movement and dislodged stones. Three of the revetments would require extensive maintenance, and the fourth would require minor maintenance (replacement of the top toe stone layer). The idealized cross section that had the best survivability and least subsequent maintenance is shown in figure 23.

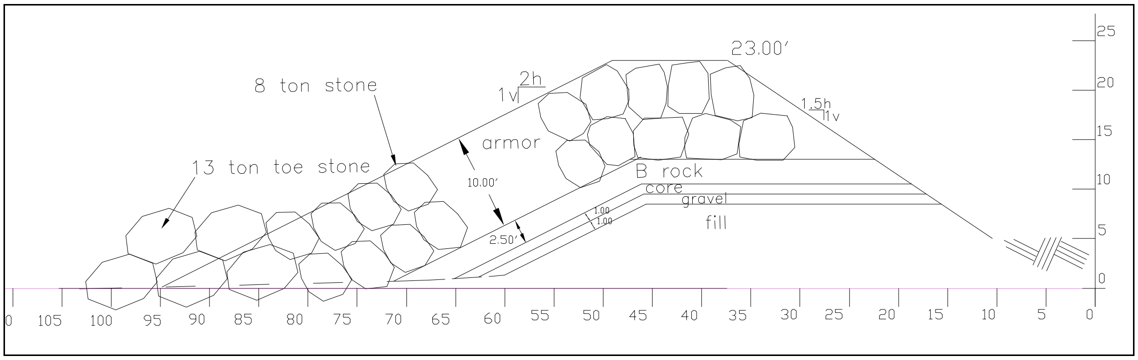


Figure 23. Idealized cross section from ice tests with best survivability from physical model.

Many uncertainties were associated with ice testing, such as the recurrence interval of ivus and ice strength during an ivu. The length, speed, and duration of an ivu are not well documented. Results of the physical model testing provided data to size the armor stone for minimum maintenance due to ice impact. Test results highlighted the importance of the structure toe when it is set back from the beach. The toe is the first element to be impacted by the ice and cause significant ice deflection. Because of the critical nature of the toe, the smaller stone comprising the filter layers under the armor are to be buried to prevent them from being gouged out by the ice. Burying the filter layers leaves the armor toe stone as the initial impact surface with the ice to begin flexure. Sizing the stone to withstand ice impact results in an armor layer that is oversized for waves. It also set the minimum structure height. The armor stone thickness is two stone widths, which results in a revetment elevation higher than the 50-year run up elevation along the low-lying coast. In an effort to minimize stone quantity and elevation, the B stone layer was reduced from two layers to one.

4.2 Development and Evaluation of Initial Damage Reduction Alternatives

The study team developed initial alternatives from the screened measures to evaluate their effectiveness and efficiency at addressing identified coastal flooding and erosion damages in the study area. Different designs were pursued to determine which was most advantageous for coastal protection. A structure designed to withstand most ice events was designed, as well as structures with armor stone for both the flooding and the erosion areas, which overlap. A beach nourishment alternative was evaluated assuming that gravel for nourishment would be imported. Elevating/relocating buildings and filling in the lagoon were also considered. A more detailed discussion of the structural alternatives is in Appendix A. An M-CASES summary cost estimate for each of the 16 alternatives identified below is provided in Appendix C. The detailed economic analysis for the study is discussed in Appendix D. The price level for all the alternative cost estimates is October 2007. The economic analysis is based on a 4-7/8 percent interest rate over a 50-year period of analysis. Transect locations are shown on figure 10 (see page 16). For each damage reach, the transect forming its western boundary is the same numerical designation as the damage reach. For example, the western edge of Reach 24 is Transect 24 and the eastern edge is Transect 25.

The initial alternatives considered included:

- No Action,
- Revetted Berm Sized for Waves
- Revetted Berm Sized for Ice
- Revetment (to reduce bluff erosion damages from coastal storms)
- Beach Nourishment
- Non-Structural (Elevate/Relocate Residential and Commercial Structures)
- Fill Tasigrook Lagoon

Although not specifically described in the following paragraphs, each of the action alternatives would also include the non-structural measure of community participation in the NFIP as discussed in section 4.1.3.1. Future with-project conditions for each alternative are described in the following sections.

4.2.1 No-Action Alternative

The No-Action Alternative would not include any additional coastal storm protection (flooding or erosion) measures in the study area other than those already proposed and accounted for in the determination of expected future without-project conditions. As discussed previously, it is assumed that the NSB will continue with their annual flood fighting practices of berm building and repair of erosion damages to the beach frontage road in the absence of a Federal (Corps) project. Damages would be expected to continue as described in Section 2.2 of this report and summarized in table 6.

4.2.2 Revetted Berm Sized for Ice

Coastal flooding at Barrow is the result of a combination of tide, surge, wave set up, and wave run up, with wave run up being the water level increase that results in flooding. The coastal flood protection structure in front of Browerville and Tasigrook Lagoon is designed to address flooding by reducing the wave run up energy. The 50-year run up elevation is 12.5 feet and the 100-year run up elevation is 14 feet, but the crest height of the structure is determined by the average stone diameter (figure 24). Because the structure is set back from the beach, a two-armor-stone thickness will result in a 15-foot crest elevation. The filtering B layer, core, gravel, and fabric would be placed below the natural beach line for ice survivability. The seaward side of the structure would consist of five 13-ton stones that transition into an 8-ton stone back side. The reduced size of the structure would likely result in increased maintenance due to extreme ice impact events, but the reduced size would make the maintenance of the structure easier to perform. A stockpile of replacement stone would be kept at Barrow for maintenance activities. The B rock would be a single layer sized to filter 13-ton stone on the front of the structure and 8-ton stone on the back. The B rock, core, and gravel filter layers would be buried to match the existing beach elevation.

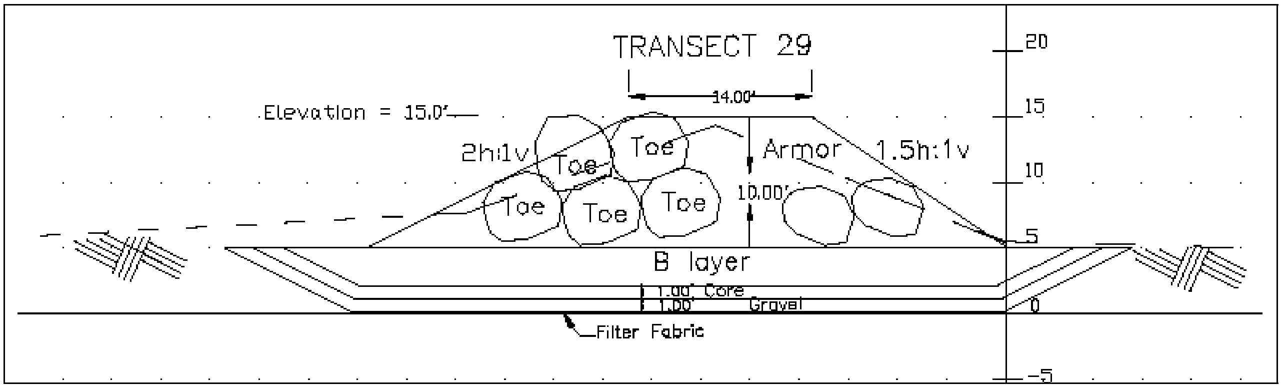


Figure 24. Revetted Berm Sized for Ice in Front of Browerville and Tasigrook Lagoon

The revetted berm sized for ice along the bluff area would consist of two layers of armor stone on the structure slope (figure 25). The stone size was obtained from ice testing. The toe of the structure would consist of five 13-ton stones that transition into an 8-ton stone slope. The B rock would be a single layer sized to filter 13-ton stone on the toe and 8-ton stone on the slope. The B rock, core, and gravel filter layers would be buried to match the existing beach elevation. The crest height was set 0.5 foot higher than the 50-year run up to keep the run up from impacting the backing bluff. The bluffs would not be excavated to provide a uniform slope on which to build; rather they would be dressed with fill material to achieve a uniform slope. The bluffs are archaeologically rich, so no excavation would be permitted on the bluff face.

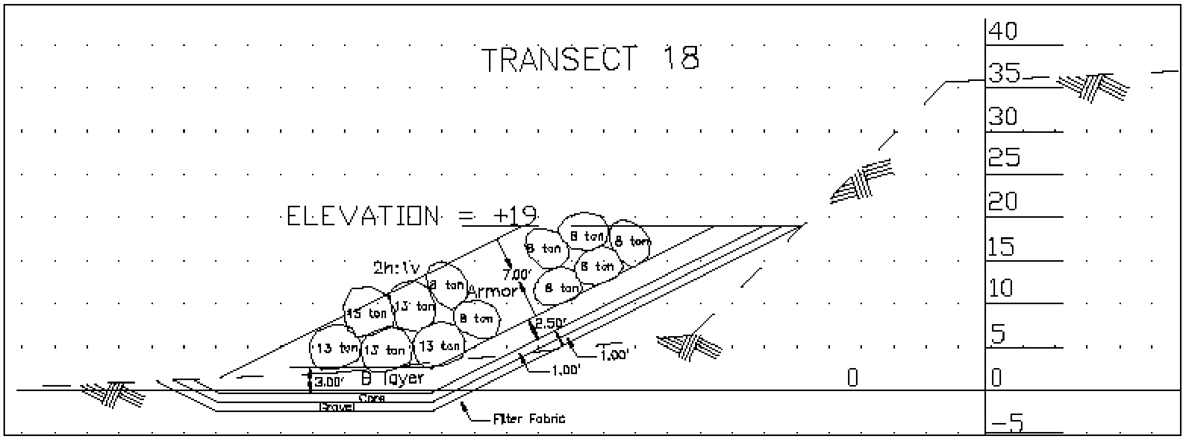


Figure 25. Revetted Berm Sized for Ice Along Bluff

Alternative 9 would provide the section shown in figure 24 for 8,750 feet from Transects 22 to 43, where it would tie to high ground along the eastern side of Amaaogak Street. The ice revetment would be effective at eliminating all coastal flooding damages identified in the study area, including elimination of potential for flood damages to all 520 structures in the coastal floodplain with first floor elevations at or below the 20-foot elevation. Alternative 13 would provide the section shown in figure 25 for 2,000 feet from Transects 22 to 27. The Bluff Protection Revetment would provide coastal erosion protection for about 3 acres of land and nine structures within or near the 50-year estimated erosion zone. Table 10 provides a comparison of significant parameters for these alternatives.

Table 10. Comparison of Revetted Berms Sized for Ice Alternatives

	Alternative 9	**Alternative 13**
Location by Transect	22 to 43	22 to 27
Length	8,750 ft.	2,000 ft.
Top Elevation (MSL)	+ 15.0 ft.	+19.0 ft.
Protect to Contour	+14.0 ft.	n/a
Access Crossings	4 ped. and 5 vehicle	1 pedestrian
Drainages Crossed	9	2
Land Required	14.7 ac.	8.5 ac.
Rock Quantity	164,911 cy	40,442 cy
Gravel Quantity	20,904 cy.	5,193 cy.
O&M Stockpile	23,467 cy.	23,467 cy
Maintenance Interval	5 yr.	5 yr.
Initial Construction Cost	$183,522,000	$48,830,000
Total Investment Cost	$265,794,000	$69,523,000
Annual O&M Cost	$8,835,000	$8,835,000
Average Annual Cost	$23,114,000	$12,570,000
Average Annual Benefit	$1,069,408	$305,200
Net NED Benefits	-$22,044,600	-$12,264,800
Residual Damages	$108,900	$873,100
Benefit-to-Cost Ratio	0.046 to 1	0.024 to 1

Both alternative have the same estimated O&M cost because it is based on an ivu event being of such magnitude as to disrupt a set length of revetment.

4.2.3 Revetted Berm Sized for Waves

The revetment structures described in the previous section could be reduced in size if they were sized to withstand waves, but not ice impacts. The structure would have higher maintenance costs associated with ice shove events, but would have a smaller footprint. The wave run up on a porous structure along the coast was calculated as described previously, and the 50-year and 100-year run up elevations would be 12.5 feet and 14 feet, respectively. As with the design for ice, the crest elevation of the structure would be determined by the average stone diameter. A two armor stone and B layer thickness would result in a 14.5-foot crest elevation (figure 26). The structure would consist of two layers of 2.7-ton stones with a 2 horizontal on 1 vertical seaward slope and 1.5 horizontal on 1 vertical landward slope. The structure's reduced size would likely result in increased maintenance due to ice impact, but the reduced size would make the structure easier to maintain. A stockpile of replacement stone would be kept at Barrow for maintenance. The B rock would be a double layer placed on a 1-foot layer of core, 1- foot layer of gravel, and an underlayment of filter fabric. The B rock, core, and gravel filter layers would be buried to match the existing beach elevation.

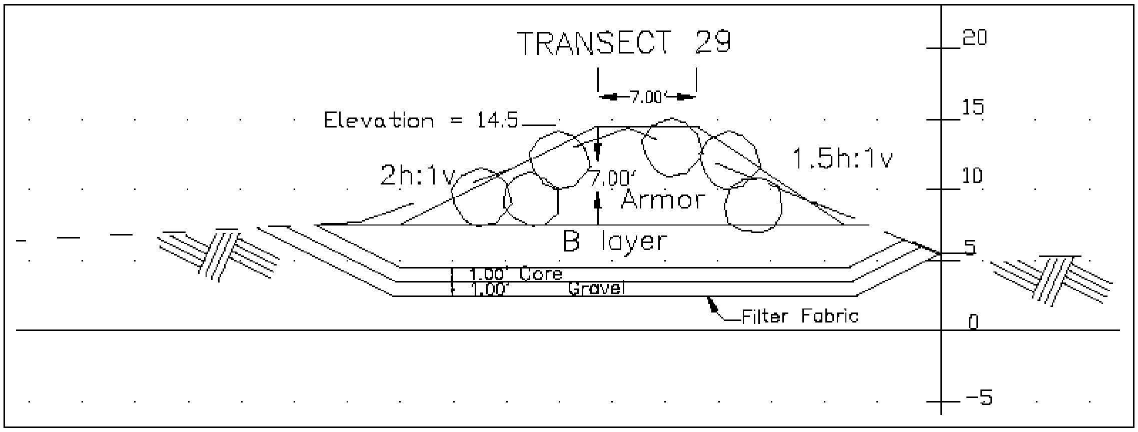


Figure 26. Revetted Berm Sized for Waves

Four alternatives were analyzed for the wave event revetted berm. The top of the rock structure would be set by the hydraulic conditions previously discussed. Different levels of damage reduction would be achieved by varying the lengths of shoreline protected. The existing ground elevation at the tie-in points would determine the level of protection. Alternative 1 would provide protection to +8.0 feet MSL for 1,800 feet from Transects 27 to 31.5 (about 335 feet west of Brower's Café). Alternative 2 would provide protection to contour elevation +10.0 feet MSL for 2,745 feet from Transects 24.6 to 31.5. Alternative 3 would provide protection to +12.0 feet MSL for 4,800 feet from Transects 22 to 33. Alternative 4 would provide protection to contour elevation +14.0 feet MSL for 8,750 feet from Transects 22 to 43 (same as Alternative 9). Table 11 is a comparison of significant parameters for these alternatives.

Table 11. Comparison of Revetted Berms Sized for Waves

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Location by Transect	27 to 31.5	24.6 to 31.5	22 to 33	22 to 43
Length	1,800 ft.	2,745 ft.	4,800 ft.	8,750 ft.
Top Elevation (MSL)	+ 14.5 ft.	+14.5 ft.	+14.5 ft.	+14.5 ft.
Protect to Contour	+8.0 ft.	+10.0 ft.	+12.0 ft.	+14.0 ft.
Access Crossings	2 pedestrian	3 pedestrian 2 vehicle	3 pedestrian 2 vehicle	4 pedestrian 5 vehicle
Drainages Crossed	3	3	3	9
Land Required	4.7 ac.	8.0 ac.	8.9 ac.	14.7 ac.
Rock Quantity	17,934 cy	27,454 cy	49,115 cy	87,966 cy.
Gravel Quantity	3,333 cy.	5,098 cy.	8,720 cy.	16,128 cy.
O&M Stockpile	19,926 cy.	19,926 cy.	19,926 cy.	19,926 cy.
Maintenance Interval	5 yr.	5 yr.	5 yr.	5 yr.
Initial Construction Cost	$24,591,000	$32,790,000	$53,876,000	$91,350,000
Total Investment Cost	$43,186,000	$51,787,000	$75,296,000	$118,006,000
Annual O&M Cost	$7,761,000	$7,761,000	$7,761,000	$7,761,000
Average Annual Cost	$10,082,000	$10,544,000	$11,807,000	$14,101,000
Average Annual Benefit	$677,000	$806,000	$1,026,000	$1,069,000
Net NED Benefits	-$9,405,000	-$9,738,000	-$10,781,000	-$13,032,000
Residual Damages	$501,000	$372,000	$153,000	$109,000
Benefit-to-Cost Ratio	0.067 to 1	0.076 to 1	0.087 to 1	0.076 to 1

4.2.4 Revetment

The sole purpose of the bluff revetment would be to prevent erosion of the bluff with resulting damages to the structures, roads, utilities, public facilities, and the cultural historic site. Different levels of damage reduction can be achieved by varying the reach protected. The revetment along the bluff area for all reaches would consist of two layers of 2.7-ton armor stone on the structure slope and two layers of B stone (figure 27). The B rock, core, and gravel filter layers would be buried to match the existing beach elevation. Similar to the revetment design for ice, the crest height was set at 19 feet, which is 0.5 foot higher than the 50-year run up. The bluffs would not be excavated to provide a uniform slope on which to build; rather they would be dressed with fill material to achieve a uniform slope. The bluffs are archaeologically rich, so no excavation would be permitted on the bluff face.

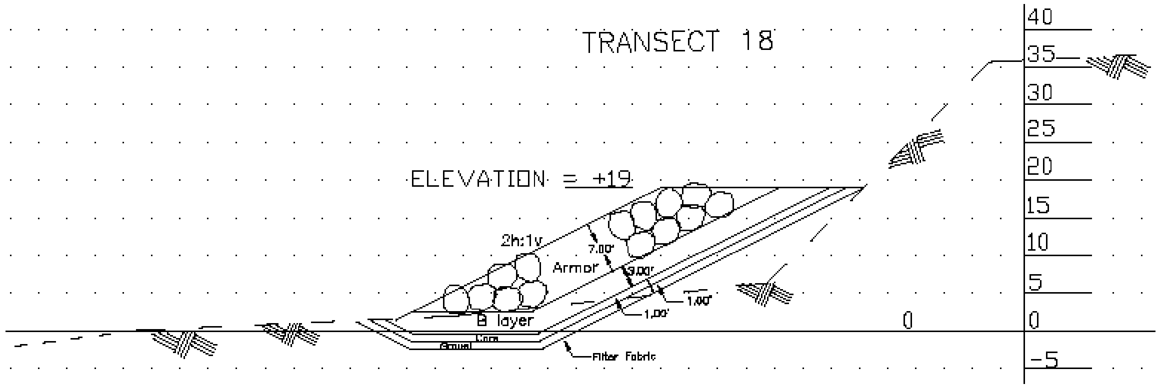


Figure 27. Revetment with armor sized for wave protection

Three alternatives were analyzed for the wave event revetment for bluff protection. The top of the rock structure would be set by hydraulic conditions previously discussed. Different levels of erosion damage reduction would be achieved by varying the lengths of shoreline protected. Alternative 10 would provide protection for 2,000 feet from Transects 17 to 22. Alternative 11 would provide protection for 1,040 feet from Transects 22 to 24.6. Alternative 12 would provide protection for 2,000 feet from Transects 22 to 27. Table 12 is a comparison of significant parameters for these alternatives.

Table 12. Comparison of Revetments

	Alternative 10	Alternative 11	Alternative 12
Location by Transect	17 to 22	22 to 24.6	22 to 27
Length	2,000 ft.	1,040 ft.	2,000 ft.
Top Elevation (MSL)	+ 19.0 ft.	+19.0 ft.	+19.0 ft.
Protect to Contour	n/a	n/a	n/a
Access Crossings	1 pedestrian	none	1 pedestrian
Drainages Crossed	none	1	2
Land Required	3.7 ac.	4.7 ac.	8.5 ac.
Rock Quantity	32,275 cy	15,161 cy	25,108 cy
Gravel Quantity	5,037 cy.	2,424 cy.	4,043 cy.
O&M Stockpile	19,926 cy.	19,926 cy.	19,926 cy.
Maintenance Interval	5 yr.	5 yr.	5 yr.
Initial Construction Cost	$36,786,000	$21,887,000	$30,345,000
Total Investment Cost	$55,980,000	$40,349,000	$49,223,000
Annual O&M Cost	$7,761,000	$7,761,000	$7,761,000
Average Annual Cost	$10,769,000	$9,929,000	$10,406,000
Average Annual Benefit	$39,600	$200,700	$305,200
Net NED Benefits	-$10,729,400	-$9,728,300	-$10,100,800
Residual Damages	$1,138,788	$977,600	$873,100
Benefit-to-Cost Ratio	0.004 to 1	0.020 to 1	0.029 to 1

4.2.5 Beach Nourishment

Beach nourishment was considered as an alternative to reduce flood and erosion damages. It involves placing gravel in selected reaches along the shoreline and periodic maintenance of the gravel. The reaches selected here coincide with those previously used for the revetted berm and bluff revetments. The beach nourishment configuration evaluated provides the same level of benefits as the revetted berm or bluff revetments for the same reach. Figure 28 shows the design for beach nourishment. The fill would extend to the elevation required for flood protection. The volume is based on the fill needed to raise the beach 1 foot, 3 feet, 5 feet, and 7 feet to provide protection to the contour elevation +8.0 feet, +10.0 feet, +12.0 feet, and +14.0 feet, respectively. The cross section shown in figure 27 is the profile for raising the beach 3 feet. The depth of closure is assumed to be -19.5 feet, which is the depth where the bathymetry begins to increase and an offshore bar is present. The renourishment interval is based on the gross sediment transport estimates distributed over the entire length of beach proposed for flood protection and is triggered when the nourishment volume left on the beach is equal to 5 years of transport. This estimate is less conservative than the beach nourishment estimate for the bluff area because the beach is wider in this area and the wave energy would be dissipated more effectively over a wide beach. The effects on sediment transport of ice reworking the beach and the transport associated with ice freezing to the beach material are unknown. The initial nourishment to increase the beach elevation 5 feet and the associated renourishment intervals are shown in table 13 under Alternative 7.

Four alternatives were analyzed for beach nourishment for flooding. Table 13 is a comparison of significant parameters for the nourishment alternatives with the wave revetment alternatives. Different levels of damage reduction would be achieved by varying the height of fill and length of shoreline protected. The existing ground elevation at the tie-in points would determine the level of protection. Alternative 5 would provide protection to +8.0 feet MSL for 1,800 feet from Transects 27 to 31.5 (about 335 feet west of Brower's Café). Alternative 6 would provide protection to contour elevation +10.0 feet MSL for 2,745 feet from Transects 24.6 to 31.5. Alternative 7 would provide protection to +12.0 feet MSL for 4,800 feet from Transects 22 to 33. Alternative 8 would provide protection to contour elevation +14.0 feet MSL for 8,750 feet from Transects 22 to 43 (same extent as Alternative 9).

Table 13. Comparison of Beach Nourishment Alternatives in Revetted Berm Area

	Alternative 5	**Alternative 6**	**Alternative 7**	**Alternative 8**
Location by Transect	27 to 31.5	24.6 to 31.5	22 to 33	22 to 43
Length	1,800 ft.	2,745 ft.	4,800 ft.	8,750 ft.
Depth of Beach Fill	+ 1.0 ft.	+3.0 ft.	+5.0 ft.	+7.0 ft.
Protect to Contour	+8.0 ft.	+10.0 ft.	+12.0 ft.	+14.0 ft.
Access Crossings	none	none	none	none
Drainages Crossed	3	3	3	9
Land Required	2.7 ac.	6.0 ac.	6.9 ac.	12.7 ac.
Rock Quantity	none	none	none	none
Gravel Quantity	48,000 cy.	218,000 cy.	581,000 cy.	1,553,000 cy.
Renourishment Quantity	26,000 cy.	184,000 cy.	526,000 cy.	1,448,000 cy.
Renourishment Interval	6 yr.	27 yr.	48 yr.	69 yr.
Initial Construction Cost	$28,488,000	$115,059,000	$224,368,000	$806,969,000
Total Investment Cost	$29,885,000	$140,019,000	$329,533,000	$1,242,545,000
Annual O&M Cost	$3,783,000	$4,785,000	$13,754,000	$25,867,000
Average Annual Cost	$5,389,000	$12,307,000	$31,458,000	$92,619,000
Average Annual Benefit	$677,000	$805,900	$1,025,800	$1,069,400
Net NED Benefits	-$4,712,000	-$11,501,100	-$30,432,200	-$91,549,600
Residual Damages	$501,300	$372,400	$152,500	$108,900
Benefit-to-Cost Ratio	0.126 to 1	0.065 to 1	0.033 to 1	0.012 to 1

Figure 28 shows a design for beach nourishment in the bluff area. The fill would extend to a maximum height of +19 feet or the top of the bluff/dune, whichever is higher. The volume of fill would be dependent on the length of bluff/dune to be protected. The cross section is based on the fill needed to raise the beach 5 feet with a depth of closure assumed to be -17 feet for the high bluff area. This is the depth at which the bathymetry begins to increase and an offshore bar is present. The depth of closure is assumed to be -19.5 feet as the bluffs decrease in elevation to dunes to the northeast and the offshore bar moves deeper. Alternatives for different lengths of protection and the associated initial nourishment and renourishment intervals are shown in table 14. The renourishment interval is based on the gross sediment transport estimates for the length of beach proposed for protection. This conservative renourishment estimate was used because of the narrow beach, shoreline analysis indicates that this area has not stabilized, and the unknown effects on sediment transport of ice reworking the beach and the transport associated with ice freezing to the beach material. The initial nourishment to increase the beach elevation 5 feet and the associated renourishment intervals are shown in table 13.

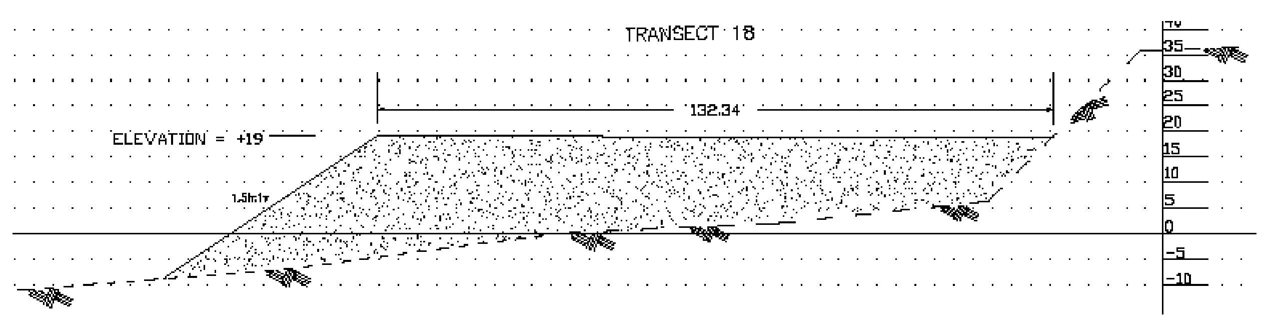


Figure 28. Preliminary beach fill design for revetment area.

Table 14. Nourishment Scenarios

Transects Init	**ial Nourishment Volume [cy]**	**Renourishment Interval [yr]**	**Renourishment Amount [cy]**
17-22	191,000	5	91,000
22-24.625	139,000	2	39,000
22-27	265,000	8	165,000

Different levels of damage reduction could be achieved by varying the height of fill and length of shoreline protected, but only one of the beach nourishment scenarios was developed into an alternative. Alternative 14 would provide protection for 2,000 feet from Transects 22 to 27. Table 15 provides the significant parameters for this alternative.

Table 15. Beach Nourishment Alternative in Revetment Area

	Alternative 14
Location by Transect	22 to 27
Length	2,000 ft.
Depth of Beach Fill	+ 12.0 ft.
Protect to Contour	n/a
Access Crossings	none
Drainages Crossed	2
Land Required	6.5 ac.
Rock Quantity	none
Gravel Quantity	265,000 cy.
Renourishment Quantity	165,000 cy.
Renourishment Interval	8 yr.
Initial Construction Cost	$139,867,000
Total Investment Cost	$157,899,000
Annual O&M Cost	$22,742,000
Average Annual Cost	$31,225,000
Average Annual Benefit	$305,200
Net NED Benefits	-$30,919,800
Residual Damages	$873,100
Benefit-to-Cost Ratio	0.010 to 1

4.2.6 Non Structural (Elevate/Relocate Buildings)

This alternative identified 34 structures that would experience storm-caused erosion and/or flood damages during the 50-year analysis period. To reduce/eliminate these damages, structures would either be relocated to flood/erosion free land (24) or raised in place (10), so the first floor elevation would be above the elevation where damage would occur. This measure would eliminate 87 percent of flood damages to structures and contents in the study area. Floods would continue to occur but damages to structures and contents would be reduced.

Buildings are supported on pile foundations. A new pile support system would be installed on raised buildings to bring the structures up to the required height. The utility services for each structure would be disconnected, the structure temporarily moved aside, a new pile foundation installed, the structure placed on the new foundation, and the utilities reconnected. No work would be performed along the beach.

Relocated buildings would be disconnected from utilities, moved over city streets using transporters to a vacant site where a new pile foundation had been constructed, placed on the new pile foundation, and the utilities reconnected. To further reduce risk to human life, a flood evacuation plan would be developed as part of the required Floodplain Management Plan,

Total initial project cost is estimated to have a present value of $44 million. Including O&M costs, the structure elevation/relocation alternative had an average annual cost of $2.4 million. Annual damages prevented (benefits) are estimated at $213,000 (a reduction of 18 percent in the total storm caused damages in the study area). This alternative resulted in negative net benefits of -$2.2 million annually. The benefit to cost ratio is 0.09 to 1. Residual annual damages are estimated at $965,000. Table 16 provides a summary of this alternative.

Table 16. Summary of Non- Structural Alternative

	Alternative 15
Location by Transect	20 to 37
Buildings Elevated	10
Buildings Relocated	24
Land Required	none permanently
Rock Quantity	none
Gravel Quantity	none
Initial Construction Cost	$42,123,000
Total Investment Cost	$$44,189,000
Annual O&M Cost	$0
Average Annual Cost	$2,374,000
Average Annual Benefit	$212,950
Net NED Benefits	-$2.161,050
Residual Damages	$965,350
Benefit-to-Cost Ratio	0.090 to 1

4.2.7 Fill Tasigrook Lagoon

Another alternative to the 8-foot protection level between Transects 27 and 31.5 is to fill in Tasigrook Lagoon fronting the beach and relocate Eben Hopson farther inland closer to the dam than the beach. City of Barrow personnel had proposed filling in the lagoon as a drainage solution during a coordination meeting with the NSB discussing drainage issues associated with any beach structure fronting the lagoon. It would provide a means to reduce potential storm caused erosion and flood damages to the Barrow water supply dam and the low-lying segment of road fronting the lagoon. It would also address local environmental concerns about sediments underlying the lagoon, which a number of decades ago was the sewage pond for Barrow. Hopson Road crosses the lagoon and has open-ended culverts that permit water to drain. A channel is created in the shoreside berm every spring to allow excess melt water to drain from Isatkoak Lagoon, over the dam spillway and under the road. Once the lagoon is drained sufficiently, the berm is rebuilt across the channel when needed for storm protection. The NSB was concerned about construction of a permanent drainage structure through the shoreline berm or any new revetment. They feared the whole culvert and gates would be frozen just when they would be needed in the short snowmelt and runoff season. They proposed that if the front lagoon was filled, they would pump the drainage water from Isatkoak Lagoon to achieve the desired water level in the spring. The lagoon itself is about 1,700 feet long and nominally 400 feet wide, having a surface area of about 16 acres. Filling in the first lagoon to a +8.0 feet elevation would remove the potential flooding issues associated with run up in that area. Assuming the bottom of the lagoon is at 0 feet, an 8-foot fill in that area would require 250,000 cubic yards of material. Because this would not be beach fill material, local commercial material sources would be used for fill and road construction. Materials would be trucked to the lagoon, where the materials would be spread to design elevations to drain seaward. Only one alternative was developed for filling in the lagoon. Alternative 16 would provide protection for 2,000 feet from Transects 27 to 32. Table 17 shows the significant parameters for this alternative.

Table 17. Summary of Lagoon Fill Alternative

	Alternative 16
Location by Transect	27 to 32
Length	2,000 ft.
Depth of Fill	+8.0 ft.
Protect to Contour	+8.0 ft.
Access Crossings	none
Drainages Crossed	1
Land Required	16 ac.
Rock Quantity	none
Gravel Quantity	250,000 cy.
Renourishment Quantity	none
Renourishment Interval	n/a
Initial Construction Cost	$28,801,000
Total Investment Cost	$30,214,000
Annual O&M Cost	$0
Average Annual Cost	$1,623,000
Average Annual Benefit	$744,000
Net NED Benefits	-$879,000
Residual Damages	$433,900
Benefit-to-Cost Ratio	0.46 to 1

4.2.8 Summary of Damages Reduced and Residual Damages

Total without-project average annual coastal flood damages for Barrow are $157,300, and the coastal erosion damages total $1,021,000. Total coastal storm damages are $1,178,300. Based on results of the modeling of expected annual damages from coastal flooding and erosion associated with each initial alternative, there is no alternative that has positive net NED benefits. The damages reduced and residual damages for each alternative are compared in table 18.

Table 18. Summary of Damages Reduced and Residual Damages

INITIAL ALTERNATIVE	FLOOD DAMAGES REDUCED	EROSION DAMAGES REDUCED	TOTAL ANNUAL DAMAGES REDUCED	% REDUCTION ANNUAL DAMAGES	RESIDUAL ANNUAL DAMAGES
DO NOTHING	$0	$0	$0	0%	$1,178,300
Revetted Berm Sized for Ice					
Reduce flooding-Alt 9	$87,200	$982,200	$1,069,400	91%	$108,900
Reduce erosion-Alt 13	$0	$305,200	$305,200	26%	$873,100
Revetted Berm Sized for Waves					
Alternative 1	$0	$677,000	$677,000	57%	$501,300
Alternative 2	$24,400	$781,500	$805,900	68%	$372,400
Alternative 3	$43,600	$982,200	$1,025,800	87%	$152,500
Alternative 4	$87,200	$982,200	$1,069,400	91%	$108,900
Revetment					
Alternative 10	$0	$39,600	$39,600	3%	$1,138,700
Alternative 11	$0	$200,700	$200,700	17%	$977,600
Alternative 12	$0	$305,200	$305,200	26%	$873,100
Beach Nourishment					
Alternative 5	$0	$677,000	$677,000	57%	$501,300
Alternative 6	$24,400	$781,500	$805,900	68%	$372,400
Alternative 7	$43,600	$982,200	$1,025,800	87%	$152,500
Alternative 8	$87,200	$982,200	$1,069,400	91%	$108,900
Alternative 14	$0	$305,200	$305,200	26%	$873,100
Non Structural-Alt 15	$36,550	$176,400	$212,950	18%	$965,350
Fill Tasigrook Lagoon-Alt 16	$67,400	$677,000	$744,400	63%	$433,900

4.2.9 With-Project Natural, Cultural, and Social Resources of Concern

An early version of this report contained an extensive discussion of the environmental, cultural, and social impacts of each of the considered alternatives. Since the final feasibility study analyses determined that none of the potential alternatives provided positive net NED benefits, none of these alternatives would normally be recommended. Consequently, the extensive alternative comparison was deleted from this report. A remnant of that analysis can be found in Appendix D (Sections 7 and 9). A brief summary of the Natural Resources and Cultural Resources and Social Issues and Concerns that implementation of an alternative might raise follows in the following paragraphs. Considerations in opening new gravel sources are also discussed.

4.2.9.1 Natural Resources

Marine Mammals. Marine mammals would generally not be affected by any of the alternatives considered to date. Polar bears that come to shore at Barrow could be shot during a human encounter where the revetment blocks personnel escape routes. Barges hauling rock or other materials would need to be scheduled to avoid the whale migration period and routes.

Birds. Although bird foraging on the beach would be eliminated in areas of the revetment, there would be very little effect on local populations because of abundance of similar habitat. No nesting habitat would be affected by alternatives considered.

Fish Habitat. Revetment alternatives would not extend into the near-shore fish habitat zone, except minimally during construction at barge landing points.

4.2.9.2 Cultural Resources

Alternatives may affect archeological sites and/or historic buildings or cultural traditions. The non-structural alternative of moving homes or the revetment alignment may affect cultural resources. Old homes may not survive the process of elevation, relocation, or some other altering. Elders living in their homes may not favor moving from their traditional coastal location. The Utqiagvik archeological site may be impacted during construction. Construction along the uplands (not the beach) would require monitoring because of the potential to uncover unknown archeological sites. Altering the popular tourist “picture site” at the Browerville Café by obstructing the sea view and changing the cultural setting could be an issue.

4.2.9.3 Social

Beach Access. Alternatives provide for appropriate beach access for subsistence, cultural, and recreational activities. The alternatives have access points for vehicle and pedestrian uses, as well as ladders or ramps in other areas. Life safety is an issue in the event of a polar bear encounter.

Ocean View. Revetment alternatives may affect some residents’ aesthetic view of the sea. The rock revetment could be high in some locations, completely obstructing views of the sea from some homes or businesses.

4.2.9.4 Potential BIA Site Gravel Source Development Issues

If the BIA site were developed as a new gravel materials source, loss of wetland habitat and associated ecological repercussions would be a concern, especially impact to bird habitat where Steller’s and Spectacled Eiders’ nesting habitat is found. Land use, access, and ownership issues would need to be resolved for the land where the BIA site is located.

4.2.10 Summary of Environmental/Cultural Impacts and Identification of Potential Mitigation Measures

None of the alternatives cause significant natural resources impacts. Consequently, no environmental mitigation measures are required. However, for certain alternatives there could be effects to historic properties due to the visual affects of the revetment on the landscape in Browerville and potential archaeological impacts along the revetment alignment. Revetment construction in front of the Utqiagvik site could be considered mitigation for impacts elsewhere because of the stabilizing consequence of the structure. Possible cultural mitigation measures to be included in any revetment alternative include:

- Landing/sea view area on top of the revetment constructed in front of the Browerville Café.
- Interpretive panels explaining the significance of the Browerville area.
- Archaeological monitoring or creation of exclusion zones to avoid or minimize impacts to identified historic and cultural properties.

- Access ramps between the community and the ocean for launching boats or driving snow machines.
- Ladders, platforms, or boardwalks for beachcombers and other pedestrians.
- Cement pads used to haul whales onto for butchering.

4.2.11 Evaluation of Initial Alternatives

Based upon the findings of the economic analysis of preliminary alternatives and engineering and plan formulation, table 19 provides a summary of the 16 alternatives compared with the evaluation criteria discussed in Section 3.5. Each of the alternatives is complete, since all elements (including costs) required to achieve the estimated benefits have been included in the analysis. The alternatives provide varying levels of effectiveness, producing different levels of damage reduction. The initial screening of alternatives indicates that none of the alternatives provides an economically efficient plan. The costs required to realize the benefits are substantially greater than the value of the benefits. Each of the alternatives has a varying level of acceptability. Normally, measures that show positive economic net benefits are combined to form better alternatives. However, for this study this is not possible.

Table 19. Summary Evaluation of Initial Alternatives.

INITIAL ALTERNATIVE	**Completeness (initial cost in $ million)**	**Effectiveness (percent coastal damages reduced)**	**Efficiency (net NED Benefits)**	**Acceptability**
NO ACTION	n/a	0%	-$1,178,300	Low
Revetted Berm Sized for Ice:				
Reduce flooding-Alternative 9	Yes ($184)	91%	-$22,044,600	High
Reduce erosion-Alternative 13	Yes ($49)	26%	-$12,264,800	High
Revetted Berm Sized for Waves				
Alternative 1	Yes ($25)	57%	-$9,405,000	Low
Alternative 2	Yes ($33)	68%	-$9,738,100	Moderate
Alternative 3	Yes ($54)	87%	-$10,781,200	Moderate
Alternative 4	Yes ($91)	91%	-$13,031,600	High
Revetment				
Alternative 10	Yes ($37)	3%	-$10,729,400	Low
Alternative 11	Yes ($22)	17%	-$9,728,300	Moderate
Alternative 12	Yes ($30)	26%	-$10,100,800	High
Beach Nourishment				
Alternative 5	Yes ($30)	57%	-$4,712,000	Low
Alternative 6	Yes ($140)	68%	-$11,501,100	Low
Alternative 7	Yes ($330)	87%	-$30,432,200	Low
Alternative 8	Yes ($1,242)	91%	-$91,549,600	Low
Alternative 14	Yes ($140)	26%	-$30,919,800	Low
Building Elevation/Relocation				
Alternative 15	Yes ($42)	18%	-$2,161,050	Low
Fill Itasigrook Lagoon				
Alternative 16	Yes ($29)	63%	-$978,600	Moderate

4.2.12 Risk and Uncertainty

The analysis performed for this study used historical information to assess wind, waves, currents, sediment transport, ice development, and current economic conditions, including past flood and erosion damages at Barrow. Risk and uncertainty was incorporated into the basic hydraulic and economic analyses, particularly the SBEACH hydraulic model and the Beach-*fx* economic model. Another element of uncertainty exists because neither are the future wave and ice events specifically known or predictable nor is the scope and reliable cost of project operation, maintenance, repair, replacement, or rehabilitation during the project's useful life.

In recent years evidence has suggested that the arctic environment is experiencing a warming trend. The magnitude, duration, and effect of a warming trend is not known. However, the Office for Naval Research, the Naval Ice Center, the Oceanographer of the Navy, and the Arctic Research Commission held a conference in 2002 that discussed the shrinking polar ice cap. They indicated that the polar ice pack is projected to retreat to the extent that a new shipping route may be opened. While this would reduce the effect of ice on the coastal structure, it could result in an increased frequency of large storms experienced in the Chukchi Sea. The waves impacting a structure would continue to be depth limited unless there is significant sea level rise. The risk of failure is somewhat controllable because the rock structures discussed in this report would be placed above the water line and available for visual inspection for damage from storms or ice, which can facilitate remedial actions being completed prior to full failure of the structure.

Much of Alaska is undergoing a drop in sea level due to glacial rebound, but specific information on sea level at Barrow is lacking. A study of sea level change in the Russian sector of the Arctic Ocean indicates that sea level is rising at a rate of approximately 0.07 inches/year. Over a 50-year period, that would contribute 3.5 to 4 inches of elevation. This will have a slight impact on the wave heights that can be supported and the anticipated flood elevation. This would be the lower range of sea level rise that could be experienced at Barrow. The Corps of Engineers has chosen to follow the recommendations of the National Research Council (NRC) as described in the publication *Responding to Changes in Sea Level: Engineering Implications* (NRC, 1987). For a 50-year project life, a project at Barrow could see sea level rise as high as 2.1 feet. The upper level of sea level rise and the associated increase in depth limited wave height is accommodated by using the water level that corresponds to the 95 percent confidence interval when sizing the armor stone for waves. The associated increase in run up due to sea level rise was not calculated, but if a stockpile was maintained on site there would be stone readily available to increase the structure height should an increase in water level be realized along the coast of the magnitude predicted by the NRC equations.

4.3 Designation of Plans

4.3.1 Non-Structural Plan

Alternatives included three potential non-structural measures for consideration. The public building relocation option was not needed because other activities and projects already underway in Barrow would be moving certain public buildings and facilities that might suffer flood damage in the future. Elevation or relocation of buildings was the preliminary alternative that was designated the Non Structural Plan. The third non-structural measure was community participation in the NFIP, which is mandated by Congress. This non-structural measure would be added to any "build" alternative.

4.3.2 National Economic Development Plan

Based upon the findings of the economic analyses documented in this report, none of the plans provided net positive NED economic benefits. Therefore, no alternative was designated as the NED Plan.

4.4 Conclusions

As stated previously, the NSB, the local sponsor, and the local community of Barrow are extremely concerned about the effects of long-term erosion and flooding, but particularly the effect that erosion will have on the viability of Barrow over both the near- and long-term. Barrow has intrinsic value much greater than the population and size of the city. Its continued existence as a viable community is essential for all the smaller NSB villages that rely on Barrow to serve as a hub. Preserving Barrow helps preserve the Inupiat culture, which has existed in arctic Alaska for thousands of years.

The community has been farsighted as it has pursued capital improvement projects. The new landfill, wastewater treatment plant, hospital, arctic research center, water supply dam rehabilitation, and access road improvements have been planned, designed, and will be constructed recognizing the very real threat of flooding and erosion. However, the local community is pursuing those improvements under other Federal, State, and local programs, and those programs have progressed to the point that they became part of the without-project condition.

This TR examined a range of alternatives that could meet both local needs and contribute to meeting National Economic Development (NED) objectives. The study considered ten structural measures and five non-structural measures to reduce erosion and flood damages (Section 4.1). These measures were screened down to five basic alternatives with scale variations: rock revetments (nine variations), beach nourishment (five variations), joining the National Flood Insurance Program, elevating/relocating buildings, and lagoon filling. Sixteen specific cost estimates were prepared for the alternatives involving some construction and compared with the estimated storm damages that could be reduced by each alternative (Section 4.2). The first cost of the alternatives ranged from $22 million to $807 million. In all cases, the estimated costs of implementing each alternative exceeded its estimated NED benefits, resulting in negative net NED benefits. The alternative that had the least negative net NED benefits was "Lagoon Filling," with a first cost of $29 million and $744,000 NED benefits, which result in negative net benefits of $879,000 and a benefit-to-cost ratio of 0.46 to 1.0.

There is no economically justified solution under the General Investigations authority. Potential storm damage reduction projects at Barrow can not be pursued through the normal process for projects specifically authorized by Congress.

U.S. Army Corps
of Engineers
Alaska District

Barrow, Alaska

Coastal Storm Damage Reduction Technical Report

Appendix A – Hydraulic Design

December 2008

APPENDIX A

HYDRAULIC DESIGN

List of Figures

List of Tables

1.0 INTRODUCTION

This hydraulic design appendix describes the technical aspects of the Barrow Storm Damage Reduction Study. It provides the background for determining the Federal interest in construction of a project that would limit damages to the Barrow coastline from storms impacting the north coast of Alaska.

The North Slope Borough (NSB) currently provides temporary flooding and erosion control measures for storm events. The NSB requested that the Corps of Engineers determine the feasibility of Federal participation in a storm damage reduction project.

To determine the feasibility of a project, numerical model studies were conducted to better define the winds, waves, currents, and sediment movement along the coastline at Barrow. A physical model study was performed to design a protective measure that could withstand ice ride up.

1.1 Project Purpose

The following objective was identified before beginning this engineering analysis.

> Identify a design to reduce damage from flooding and coastal erosion in an environmentally and economically sound manner.

1.2 Description of Project Area

Barrow, the northernmost community in the United States, is located on the Chukchi Sea coast. It is 725 air miles from Anchorage at 71^{o} 18’ N, 156^{o} 47’ W. (Sec. 06, T022N, R018W, Umiat Meridian). It is approximately 6 miles south of Point Barrow, which divides the Chukchi and Beaufort Seas. The shoreline runs northeast to southwest, with the town facing the Chukchi Sea (figures 1 and 2). The airport is at the southern end of town. Isatkoak Lagoon separates the community of Barrow from the community of Browerville, which are collectively called Barrow. Farther to the northeast are the South and Middle Salt lagoons and the former Naval Arctic Research Lab (NARL) (figure 3). The sun does not set between May 10th and August 2nd, and does not rise between November 18th and January 24th.

Figure 1. State of Alaska Location Map

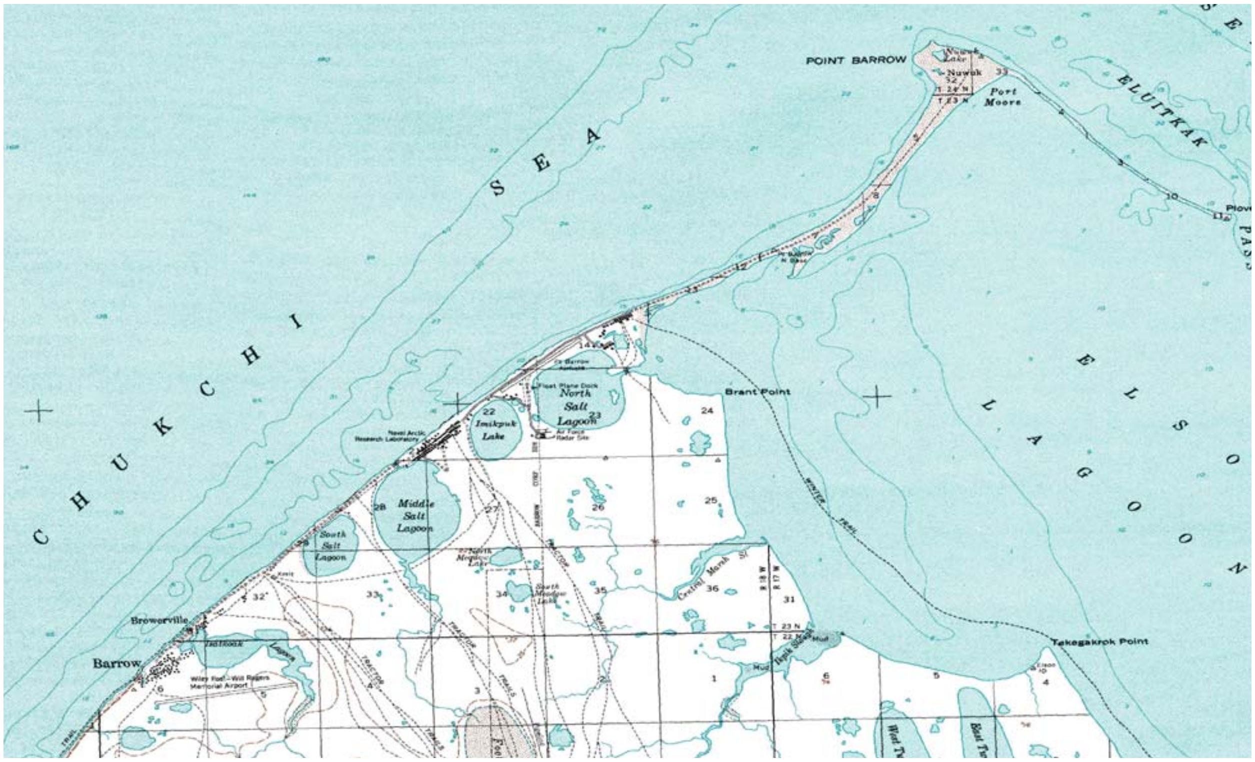


Figure 2. Barrow and surrounding area.

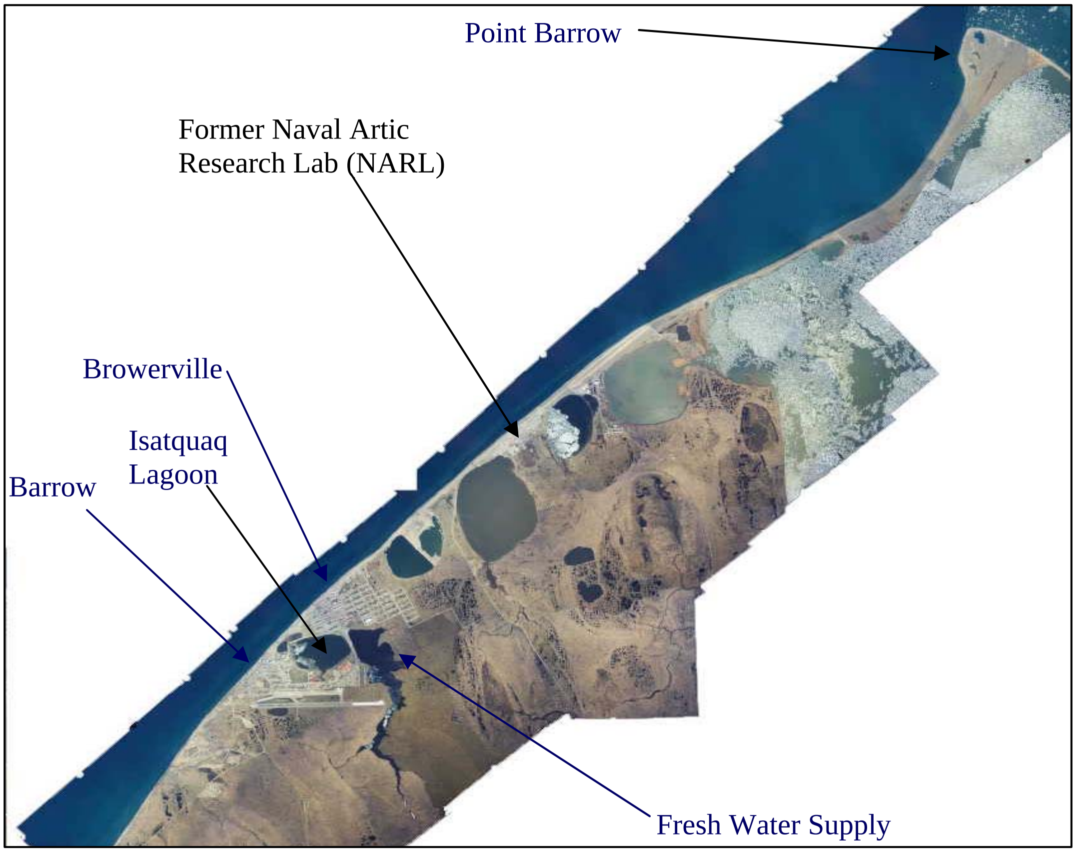


Figure 3. Barrow and local features.

Bluffs, up to 30 feet high, occur along the beach in the southwestern portion of Barrow (figure 4). These decrease in height until they disappear between the Airport and Isatkoak Lagoon (figure 5). North of this, the back edge of the beach rises to an elevation of approximately 8 feet, where it decreases in grade to fairly level tundra (figure 6).

Figure 4. Bluffs at the south end of Barrow.

Figure 5. Decreasing bluff height in front of the community of Barrow.


9/29/1999

Figure 6. Beach and level tundra north of the community of Browerville.

The beach fronting Barrow and extending out to Point Barrow is composed of sand and gravel with an average median diameter of 3.0 mm. The beach material is poorly sorted with significant size fractions between 0.3 and 20 mm. An example of the beach sediment is shown in figure 7. The scale in this figure is in inches.

Figure 7. Example of beach sediment taken at the water line, SW Barrow, 10/28/2004.

1.3 Background

Barrow is on a coastline that runs from the northeast to the southwest. This orientation leaves Barrow most vulnerable to storms from the north and west. The shoreline is most susceptible to storm activity in the months of August through October (late summer to fall) when there is open water and the permanent ice pack stays a few hundred miles offshore. From November through July, there is generally enough ice present to restrict wave development. The location of the ice edge plays an important role in limiting the fetch for the development of storm waves, which have their greatest impact on the beach during the open water season.

The two coastal problems of greatest concern to the local residents are erosion of the bluffs and storm induced flooding. Bluff erosion has endangered several of the ocean-front homes (figure 8), and has destroyed archeological evidence found in the bluffs (figure 9). Flooding has occurred several times when summer and fall storms arrive from the west accompanied by large waves and elevated water levels. The October 1963 storm is remembered as being particularly severe and caught many residents unprepared (figures 10-13).

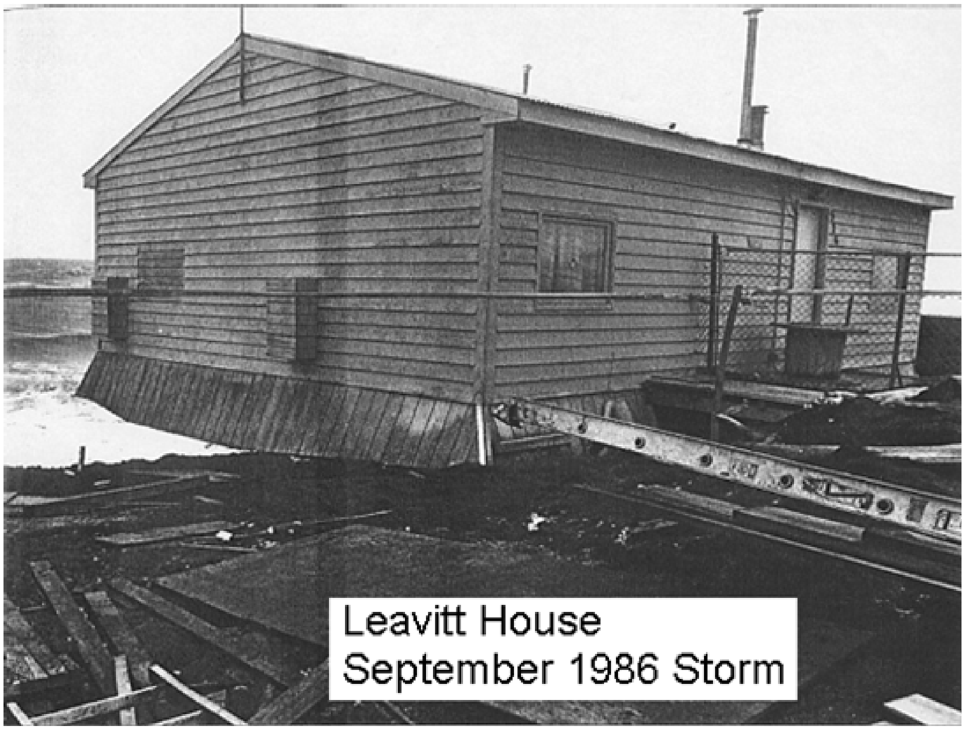
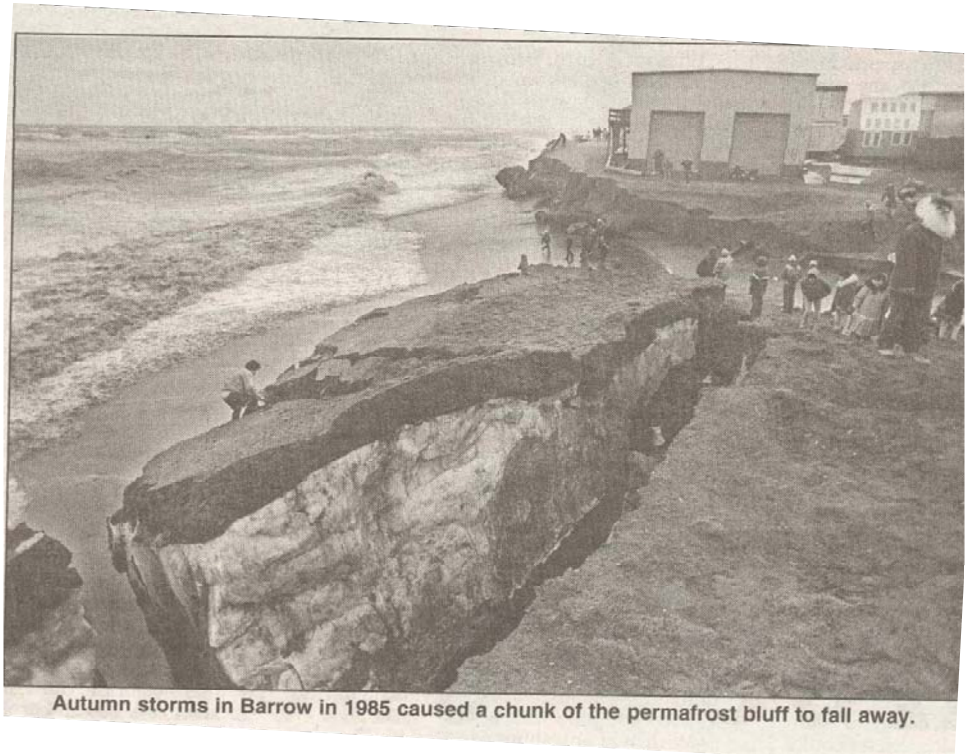


Figure 8. Undermining of structure from erosion.



Autumn storms in Barrow in 1985 caused a chunk of the permafrost bluff to fall away.

Figure 9. Massive bluff failure during a 1985 storm exposed the foot of a man located near the site of a 16th century house mound. Before the foot could be excavated a storm washed his remains away.

Figure 10. Flooding damage caused by the October 1963 storm.

Figure 11. Flooding at Barrow.

Figure 12. Flooding at the Naval Arctic Research Laboratory.

Figure 13. Flooding the coastal road (2002).

Previous Storm Damage Reduction Measures. The North Slope Borough has made numerous attempts at curbing the erosion and flooding that impact the coast fronting Barrow. Coastal erosion and flooding mitigation measures that have been or currently are being used include:

- Pushing the beach material into berms during storm events (figures 14 and 15)
- Placing sacrificial berms along the road (figure 16)
- Offshore dredging and beach nourishment (figure 17)
- Geotextile sack revetment (figure 18)
- Filled utilidor seawall (figure 19)
- Laid back tar barrels (figure 20)
- Geotextile tubes (figure 21)

Figure 14. Bulldozer working on the beach building berms.

Figure 15. Bulldozer pushing beach material during heavy surf.

9/29/1999

Figure 16. Sacrificial berms placed along road.

Figure 17. Remains of beach nourishment after storm. The dredging program was never completed. The North Slope Borough’s dredge grounded during a storm in 2000.

Figure 18. Supersack revetment.

Figure 19. Wooden utilidors backfilled with local material.

Figure 20. Tar barrels laid on beach at an angle.

Figure 21. Geotextile tube protection.

The most current storm damage reduction measure was the installation of a seawall type structure using geotextile fabric encased in a wire basket (figure 22). This was installed in the summer of 2004. To date it has held up well in Barrow, but has failed at three other coastal applications in Alaska. The cause of the system failure at the other locations in the State is not certain, but factors that would increase the system's survivability at Barrow include the fact that the system was not exposed to a storm event during or immediately after construction, which gave it time to saturate with water and freeze during the winter. Once frozen, the system would act more as a solid block rather than loose granular material that could be washed out by wave action. The system at Barrow was also put in place to stem road and bluff erosion so it is set back from the shoreline typically out of the zone of wave impact.

Figure 22. Geotextile fabric encased in a wire basket.

2.0 STUDY CONSTRAINTS

During the Storm Damage Reduction Study, a number of study constraints were identified. These included:

(1) Any in-water work will need to be coordinated so as to not interfere with subsistence hunting of marine mammals.
(2) Work in the beach area is governed by ice formation.
(3) The coast is the site of numerous archaeological sites.
(4) Gravel sized material that is locally available for construction is limited.
(5) Ice constrains the shipping season for the importation of construction materials, and there are no offloading facilities other than the beach.

3.0 CLIMATOLOGY, METEOROLOGY, HYDROLOGY

3.1 Temperature

Barrow is in an arctic environment. Total average annual precipitation (rain and melted snow water) is light, averaging 5 inches. Average annual snowfall is 29 inches. Temperature extremes range from -56 to 78 degrees Fahrenheit, with average summer temperatures ranging around 40 degrees Fahrenheit (figure 23). The daily minimum temperature is below freezing 324 days of the year. Prevailing winds are easterly and the average is 12 mph. The Chukchi Sea is typically ice-free from mid-June through October.

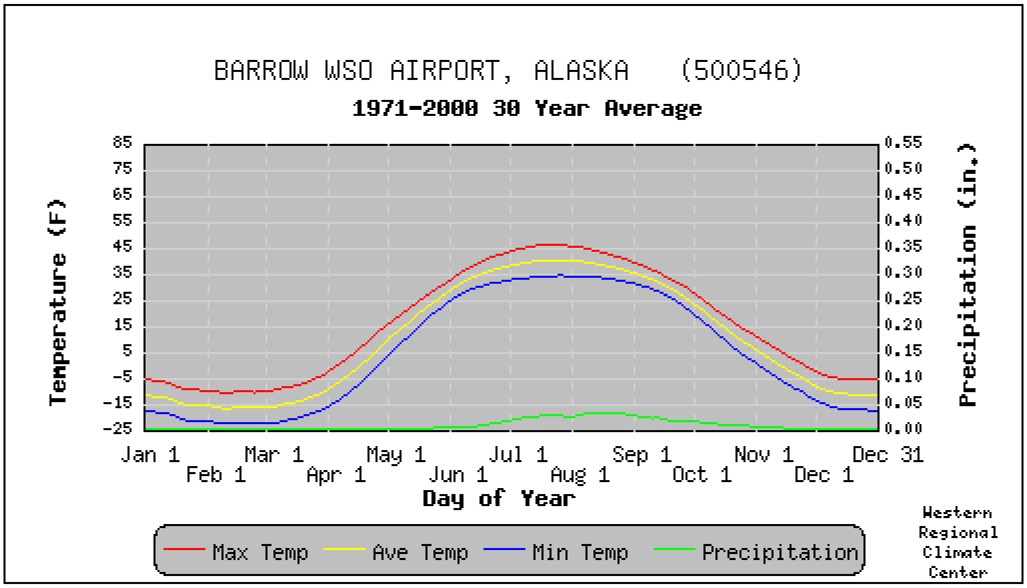


Figure 23. Temperature and precipitation at Barrow

3.2 Ice Conditions

At Barrow, freeze up typically occurs in November, but the formation of stable shorefast ice may be delayed. Stability is achieved after one or more significant pack ice “shoves” deform and ground the ice. Grounding can take place as late as January, or not at all. Thin ungrounded, maturing ice in the near-shore area is vulnerable. A strong offshore wind can tear away young ice all the way to the beach, leaving open water even when winter temperatures are low. In “cold years,” the ice tends to stabilize by November, but recently ice has been (more) unstable, with episodes of shorefast ice breaking off at the beach as late as January or February. Once grounded and stabilized, the shorefast ice cover remains in place until the start of breakup in July. General ice features are illustrated in figure 24.

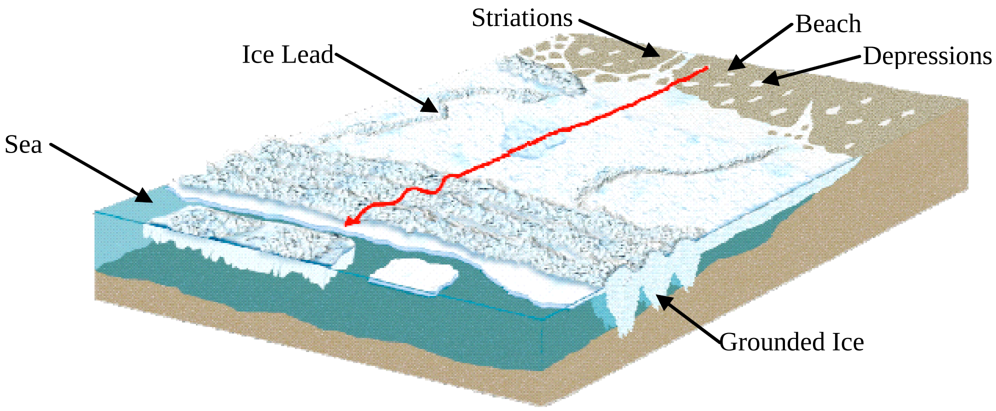


Figure 24. Illustration of near-shore ice processes.

Point Barrow extends northward and is a major barrier to ice movement. As a result, the beaches near Barrow are subjected to the pushing action of ice more than most regions. There are several possibilities when ice moves on to a beach. The ice sheet may glide over the beach, striating it much like a miniature glacier and pushing a small pile of debris ahead of it. After the ice melts, the striations show the passage of the ice and the ridge-like pile of debris marks the terminus of flow much like an end moraine. This is evident in the early summer after the ice is gone from the beach (figure 25). As the beach experiences wave action during the summer, it is smoothed and resembles the beach profile of a beach shaped by waves (figure 26). At times, the ice, instead of gliding over the beach, may dig its leading edge into the beach and buckle up into piles of ice blocks as high as 30 feet. This ice push is known locally as an “ivu” (figures 27 through 29). When this ice melts, it leaves a depression where it pushed into the beach, but any depression will be obliterated eventually by wave action. The ice, however, when it buckles, may also push gravel ahead of it in a mound several feet in height. Sometimes, the ice carries additional sediment that was frozen to its base when in shallow water or washed or blown onto its surface. An ice-push, after melting, leaves a mound on the beach until storm waves smooth it beyond recognition (*The Effects of Ice on the Beach and Nearshore, Point Barrow, Alaska*, J.D. Hume, M. Shalk, Aug 8, 1973. The effect of sediment transport by ice was not considered in this feasibility study.

Figure 25. Beach after the ice goes out appears heavily worked.

Figure 26. Beach after a season of wave action is smooth and typical of beaches in temperate regions.

Figure 27. Ice on the beach.

Figure 28. Ice can push very far inland and overtop the road.

Figure 29. Grounded ice stacks on offshore bars.

A search of ice data collected from the Barrow area was performed to determine ice strength and thickness. Results of the search are presented in figures 30 and 31. Representative ice covers are on the order of 4.9 feet thick (1.5 meters) and have a flexural strength of 90 psi (600 kPa). This information was used in a physical model study at the Cold Regions Research and Engineering Laboratory (CRREL) described later in this report.

Figure 30. Location of ice measurements.

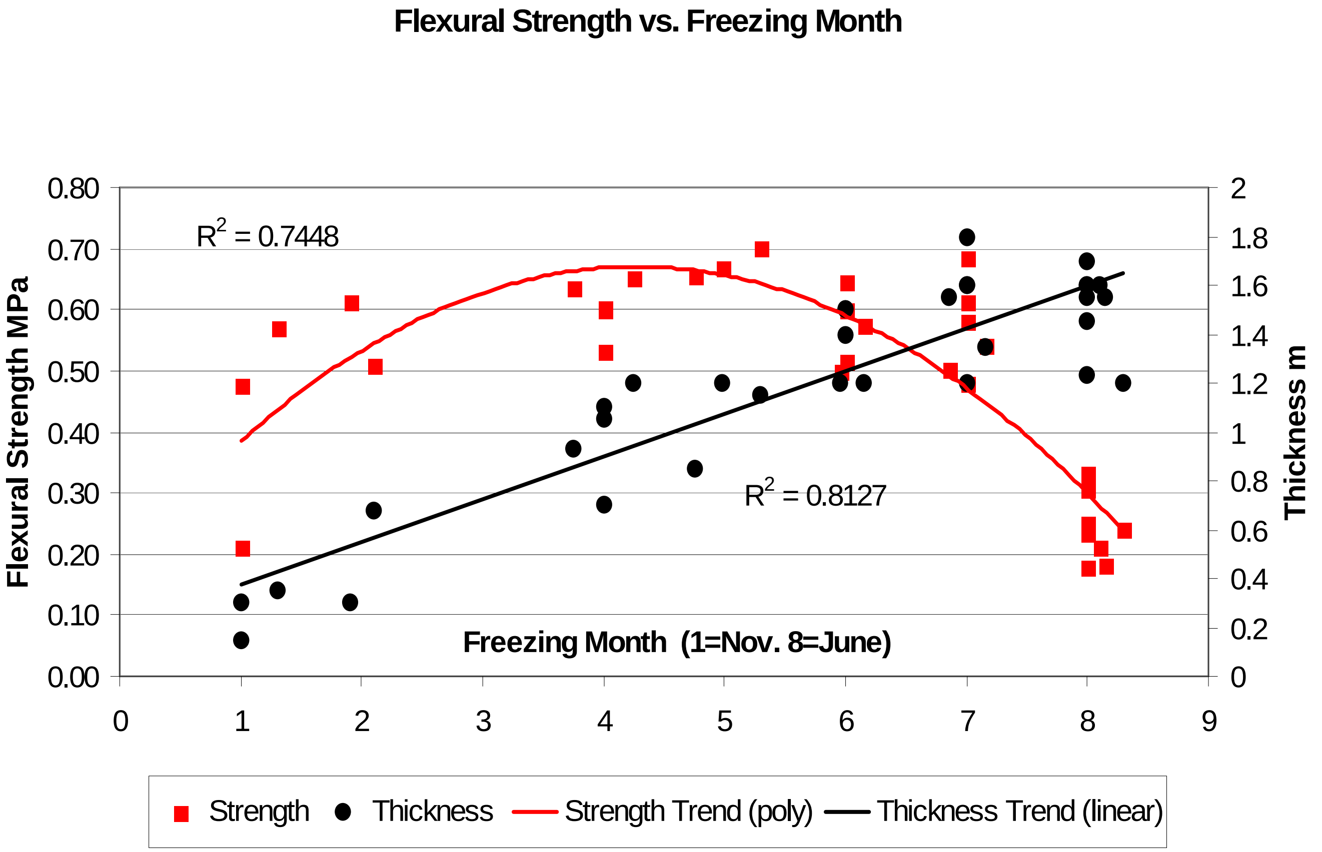


Figure 31. Summary of ice measurements.

3.3 Tides

Barrow is in an area of semi-diurnal tides with two high waters and two low waters each lunar day.

Tidal parameters at Barrow are similar to those predicted for Point Barrow. The tidal parameters in table 1 were determined using the U.S. Coast and Geodetic Survey Tidal Benchmarks at Point Barrow. Mean Lower Low Water is based on 106 high waters and 107 low waters, August 1 to September 29, 1945. There was no reported highest observed water level and no lowest observed water level.

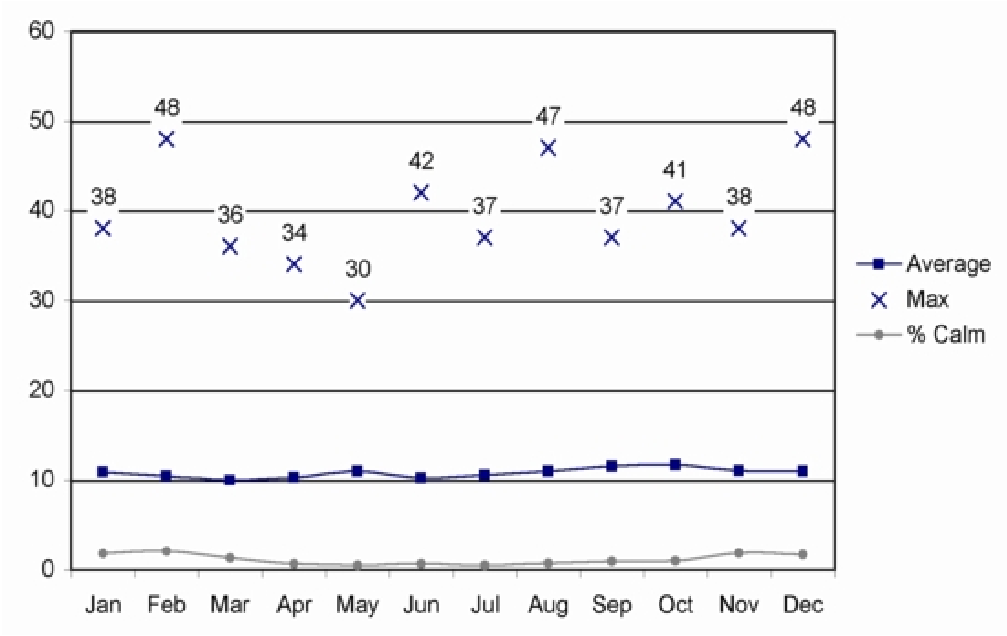
Table 1. Tidal Parameters – Point Barrow

Parameter	Elevation (ft)
Mean Higher High Water (MHHW)	0.50
Mean Sea Level (MSL)	0.25
Mean Lower Low Water (MLLW)	0.00

3.4 Wind

The Alaska Climate Research Center at the Geophysical Institute, University of Alaska Fairbanks compiled wind data from 1971 to 2000 for Barrow. There is an average wind of 10 miles per hour (mph) (figure 32). The predominant wind direction is out of the east and northeast with the majority of the wind coming out of the east northeast (table 2).

Barrow, AK
71° 17'N / 156° 46' W 30.8 ft. above sea level



.
Figure 32. Mean and maximum monthly wind speed (mph) and percent of calm observations. 1971-2000

Table 2. Monthly and annual wind frequency distribution (%) Wind Direction – Barrow 1971-2000

Direction	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
N	2.8	4.1	3.9	3.4	2.4	4.8	4.9	4.6	3.8	4.0	3.0	2.6	3.7
NNE	2.9	3.0	5.4	4.1	2.6	4.7	4.4	3.7	3.0	3.2	2.7	2.8	3.5
NE	12.6	10.9	12.9	14.6	9.5	8.9	7.7	6.3	9.5	9.5	12.4	13.3	10.6
ENE	22.2	18.1	19.4	22.0	23.0	15.8	14.7	10.5	17.0	17.6	23.0	27.1	19.2
E	10.7	11.1	10.9	13.7	19.7	18.5	18.5	14.7	13.3	12.8	15.5	13.6	14.4
ESE	5.5	7.3	5.4	7.3	11.7	9.0	7.7	7.9	7.6	9.0	8.3	6.6	7.8
SE	3.7	4.1	3.2	3.4	4.8	3.7	2.9	3.7	4.8	6.8	5.2	3.5	4.2
SSE	3.0	2.6	2.5	2.8	3.0	2.9	2.2	2.9	4.1	5.6	4.4	2.4	3.2
S	3.4	3.5	2.7	3.2	2.8	2.1	2.1	3.0	4.3	6.3	4.7	2.9	3.4
SSW	4.7	4.7	4.0	3.2	2.5	1.5	2.1	3.4	3.9	4.7	4.4	3.5	3.5
SW	4.2	4.9	4.3	4.2	3.5	3.8	5.0	5.3	4.2	2.3	1.9	3.2	3.9
WSW	4.8	5.8	6.1	4.1	4.1	5.4	8.4	9.1	5.2	2.2	2.1	3.8	5.1
W	5.5	6.4	5.7	3.4	3.2	5.1	6.7	8.2	5.5	2.5	2.1	4.7	4.9
WNW	5.7	5.4	5.3	3.5	2.3	4.8	4.9	6.3	5.0	3.8	3.6	4.3	4.6
NW	5.0	4.5	4.1	3.5	2.4	4.2	3.8	5.9	4.7	5.2	3.3	3.2	4.2
NNW	3.5	3.8	4.3	3.4	2.4	4.7	3.9	4.5	4.0	4.7	3.6	2.6	3.8

4.0 WAVE CLIMATE

Specification of a long-term wave climate along a coastal reach is dictated by principal forcing functions: the winds and site-specific oceanographic or geographical constraints. In the case of Barrow, the complexities increase because of its location and the ever-changing offshore ice coverage opening up the area for wind-wave development or preventing it as the ice builds in the fall. Because of its location, Barrow remains relatively protected from growing wave conditions in the Beaufort Sea to the east and swells south of Cape Lisburne in the Chukchi Sea. Barrow is unique and its wave climate is dictated by storms in the Arctic Ocean, limited in extent by the pack ice.

The Coastal and Hydraulics Laboratory (CHL) of the Engineer Research and Development Center (ERDC) developed a deep-water wave hindcast for the years 1982-2003 using hindcast generated wind data, supplemented with 27 pre 1982 storms, and then transformed the waves from a deep-water wave hindcast boundary output point to the near-shore at Barrow.

4.1 Wind Hindcast

The specification of the wind fields is critical to the generation of an accurate wave climate. A ten percent uncertainty in the wind speed estimate will lead to an approximate 20 percent uncertainty in the wave height. To characterize accurately the forcing mechanisms for the wave and current modeling, Oceanweather Inc. (OWI), performed a hindcast for the years 1982-2003 under contract to the Coastal Hydraulics Laboratory (CHL). The hindcast was supplemented with 27 storms for the years 1954 to 1982.

Wind Field Description. The Interactive Optimum Kinematic Analysis (IOKA) System (Cox et al. 1995) was used to construct the Barrow wind fields. All wind field estimates were restricted to the target domain shown in figure 33. Five critical elements are required for the IOKA system:

- Background wind fields
- Point source measurements (airport anemometer records, buoy data)
- Ship records (archived wind speed and direction)
- Scatterometer estimates of the wind speed
- Kinematic control points (KCPs).

These data sets (excluding the KCPs) must be adjusted for stability and brought to a common reference level. Stability accounts for the changes in the boundary layer due to differences between air and water temperatures. Considerations to the differences in boundary layer effects over the pack ice were neglected.

The background wind fields selected for the Barrow project were derived from the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) Reanalysis Project. These wind fields were spatially interpolated to a fixed spherical grid.

Point source measurements such as buoy data and airport records reflect wind speeds and directions based on short time burst averaging. These short-term averages (1 to 10 minute averages) are temporally interpolated to hourly data. Land-based wind measurements were also adjusted for boundary layer effects. Every land based, point source measured data set was individually investigated, and adjustments were made as needed. These adjustments depended not only on the wind direction, but also on the wind magnitude.

Scatterometer wind fields derived from satellites are not true wind speed measurements. They are derived from inversion techniques and are extremely useful because of the spatial coverage obtained during one satellite pass. The repeat cycle is 35 days (on a 12-hour orbit); therefore, temporally continuous data are not available as in the case of point source measurements. In addition, data from all satellite-based scatterometers do not span the entire hindcast period, or any of the pre-1982 extreme storms that were considered in the study. Including these data may produce a series of discontinuities in the development of the wind field climatology; however, use of these data adds considerable value to the final wind products and outweighs concerns regarding the consistency of the climatological wind products.

Once all data sets were transformed to equivalently neutral, stable 33.3 feet (10-meter) winds, the IOKA system is used. Each input wind data product carries a specified weight that can be overridden by an OWI analyst at any time. Background wind fields are ingested into OWI’s Graphical Wind Work Station, displaying all the available data sets (point source measurements, scatterometer data). The NCEP/NCAR Reanalysis wind fields are at a 6-hour time step, so all 1-hour point source wind measurements are repositioned via “moving centers relocation.” This ensures continuity between successive wind fields.

The most powerful tool of the IOKA system is the use of KCPs by the analyst. This tool can input and define ultra fine scale features such as frontal passages, maintain jet streaks, and control orographic effects near coastal boundaries. The analyst can use the KCPs to define data sparse areas using continuity analysis, satellite interpretation, climatology of developing systems, and other analysis tools. The IOKA system contains a looping mechanism that will continually update the new wind field based on revisions performed by the analyst.

The final step in the construction of the OWI regional wind fields was to spatially interpolate the winds to a target domain and resolution. The final wind fields were spatially interpolated to the target domain at a longitudinal resolution of 0.50° and a latitudinal resolution of 0.25° at a time step of 6 hours. This was done because the NCEP/NCAR Reanalysis wind fields are resolved at 6-hour time steps.

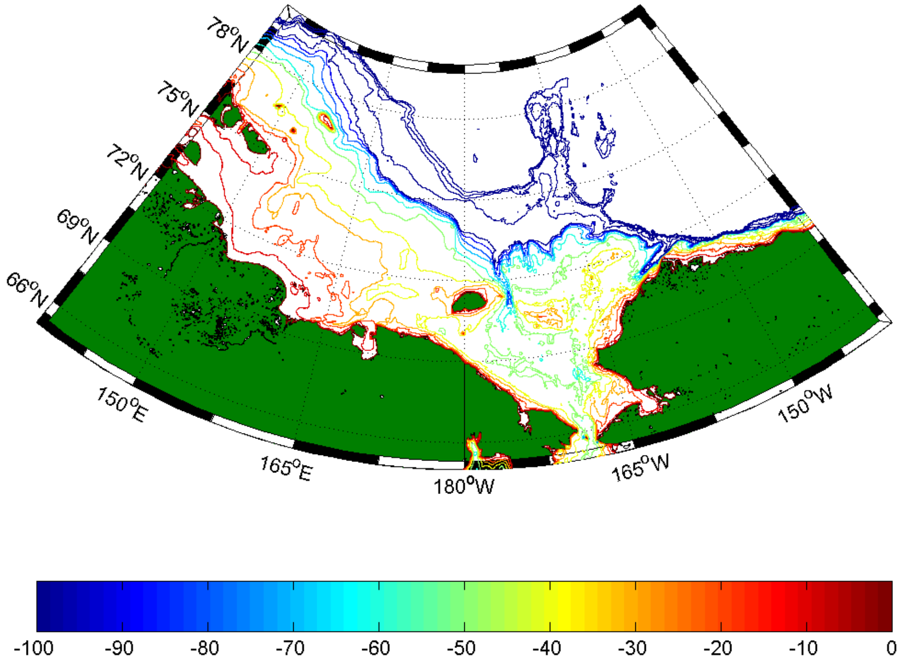


Figure 33. The Barrow deep-water wind, ice, and wave model target domain. Water depths are contoured in meters (1 meter = 3.3 feet).

4.2 Ice Field Specification

The specification of the ice edge quantifying the open water capable of wind-wave growth is one of the major controlling variables in the specification of the wave climatology. Barrow is adjacent to the Chukchi Sea and the Arctic Ocean where changes in the pack ice cover occurs more or less on a weekly basis.

Ice Field Methodology. Mean weekly ice maps were used for the modeling effort because of the rapid changes in the neighboring Chukchi Sea. An example of the final ice map for week 31 (30 July through 5 August) in 1998 is presented in figure 34. Digital ice field maps are derived from remote sensing techniques using visible and infrared imagery from the polar orbiting satellites that have been used since 1972 (VanWoert, M. 2002). Algorithms have been built to estimate the sea ice concentration and more recently sea ice thickness. Once established, these images are then translated to gridded information, and archived at the National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite Data Information Services (NESDIS). The approximate resolution is 25 km. Weekly estimates of the ice concentration were generated for this project (140° E to 140° W Longitude and 65° to 80° N Latitude) at 0.5° longitude/latitude resolution, and at 0.25° for the area defined by 167° to 142° W Longitude and 68° to 73° N Latitude (under contract to University of Alaska Anchorage). Oceanweather, Inc. constructed ice maps for selected storm events prior to the 1972 digital database.

Construction of the final wave model ice field resident on a 0.25° longitude/latitude grid system used both of the two zonal fields generated by the University of Alaska Anchorage. The coarse ice field concentration was spatially interpolated from 0.5° to the 0.25° grid and masked to the land-water grid ensuring consistency across the land/water boundary. The fine scale ice field replaced the area in proximity to the Barrow site. The concentration level (from 0 to 100 percent where the higher levels of concentration indicate increased ice compared with water) was interpolated rather than the designation of land/water mask. A predetermined concentration level of the ice field must be set to either open water or land. This study used a concentration level of 70 percent or greater to switch the water point to land. This concentration was chosen based on previous wave hindcast experience at the Delong Mountain Terminal. Examples of sea ice differences are shown in figure 35 and are derived from NOAA's Observers Guide to Sea Ice (prepared by Dr. O. Smith, University of Alaska Anchorage, http://response.restoration.noaa.gov).

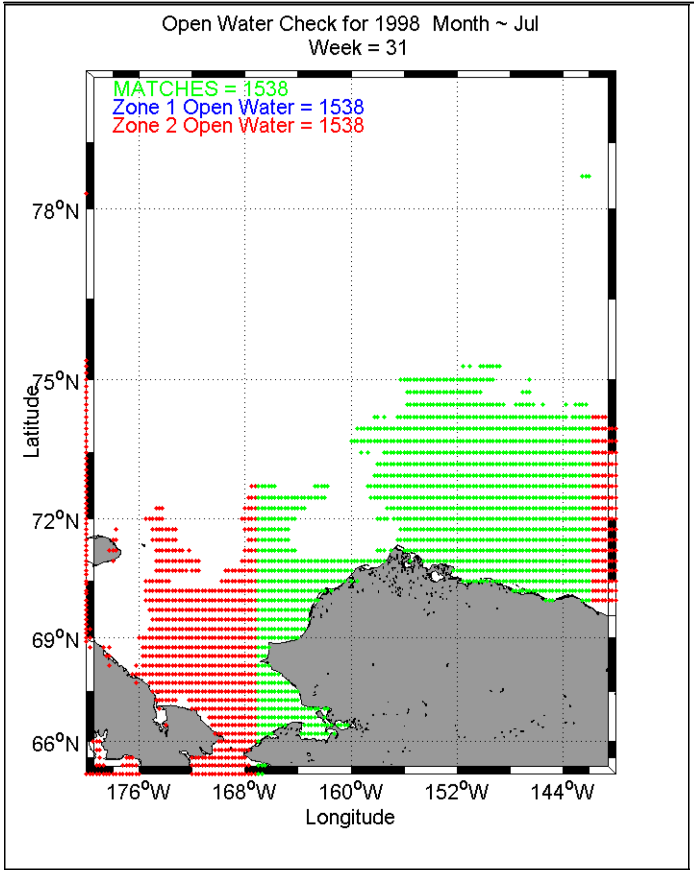
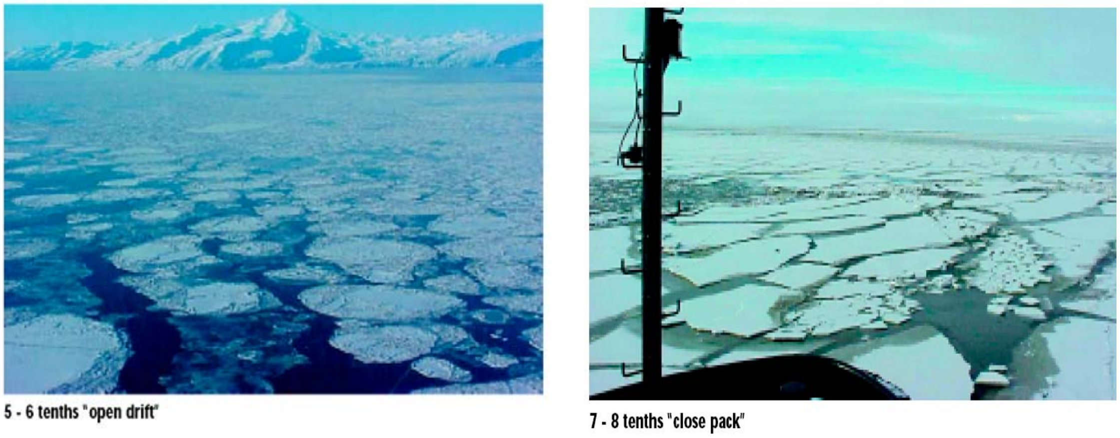


Figure 34. Example of the final ice mask used in wave model simulation.

Note: the symbols identify the open water area


5 - 6 tenths "open drift"

7 - 8 tenths "close pack"

Figure 35. Examples of sea ice concentration. Left 50 to 60 percent, right panel 70 to 80 percent concentration.

4.3 Deepwater Hindcast

The deep-water waves were analyzed using the **WA**ve prediction **M**odel (WAM). WAM is a third generation wave model that predicts directional spectra as well as wave properties such as significant wave height, mean wave direction and frequency, swell wave height, and mean direction. All source terms (wind input, wave-wave interaction, white capping, wave bottom effects, and wave breaking) are specified with the same degree of freedom in WAM, with which the resulting directional wave spectra are specified. There is no a priori assumption governing the shape of the frequency or directional wave spectrum. WAM has been used extensively at weather prediction centers with the option to include ice coverage.

Model Assumptions for WAM are:

- Time dependent wave action balance equation.
- Wave growth based on sea surface roughness and wind characteristics.
- Nonlinear wave and wave interaction by Discrete Interaction Approximation (DIA).
- Free form of spectral shape.
- High dissipation rate to short waves.

The domains describing the wind, ice, and wave model are found in table 3 and were shown in figure 33. For the Barrow study only the *open water season* (June through the end of December) of each year are simulated. Each year's simulation is started from fetch-limited calculations based on the 0000-hour wind field on 1 June.

Table 3. Wind, Ice, and Wave Model Domain Specification

Field Specification	**Longitude**		**Latitude**		**Resolution**	
	West	**East**	**South**	**North**	**Δ Lon / Δ Lat**	**Δt**
Wind Field	140.0 E	140.0 W	65.0	80.0	0.50 / 0.25 deg	6-hr
Ice Field Zone 2	140.0 E	140.0 W	65.0	80.0	0.50 / 0.50 deg	Weekly
Ice Field Zone 1	167.0 W	142.0 W	68.0	73.0	0.25 / 0.25 deg	Weekly
Ice Field Final	140.0 E	140.0 W	65.0	80.0	0.25 / 0.25 deg	weekly
WAM Waves	140.0 E	140.0 W	65.0	80.0	0.25 / 0.25 deg	120 / 600 s

4.3.1 Verification of Deepwater Wave Model

There is no regularly maintained wave buoy in the Chukchi Sea against which the model could be compared. In the absence of long-term continuous data, point-source measurements were obtained from Shell Oil Company for two non-directional wave buoys deployed in 1983 and 1984. The general location of these sites is shown in figure 36 and despite their distance from the Barrow Project Site, can strongly suggest the overall quality in the wave model’s performance. All data representing the measurements were hand-digitized from time plot records. These results should not be construed as ground-truth as in the case of digital wave records. Note the direction convention for all time plots of the θ_{mean} wave, and the wind direction are in a meteorological coordinate system (e.g. 0° from the north, 90° from the east).

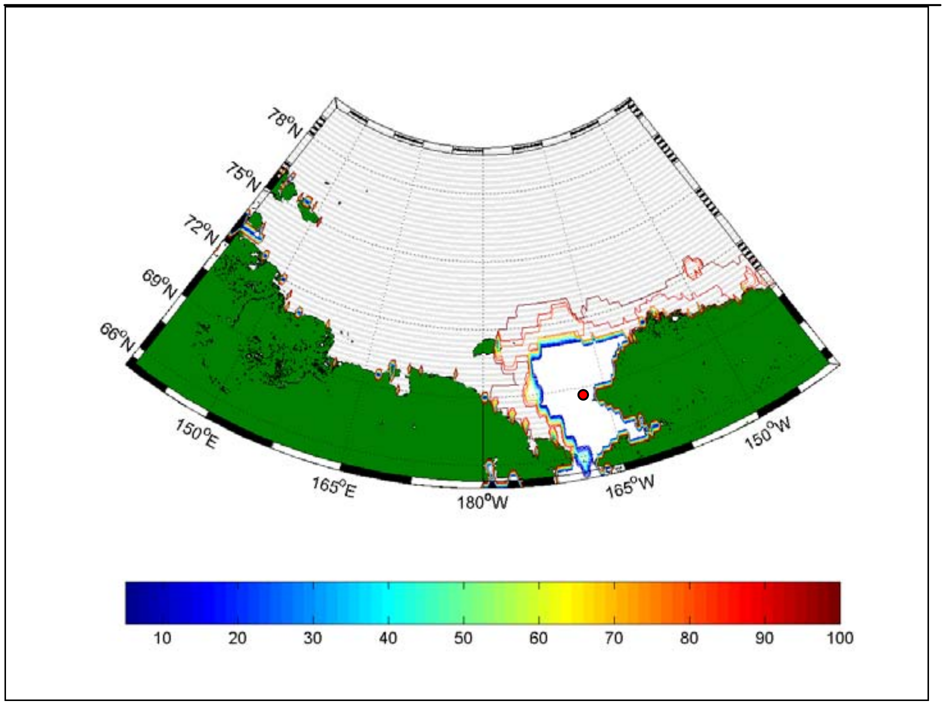


Figure 36. Location (red symbol) of the Shell Oil wave measurements for Stations A and B during two deployment cycles of 1983 and 1984. Ice concentrations are color contoured, and grey area signifies the ice pack.

All verification WAM runs were made with wind and ice fields identical to that of the climatology simulations. These tests were made to assure quality in the overall performance of the winds, ice coverage, and ultimately the wave model. Time and scatter plots as well as statistical tests were generated; however, because of the paucity of data, the statistical results will be biased and regarded as an approximation to the true performance of the wave model.

Estimates of the significant wave height (Hmo), and mean wave period, (Tmean) for 1983 are presented in figures 37 and 38 for Sites A and B. The WAM Hmo, and Tmean estimates for the first deployment period show remarkable similarity to the measurements. The storm peaks are well represented in all but one case (21 September), and are slightly low. There is one storm that is completely missed in the model results occurring at about 30 September. The maximum wave height measured during this missed event was about 1 meter (3.3 feet). The winds are in a decaying mode, and the wind directions are rapidly turning from a northeasterly direction to a southerly direction. The winds for this case may be slightly low for this case or the direction slightly off. It could also be the wave model, its grid and/or spectral directional resolutions. If the errors found at Site A, under similar meteorological conditions persist, then it would be reasonable to conclude the wave model is in error. However, in general the model emulates the measurements quite well in height and mean wave period.

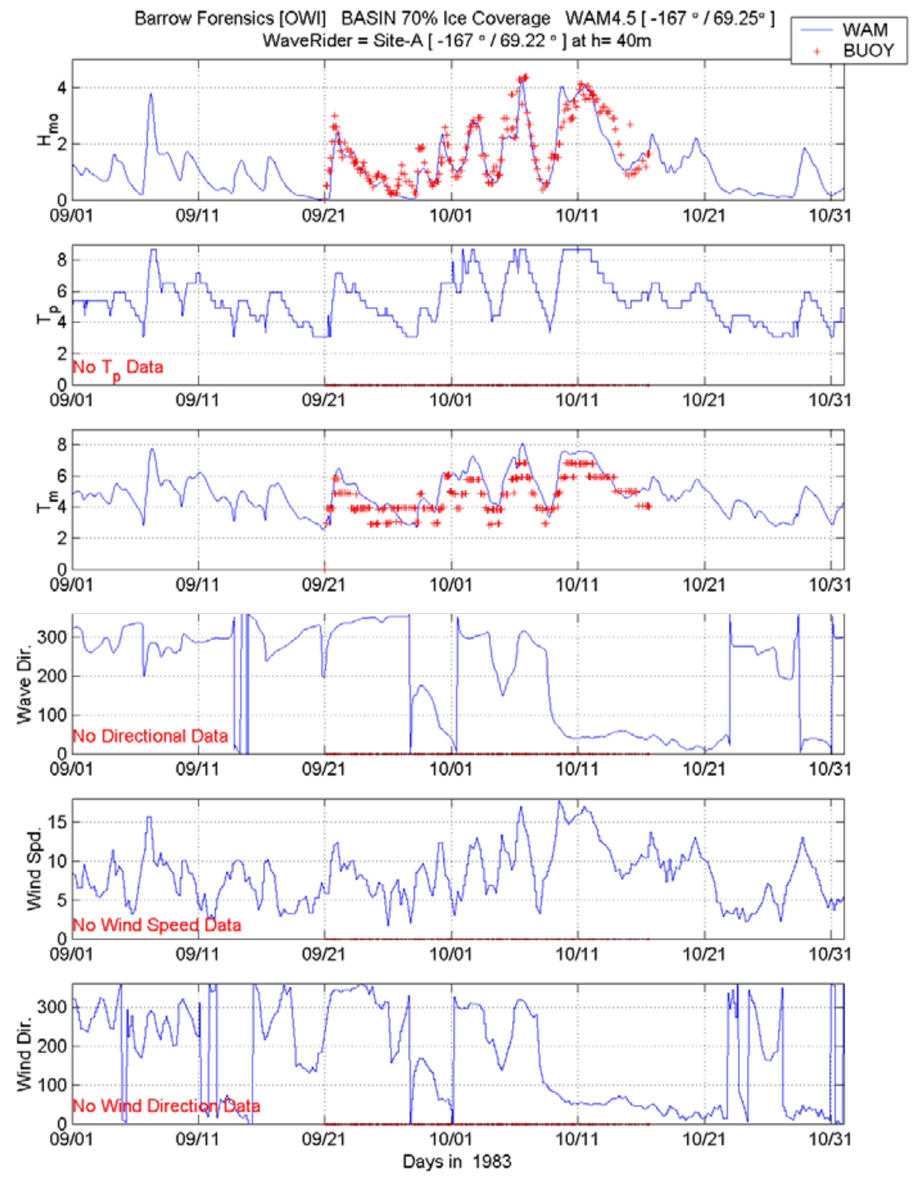


Figure 37. Comparison of WAM Cycle 4.5 (solid blue line) to Shell Oil Co. buoy data during deployment 1, at Site A.

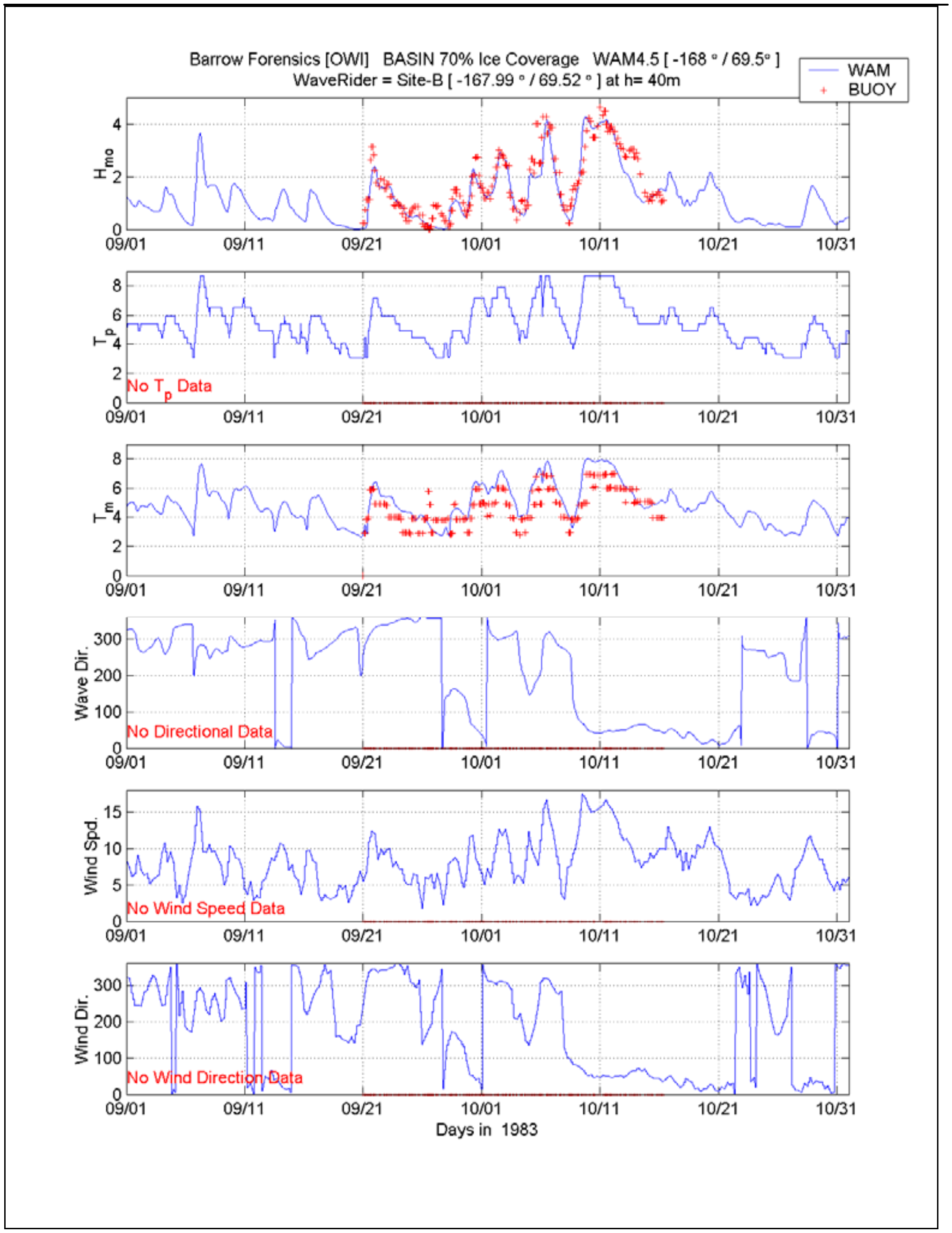


Figure 38. Comparison of WAM Cycle 4.5 (solid blue line) to Shell Oil Co. buoy data during deployment 1, at Site B.

The results of WAM during the second deployment (found in figures 39 and 40 for Site A and B, respectively) emulate the measurements, with exception to a slight over-estimation during the storms of 5-7 September and 5-8 October at Site A. At the same time, the mean wave period results are elevated by roughly 2 seconds. In general, the storm peaks are captured and the rapid growth of all storms is maintained. For the decay cycles, either rapid in the case of 21 September at Site A or much slower after the 6

October storm peak, trends are emulated in the model results. The mean wave periods, though, seem to grow correctly, then reach higher values at the most intense portion of the storm, and fail to decay as rapidly as in the measurements. It does not seem appropriate at this time to infer what the cause of these differences is. It could be elevated wind speeds, potentially blowing at an incorrect angle. It could also be the definition of the ice coverage, neglecting the fast-ice component at the shoreline, using the condition for land defined as ice concentration levels above 70 percent.

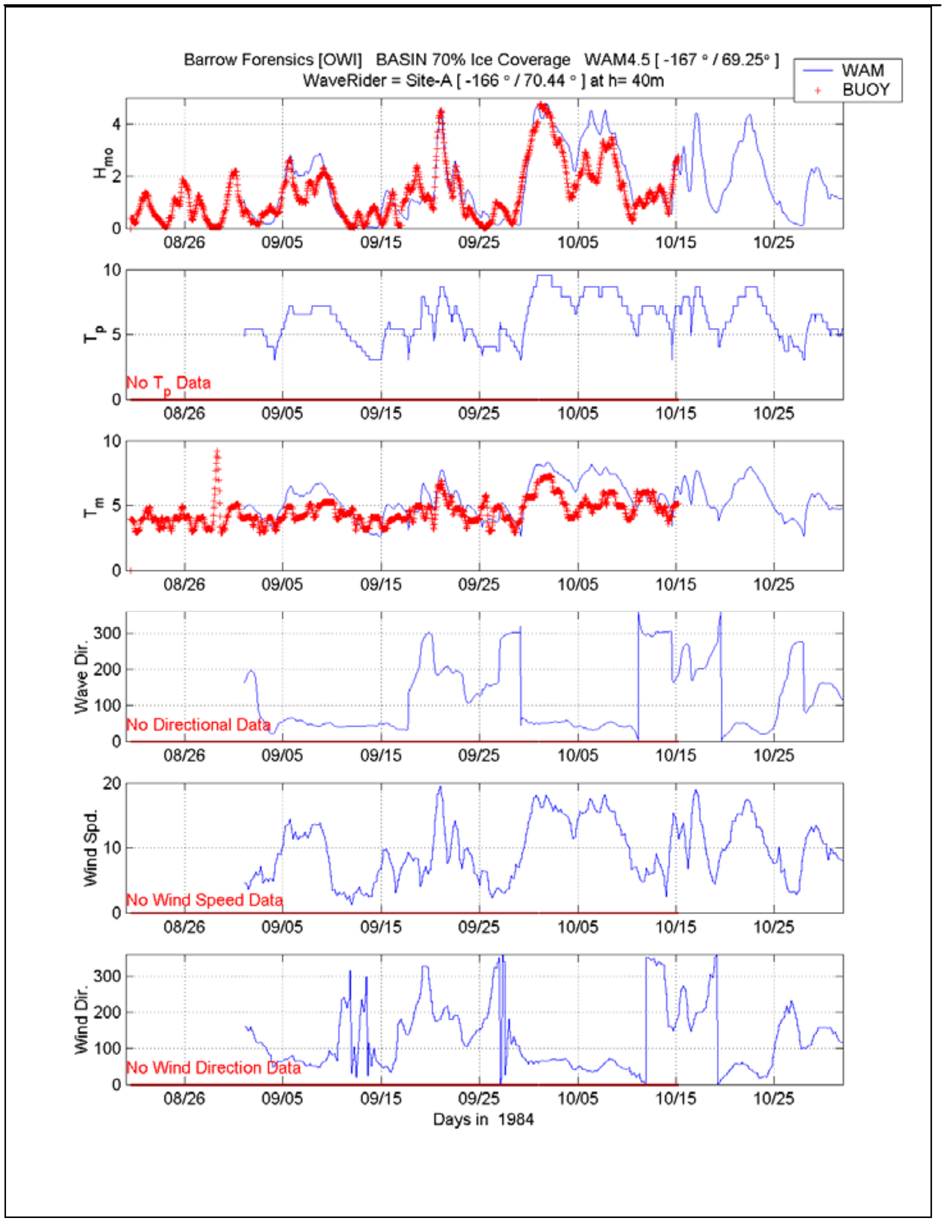


Figure 39. Comparison of WAM Cycle 4.5 (solid blue line) to Shell Oil Co. buoy data during deployment 2, at Site A.

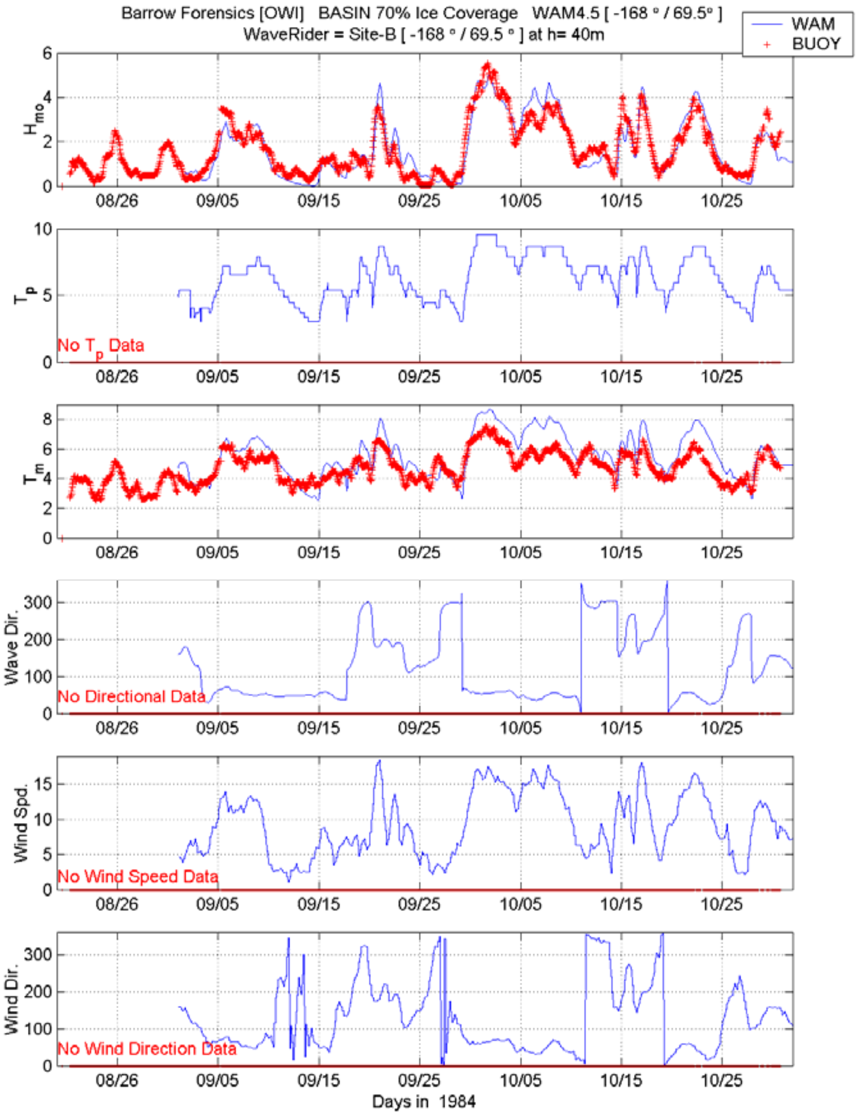


Figure 40. Comparison of WAM Cycle 4.5 (solid blue line) to Shell Oil Co. buoy data during deployment 2, at Site B.

4.3.2 Wave Climate Analysis

There are two distinct and separate parts in the development of the Barrow offshore wave climate. A continuous portion was run and encompassed the years 1982 thorough 2003 starting on 1 June and ending on 1 January of the subsequent year. The length of each simulation period varied because of the weekly changes in the ice maps, and the monthly changes in the wind fields. However, to retain continuity between each simulation period, a RESTART (or warm start) file was retrieved from the previous simulation. Hence, consistency was maintained throughout each year that was processed. For each year, WAM Cycle 4.5 was started from a cold start, preconditioning the wave field with fetch limited wave estimates derived from the input wind fields, operating on the open water dictated by the ice coverage. Wave data output for the subsequent near-shore wave transformation is shown in figure 41.

The second set of hindcasts were developed from a series of individual storm simulations that had documented evidence producing large water levels and/or elevated wave conditions along the Barrow project study site. Some of these storms were selected from a historical database used for design wave estimates for the North Slope. The U.S. Army Corps of Engineers, Alaska District provided a selected number, and the last set was derived from storm analysis procedures used by Oceanweather, Inc. The 27 storms are summarized in table 4 below. These storms were of short duration so that a mean monthly ice field was used for all storm simulations. This was dictated by the availability of high quality digital ice maps only provided on a monthly basis for the earlier storms on record. Consistency in the procedures throughout the time span was deemed more important reducing any added false discontinuity.

Table 4. Extreme Storms pre-1982

Storm No.	Date	Type	Simulation Period
1	5409	NW	54091601 - 54091900
2	5410	NW	54100300 – 54100512
3	5507A	SW	55071706 – 55072006
4	5507B	SW	55071912 – 55072212
5	5707	SW	57071500 – 57071800
6	5709	NE	57091200 – 57091500
7	6009	SW	60092500 – 60092812
8	6106	SW	61061618 – 61061918
9	6209	SW	62090312 – 62090518
10	6308	SW	63082118 – 63082400
11	6310A	NW	63100306 – 63100506
12	6310B	NE	63100600 – 63100900
13	6410	SW	64101800 – 64102100
14	6509	NE	65090500 – 65090800
15	6709	NE	67091700 – 67092000
16	6809	NW	68092112 – 68092312
17	7210	NE	72101500 – 72101800
18	7307	SW	73073112 – 73080312
19	7310	SW	73101500 – 73101712
20	7410A	NE	74100512 – 74100812
21	7410B	NE	74102212 – 74102512
22	7508	NW	75082512 – 75082718
23	7710A	NE	77101000 – 77101300
24	7710B	NE	77101812 – 77102200
25	7810	NE	78100700 – 78101000
26	7910	NE	79100312 – 79100612
27	8009	NE	80092612 - 80100100

A series of special output locations (119 total) were saved along the land/water boundary defined in the Barrow grid. These output locations are shown in figure 41, where Stations 47, 49, 51, and 52 focus in the area just offshore of the Barrow site. Station 49 is the location where the deep-water wave spectra were used as input for Near-shore Wave Simulations. Figure 42 shows Station 49 and its associated bathymetry.

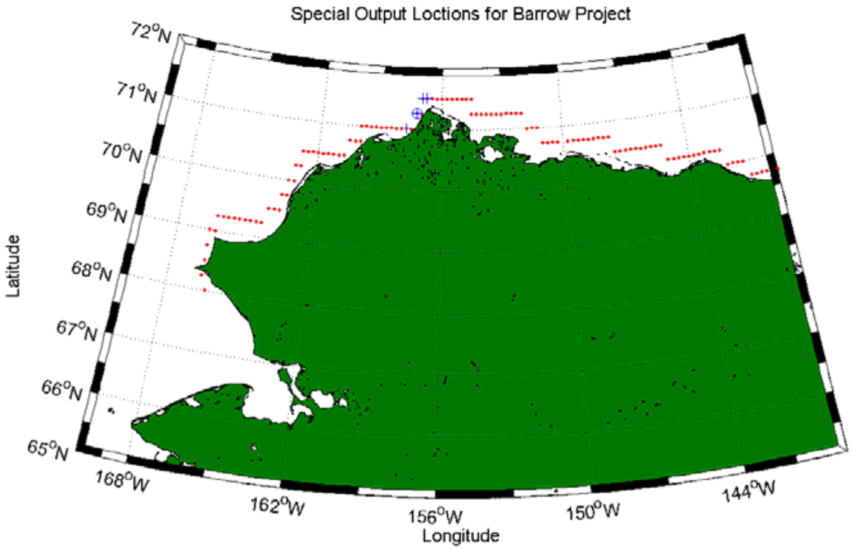


Figure 41. Special output locations (red) and Stations 47, 51, 52 (blue +) and the STWAVE input site Station 49 (blue ⊕)

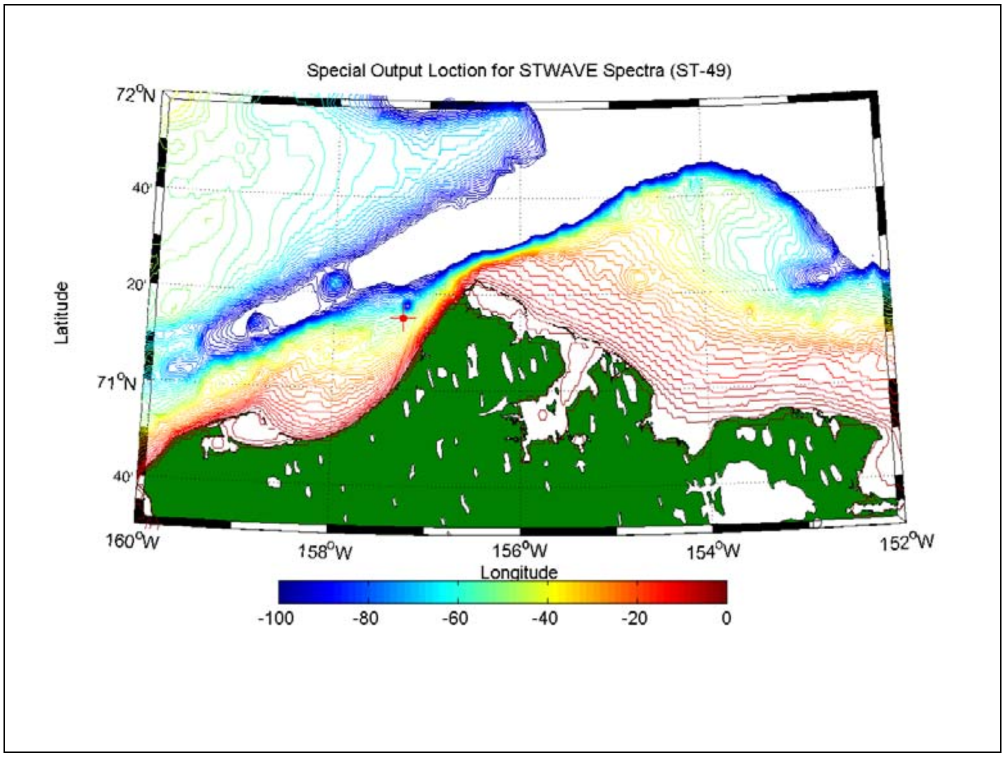


Figure 42. Zoomed view of the Barrow Site and Station 49 (red cross). Note that only water depths less than 100 meters are color contoured to emphasize the local bathymetry. Water depths greater than 100 meters exist and are identified by the white area outside the blue 100-meter contour interval.

A general perspective of the wind and wave climate for the continuous (1982 through 2003) hindcast can be shown in table or graphical form. Figure 43 presents the integral wave parameters in height, peak spectral wave period, and vector mean wave direction.

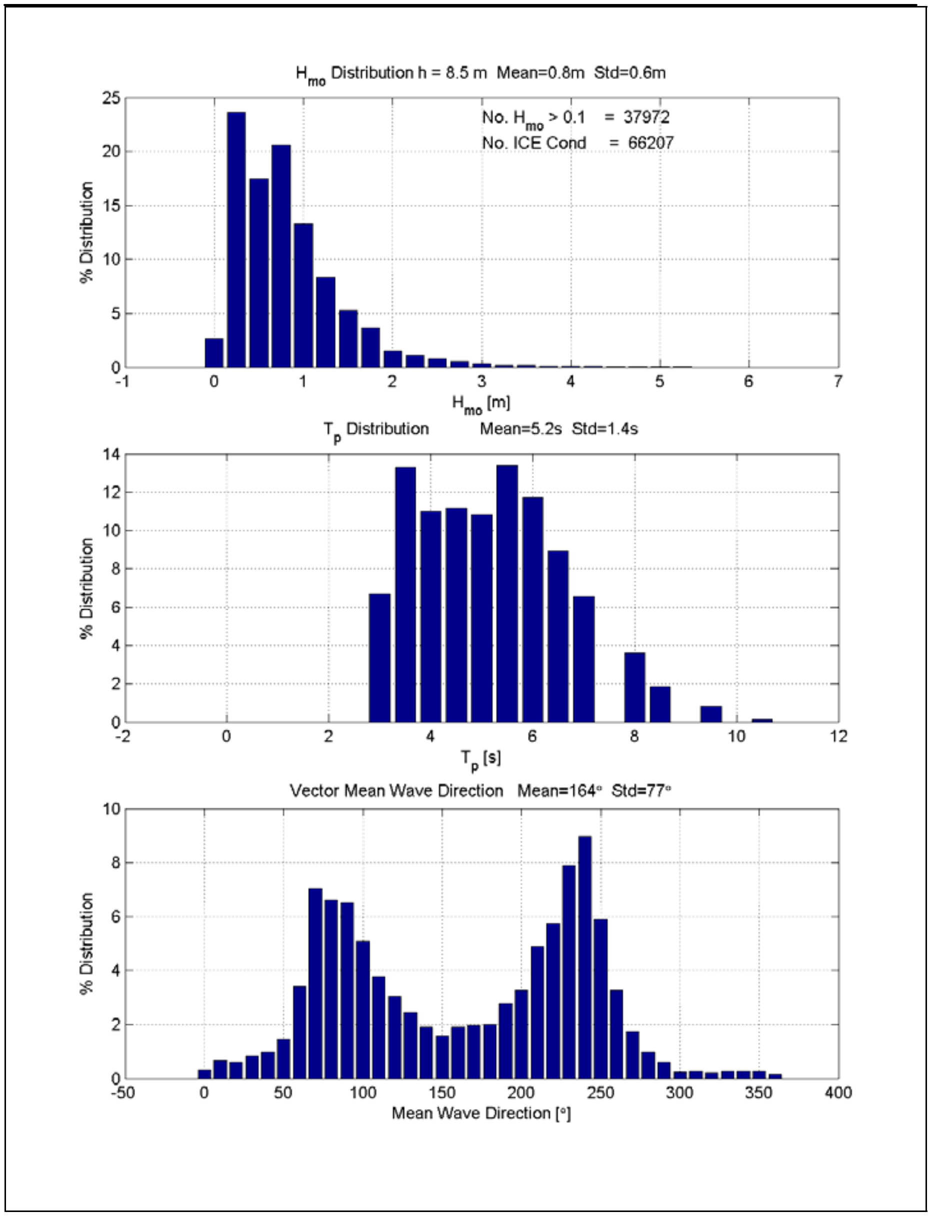


Figure 43. Height, peak wave period, and vector mean wave direction distributions for the 1982 – 2003 (June through November) at Station 49.

The Hmo and Tp distributions support a general trend for local wind-sea dominance. Very limited long-period (generally greater than 10-sec) waves are contained in the entire wave record. The absolute maximum wave height estimated is slightly over 16.4 feet with a peak spectral wave period of 10.2 sec. What is interesting to note is the mean wave directional distribution. Noting the shore normal direction is about 135 degrees, virtually all the waves contained in the left-hand lobe consist of waves coming into the coast, and most likely derived from northwesterly storms. The right-hand lobe in the vector mean wave direction consists of waves derived from the northeast. The sheltering effects of Point Barrow, starting at 315 degrees, cause the rapid drop in the occurrences.

The wind speed and directional distributions are provided in figure 44. There is a dominant trend in the winds at Station 49. For the coastal area, wind speeds in excess of 22.4 mph are limited to about 15 percent. The bulk of the winds range from 11.2 to 20.1 mph. Two lobes exist in the wind directional distribution; however, the magnitudes compared with the wave direction are quite different where there is clearly visible persistence for east-northeasterly directions.

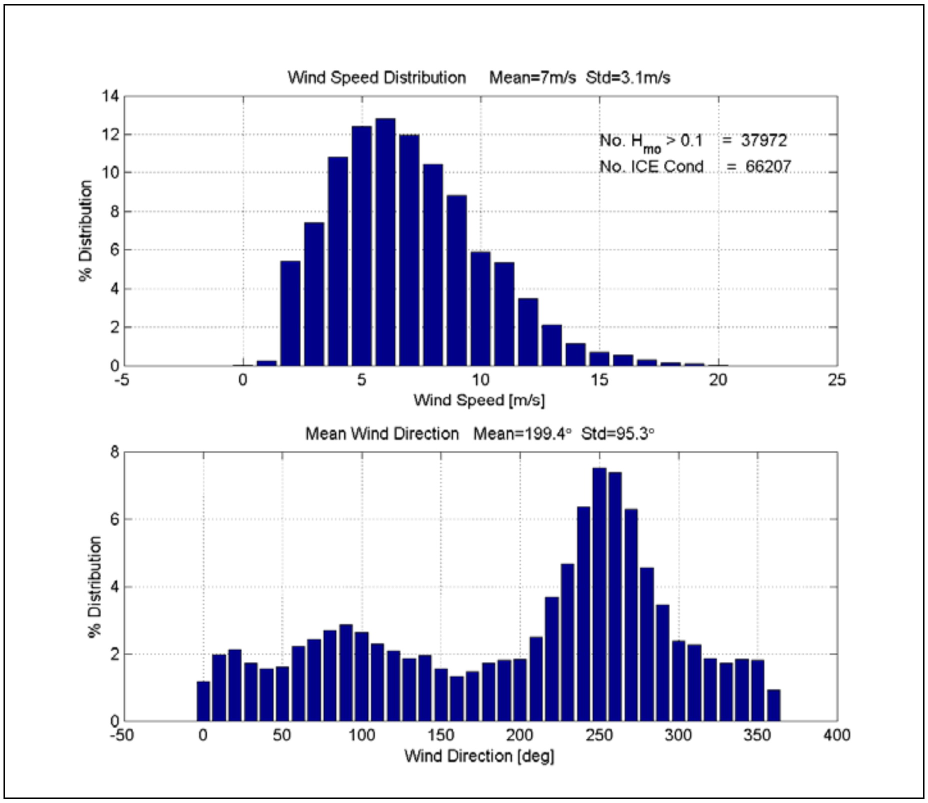


Figure 44. Wind speed and direction distributions for the 1982 – 2003 (June through November) at Station 49.

The analysis thus far removes the time domain focusing on only the distribution of wind and wave characteristics for the entire climate simulation. Figure 45 shows the bar plots of the number of observations and the mean and maximum conditions occurring June through December from 1983 through 2003. The values used for plotting purposes are also summarized in table 5. There are variations from year to year, increasing in the late 1990’s through the end of the simulation period.

Three dependent variables dictate wave height maximums. First, meteorological systems with winds in excess of 22 miles per hour (10 m/s) are needed; second, these winds need to be directed toward the Barrow project site; and third, the amount of open water needs to be sufficiently large to build the waves. It is interesting to note the large variation in maximum Hmo. There is a clearly defined long-term oscillation in the Hmo maxima. This oscillation occurs at a 4 to 5-year interval, with a nearly doubling of the wave heights at the peaks. If the analysis period was restricted to only 10 to 20 years, this pattern may not have been evident and supports the need for multi-decadal simulations to adequately define the climatic variability in the wave environment. In general, and considering the local domain, the wind speeds at the time of the Hmo maxima are over a 22-mile per hour (10 m/s) threshold. The wind directions generally are traveling more or less down the coastline. The vector-mean wave direction is nearly identical to the wind direction at the Hmo maximums, indicating a dominant local wind-sea environment, which is further supported by the Tp results in the range of 8- to over 10-s during the maximum wave height events. The shore normal direction is at approximately 135 degrees with landward attack angles between 45 and 225 degrees. The predominant storm generated waves come from the north to northeast. These would be oblique approach angles relative to the shoreline orientation. Hence, the wave climate produced in this portion of the study reflects the offshore environment, and not that close to the coast.

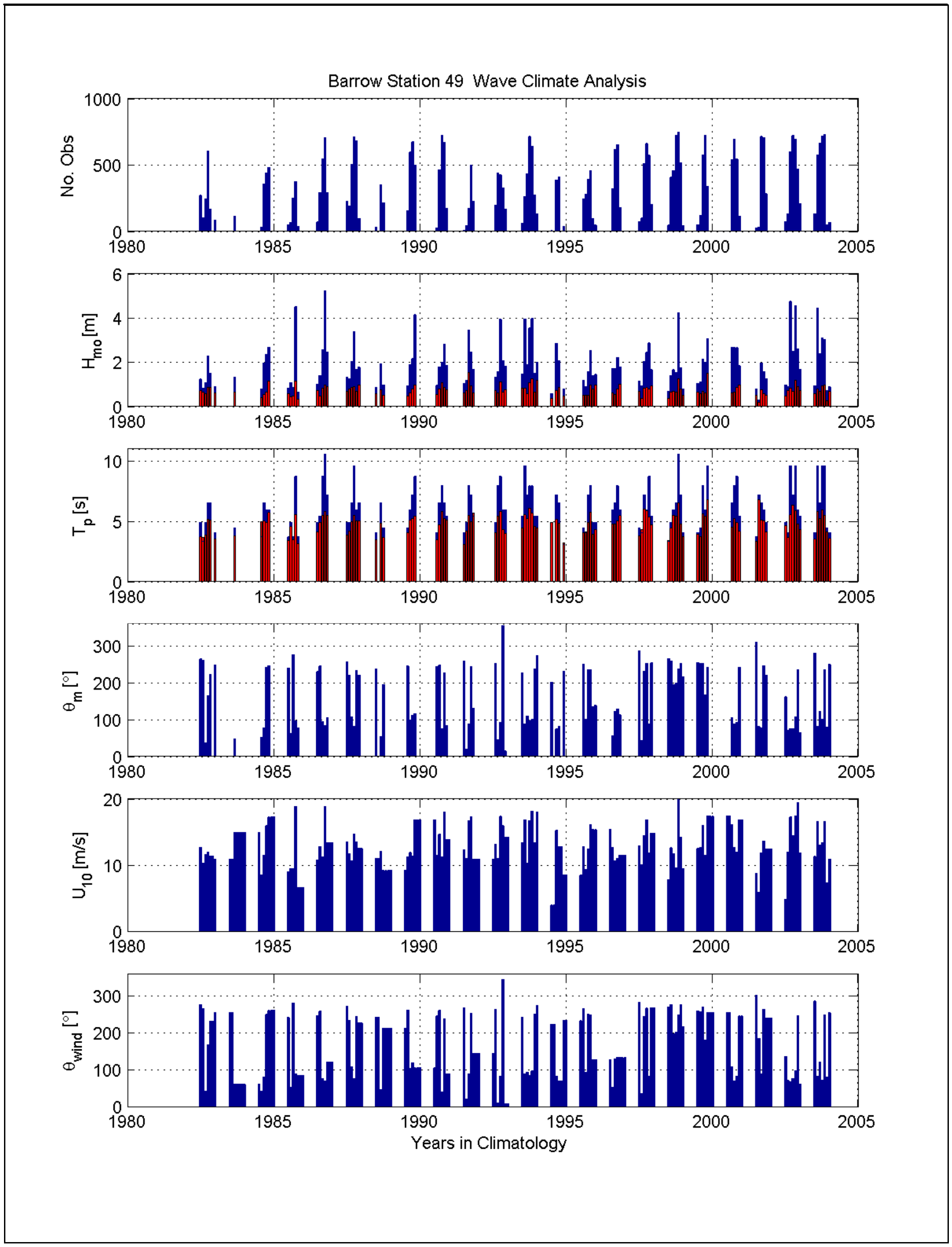


Figure 45. Climate summary at Station 49 where various panels define the variation of parameter over time (monthly information) the red indicates the mean, the blue the maximum.

In summary, there are only modest variations in the local wave climate dictated by the intensity and duration of meso-scale meteorological events. For the offshore Barrow project site, the dependency in a sustainable wind speed is far more pronounced than the fetch it blows over. Extreme events quantified by the maximum Hmo over time appear to be periodic, with an interval of about 5 years for wave heights in excess of 13.1 feet. The number of observations of these events may be on the rise due potentially to increased open water, specifically for the years 2003 and 2004.

Table 5. Wave Characteristics for 1983 through 2003 Climate Simulations

Year Month	No. Obs	Mean		Maximum at Height Max				
		H_{mo} (m)	T_p (s)	H_{mo} (m)	T_p (s)	Wave Dir	Wind Spd	Wind Dir
198206	271	0.718	3.710	1.24	4.91	263	12.7	277
198207	105	0.642	3.680	0.82	3.35	260	10.3	266
198208	245	0.587	3.878	1.09	4.91	36	11.6	44
198209	603	0.853	5.173	2.26	6.53	164	12	169
198210	169	0.854	5.062	1.49	6.53	222	11.3	232
198211	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198212	86	0.629	3.528	0.91	4.05	246	10.9	255
198306	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198307	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198308	115	0.656	3.790	1.31	4.46	48	14.9	62
198309	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198310	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198311	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198312	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198406	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198407	35	0.402	4.922	0.8	3.69	52	8.5	44
198408	355	0.554	5.010	1.95	6.53	78	11.5	82
198409	438	0.658	4.887	2.34	5.94	241	15.9	250
198410	481	1.142	5.699	2.68	5.94	245	17.2	261
198411	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198412	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198506	48	0.583	3.411	0.83	3.69	239	9	242
198507	66	0.454	4.529	1.09	4.91	63	9.5	55
198508	252	0.478	3.464	0.87	3.69	275	9.5	281
198509	374	1.162	5.540	4.49	8.69	97	18.8	91
198510	36	0.348	3.147	0.64	3.69	78	6.6	85
198511	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198512	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198606	72	0.727	4.107	1.02	4.91	229	10.8	247
198607	293	0.468	4.875	1.41	5.4	244	12.8	259
198608	547	0.817	5.473	2.55	8.69	95	11.2	77
198609	704	0.970	5.817	5.22	10.51	84	18.8	71
198610	289	0.896	5.486	2.45	7.18	105	13.4	121
198611	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198612	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198706	225	0.683	3.878	1.32	4.91	256	13.5	272
198707	192	0.803	4.191	1.26	4.91	220	11.7	234
198708	503	0.851	4.958	2.02	6.53	107	10.7	110
198709	710	0.883	5.496	3.37	9.56	81	14.7	77
198710	680	0.673	5.010	1.69	5.94	232	13.5	244
198711	97	0.982	5.028	1.77	6.53	220	12.5	227
198712	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198806	34	0.585	3.463	0.88	4.05	237	11	242
198807	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198808	352	0.757	4.800	1.93	6.53	53	12.1	48
198809	216	0.515	3.647	0.97	4.46	194	9.2	213
198810	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198811	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198812	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE

Table 5. Wave Characteristics for 1983 through 2003 Climate Simulations

Year Month	No. Obs	Mean		Maximum at Height Max				
		H_{mo} (m)	T_p (s)	H_{mo} (m)	T_p (s)	Wave Dir	Wind Spd	Wind Dir
198906	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
198907	156	0.477	4.024	0.95	4.46	244	11.2	262
198908	595	0.627	5.055	1.9	5.94	99	11.9	105
198909	672	0.800	5.235	2.16	7.18	112	11.3	120
198910	498	0.981	5.426	4.13	8.69	116	16.8	106
198911	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199006	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199007	27	0.564	3.452	0.96	4.05	243	11.5	246
199008	463	0.808	4.711	1.8	6.53	246	14.6	261
199009	720	1.071	5.777	2.01	7.9	75	11.2	42
199010	667	0.866	5.229	2.79	6.53	225	17.9	239
199011	174	0.759	5.088	1.85	5.4	84	13.8	90
199012	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199106	8	0.606	3.043	1.05	4.05	258	12.3	267
199107	46	0.721	4.182	1.19	4.91	20	11	23
199108	172	1.548	5.478	3.43	7.9	87	16.7	89
199109	498	0.950	4.921	2.45	7.18	242	17.2	254
199110	226	0.610	5.687	1.68	5.4	130	10.9	146
199111	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199112	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199206	1	ICE	ICE	ICE	ICE	ICE	10.9	146
199207	199	0.709	4.032	1.33	4.91	251	13.1	264
199208	437	0.618	5.396	1.56	7.9	45	11	11
199209	424	1.118	5.812	3.93	8.69	93	17.3	83
199210	326	0.650	4.306	2.08	5.94	353	15.9	344
199211	169	0.769	3.987	1.83	5.94	15	14.2	10
199212	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199306	60	0.839	4.456	1.47	5.4	226	13.4	243
199307	260	0.841	5.507	3.94	9.56	88	16.8	91
199308	431	0.571	5.198	1.9	7.18	109	10.3	95
199309	712	1.071	6.039	3.54	7.9	97	16.7	86
199310	639	1.257	5.632	3.96	7.9	100	18.1	98
199311	276	0.659	4.567	1.49	5.4	237	13.4	251
199312	132	1.172	4.405	2.01	5.4	272	17.9	275
199406	7	0.380	4.91	0.58	4.91	200	4	223
199407	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199408	385	0.729	5.125	2.84	7.18	75	15.2	84
199409	406	0.865	4.813	2.07	6.53	82	12.8	71
199410	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199411	37	0.475	3.225	0.78	3.05	229	8.5	233
199412	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE

Table 5 cont. Wave Characteristics for 1983 through 2003 Climate Simulations								
Year Month	No. Obs	Mean		Maximum at Height Max				
		H_{mo} (m)	T_p (s)	H_{mo} (m)	T_p (s)	Wave Dir	Wind Spd	Wind Dir
199506	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199507	246	0.499	4.062	1.18	4.46	249	12.8	266
199508	280	0.508	4.092	0.9	4.05	101	9.3	95
199509	394	0.500	4.915	1.56	7.18	235	12.4	250
199510	457	0.971	5.74	2.53	7.9	234	16.1	248
199511	95	0.811	3.909	1.38	4.91	134	15.3	129
199512	49	0.983	4.291	1.45	4.91	138	15.3	129
199606	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199607	320	0.625	4.727	1.71	5.94	56	12.6	53
199608	612	0.563	4.754	1.71	6.53	121	10.6	131
199609	652	0.787	4.995	2.22	7.9	129	11	134
199610	181	1.020	5.438	1.78	5.94	113	11.5	134
199611	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199612	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199706	73	0.695	3.809	1.13	4.46	284	12.9	282
199707	100	0.356	4.312	0.93	4.05	44	10.1	38
199708	511	0.836	5.996	2.02	7.18	230	14.4	244
199709	659	0.854	5.848	2.44	5.94	251	16.8	267
199710	571	0.804	5.319	2.86	8.69	87	11.8	84
199711	202	0.923	4.720	1.66	5.4	253	14.8	268
199712	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199806	48	0.360	3.378	0.7	3.35	264	7.8	271
199807	407	0.662	4.402	1.41	4.91	257	12.6	276
199808	458	0.694	5.494	1.66	5.94	194	11.7	199
199809	720	0.667	5.416	1.52	6.53	197	9.6	203
199810	744	1.239	6.533	4.21	10.51	237	19.8	249
199811	517	0.788	4.731	1.76	7.18	252	14.2	276
199812	44	0.514	3.703	0.79	4.05	215	9.5	217
199906	52	0.659	3.912	1.05	4.05	254	12.5	260
199907	121	0.592	3.749	1.11	4.46	252	12.7	258
199908	576	0.697	5.628	2.13	7.9	250	16	271
199909	720	0.628	5.372	1.98	5.94	166	11.5	182
199910	337	1.505	6.751	3.06	9.56	241	17.3	256
199911	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
199912	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
200006	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
200007	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
200008	537	0.604	4.501	2.65	6.53	105	16.1	109
200009	691	0.656	5.217	2.68	7.9	87	12.7	71
200010	542	0.857	4.875	2.65	8.69	93	12	83
200011	117	0.980	4.161	1.84	5.4	241	16.8	246
200012	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
200106	29	0.50828	3.328	0.8	3.69	308	8.8	301
200107	35	0.21114	6.749	0.31	7.18	81	6	186
200108	712	0.77621	5.098	1.97	6.53	77	11.8	90
200109	705	0.58187	5.008	1.57	5.94	245	13.6	264
200110	283	0.52643	4.113	1.26	4.91	219	12.4	240
200111	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE
200112	1	ICE	ICE	ICE	ICE	ICE	ICE	ICE

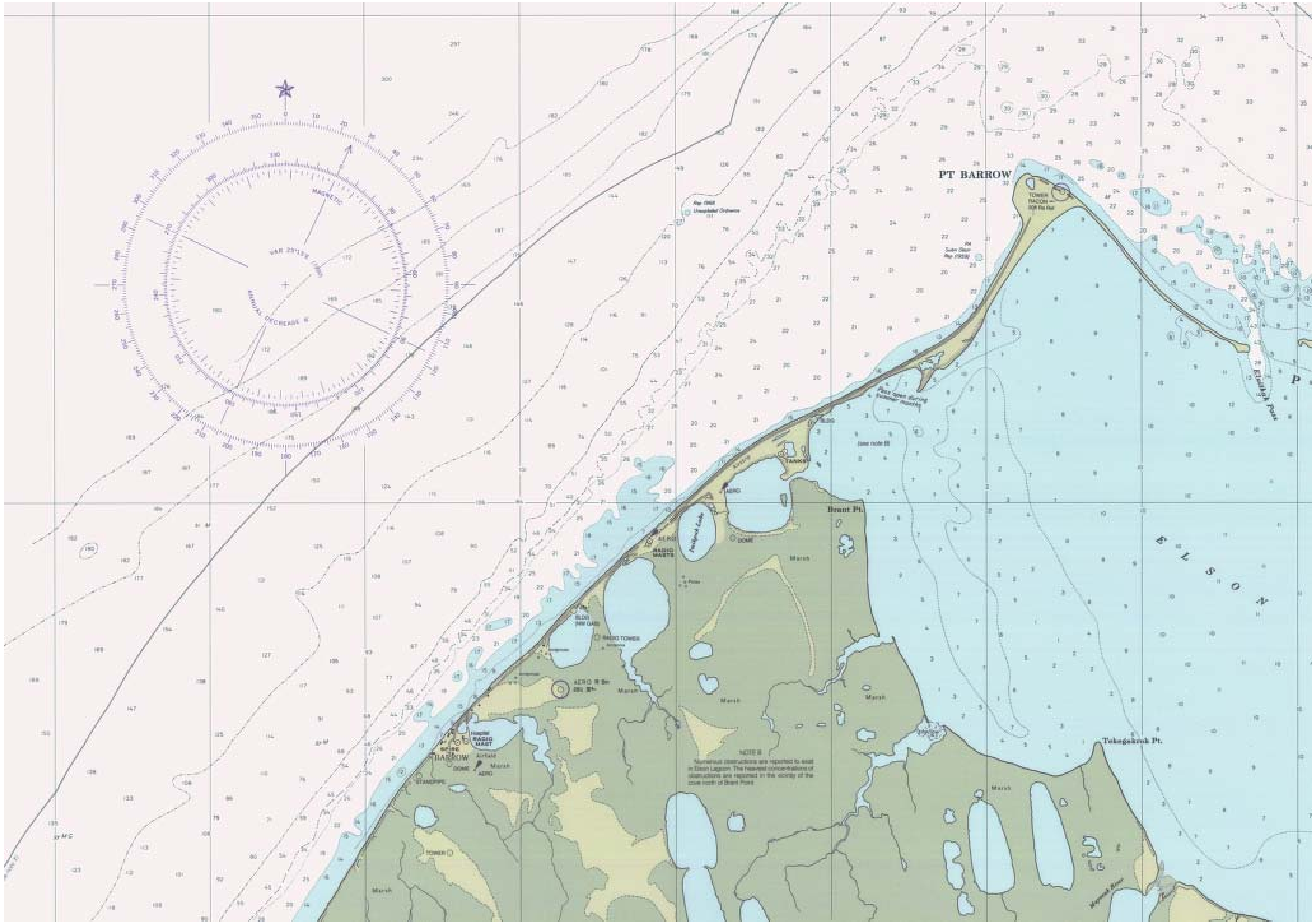


Figure 46. Barrow shoreline for reference.

4.4 Extreme and Average Wave Climate

Severe historic storms dating back to 1954, which were thought to have a significant influence on wave conditions at Barrow, were included in the hindcast. Inclusion of the additional storms provided higher confidence in the extreme wave estimates (those representing 50-year return-period events) that are critical for design of any storm damage reduction project.

The percent of occurrence for the range of wave heights and periods are shown in table 6. The largest storm of record in the extremal wave analysis occurred in September 1986. The peak significant wave height was 17 feet with a 10.5-second period. The return period predicted for this storm by the extremal analysis is 30.3 years. A plot of the deep-water significant wave height and return period is shown in figure 47. Significant wave heights for the selected storms from 1954 to 2003 are shown in table 7 along with their ranking.

Table 6. Percent Occurrence (x1000) 1983-2003 from WAM of Wave Height and Periods for all Directions at Station 71.25 N, 157.25 W

	Peak Period, sec										
H, ft	<5.0	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-12.9	14.0-15.9	16.0 +	Total
0.0-0.3	.	.	.	.	.	.	.	.	.	.	68838
0.4-1.6	6623	3158	827	643	34	1	.	.	.	.	11286
1.7-3.2	8022	1624	808	525	41	4	1	.	.	.	11025
3.3-4.8	2061	1819	627	683	75	18	.	.	.	.	5283
4.9-6.5	74	966	496	556	75	21	.	.	.	.	2188
6.6-8.1	.	74	139	356	99	53	1	.	.	.	722
8.2-9.8	.	8	26	161	80	77	5	.	.	.	357
9.9-11.4	.	.	1	88	35	16	3	.	.	.	143
11.5-13.0	.	.	.	25	40	11	9	.	.	.	85
13.1-14.7	.	.	.	.	18	5	9	.	.	.	32
14.8-16.3	.	.	.	.	1	3	.	.	.	.	4
16.4-18.0	.	.	.	.	.	3	10	.	.	.	13
18.1+	.	.	.	.	.	.	.	.	.	.	0
TOTAL	16780	7649	2924	3037	498	212	38	0	0	0	

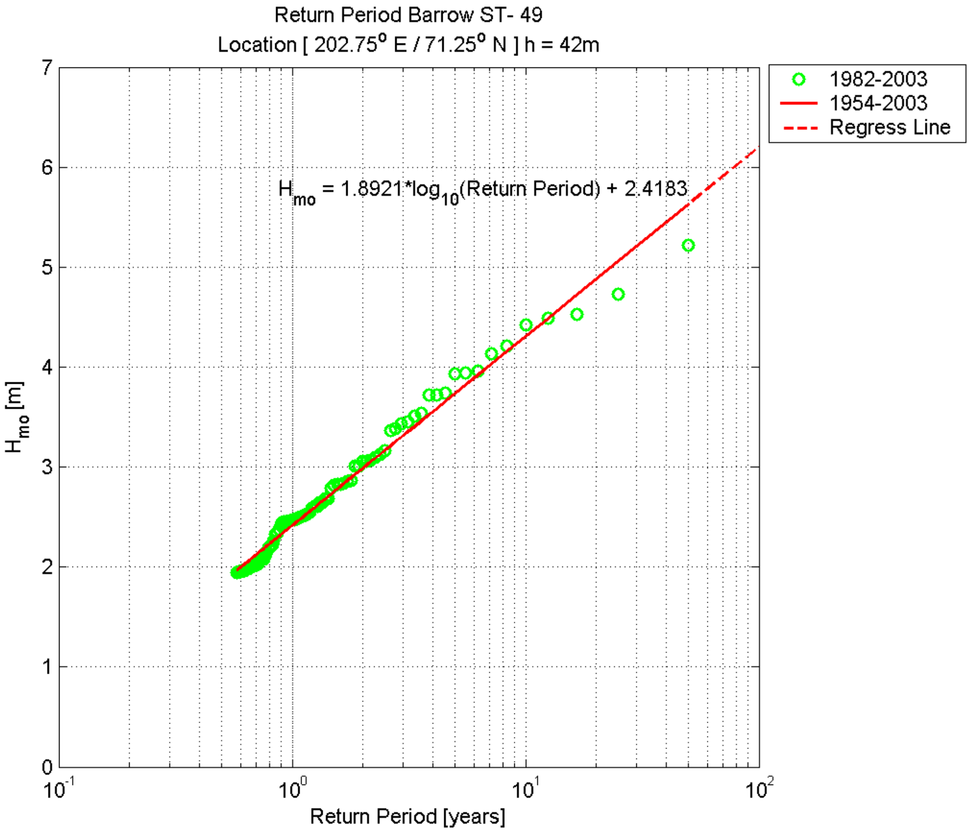


Figure 47. Deep-water wave height return period**.**

Table 7. Storm Ranking

RANK	RETURN INTERVAL	YEAR	MONTH	DATE	TIME	Hmo [m]	Hmo [ft]	Tp	DIR (TWD WCH)	Wsp [m/s]	Wdir
1	30.3	1986	9	21	12	5.22	17.1	10.51	84	18.8	71
2	16.7	2002	8	15	09	4.73	15.5	9.56	76	17.2	69
3	13.1	2002	10	06	07	4.53	14.9	9.56	106	17.4	99
4	12.4	1985	9	16	13	4.49	14.7	8.69	97	18.8	91
5	11.4	2003	7	29	19	4.42	14.5	9.56	81	16.5	83
6	8.8	1998	10	25	01	4.21	13.8	10.51	237	19.8	249
7	8.0	1989	10	09	07	4.13	13.5	8.69	116	16.8	106
8	6.5	1993	10	12	01	3.96	13.0	7.9	100	18.1	98
9	6.4	1993	7	30	07	3.94	12.9	9.56	88	16.8	91
10	6.3	1992	9	10	01	3.93	12.9	8.69	93	17.3	83
11	5.0	2002	10	09	07	3.74	12.3	9.56	122	14.1	136
12	4.9	1986	9	12	13	3.72	12.2	8.69	79	16.5	74
13	4.9	1954	9	18	10	3.72	12.2	7.9	123	16.1	112
14	3.9	1993	9	19	01	3.54	11.6	7.9	97	16.7	86
15	3.8	1993	9	27	01	3.51	11.5	8.69	108	14.6	104

RANK	RETURN INTERVAL	YEAR	MONTH	DATE	TIME	Hmo [m]	Hmo [ft]	Tp	DIR (TWD WCH)	Wsp [m/s]	Wdir
16	3.5	1968	9	22	19	3.45	11.3	8.69	112	14.1	107
17	3.4	1991	8	06	19	3.43	11.3	7.9	87	16.7	89
18	3.2	1993	10	01	13	3.38	11.1	8.69	241	19.2	255
19	3.2	1987	9	14	01	3.37	11.1	9.56	81	14.7	77
20	2.5	1962	9	05	05	3.16	10.4	8.69	72	14	60
21	2.4	1954	10	05	01	3.13	10.3	7.9	98	13.8	94
22	2.3	2003	9	11	07	3.1	10.2	9.56	101	13.4	73
23	2.2	1963	10	04	01	3.07	10.1	6.53	107	20.1	107
24	2.2	1993	10	30	13	3.06	10.0	7.9	224	17.2	238
25	2.2	1999	10	07	01	3.06	10.0	9.56	241	17.3	256
26	2.1	1998	10	17	01	3.01	9.9	9.56	233	15.7	250
27	2.1	2003	10	07	07	3.01	9.9	9.56	235	16.5	248
28	1.7	1985	9	21	01	2.87	9.4	7.18	72	15	62
29	1.7	1997	10	09	04	2.86	9.4	8.69	88	11.8	84
30	1.7	1994	8	15	01	2.84	9.3	7.18	75	15.2	84
31	1.7	2002	8	17	09	2.83	9.3	8.69	109	12.7	107
32	1.7	1993	10	04	03	2.83	9.3	7.18	103	14.6	108
33	1.6	1986	9	24	13	2.82	9.2	7.9	134	13.7	131
34	1.6	1990	10	24	13	2.79	9.2	6.53	225	17.9	239
35	1.4	2000	9	19	16	2.68	8.8	7.9	87	12.7	71
36	1.4	1984	10	01	08	2.68	8.8	5.94	245	16.5	259
37	1.3	2000	8	11	10	2.65	8.7	6.53	105	16.1	109
38	1.3	2000	10	05	13	2.65	8.7	8.69	93	12	83
39	1.3	2003	9	09	07	2.61	8.6	8.69	94	11.8	60
40	1.3	1993	10	08	19	2.61	8.6	7.18	70	14.5	69
41	1.2	2002	11	06	01	2.59	8.5	5.94	234	19.4	247
42	1.2	1986	8	19	16	2.55	8.4	8.69	95	11.2	77
43	1.1	1995	10	09	13	2.53	8.3	7.9	234	16.1	248
44	1.1	1994	8	19	16	2.52	8.3	7.18	79	13.5	82
45	1.1	1973	8	01	20	2.51	8.2	7.18	45	14.2	37
46	1.1	2002	9	03	01	2.5	8.2	7.18	75	14.4	78
47	1.1	1984	10	17	13	2.49	8.2	7.18	52	12.8	22
48	1.1	1957	9	13	07	2.48	8.1	7.18	236	17	250
49	1.1	1993	9	07	01	2.47	8.1	7.18	229	16.4	241
50	1.1	1980	9	28	01	2.47	8.1	7.18	239	17.5	251
51	1.1	1973	10	16	09	2.46	8.1	7.9	42	13.9	8
52	1.0	1992	9	16	05	2.45	8.0	7.18	112	11.9	114
53	1.0	1986	10	11	13	2.45	8.0	7.18	105	13.4	121
54	1.0	1991	9	06	02	2.45	8.0	7.18	241	16.5	253
55	1.0	1997	9	18	07	2.44	8.0	5.94	251	16.8	267
56	1.0	1978	9	27	20	2.42	7.9	7.18	90	13.1	92
57	1.0	2003	8	05	13	2.38	7.8	6.53	122	13	122

RANK	RETURN INTERVAL	YEAR	MONTH	DATE	TIME	Hmo [m]	Hmo [ft]	Tp	DIR (TWD WCH)	Wsp [m/s]	Wdir
58	0.9	1984	9	30	23	2.34	7.7	5.94	241	15.9	250
59	0.9	1998	10	14	07	2.33	7.6	9.56	239	14.2	267
60	0.8	1982	9	17	04	2.26	7.4	6.53	163	12	169
61	0.8	1996	9	09	13	2.22	7.3	7.9	129	11	134
62	0.8	1986	8	22	07	2.2	7.2	6.53	130	12.7	140
63	0.8	1987	9	24	01	2.19	7.2	7.18	246	16.5	263
64	0.7	1989	9	14	01	2.16	7.1	7.18	112	11.3	120
65	0.7	1999	8	20	13	2.13	7.0	7.9	250	16	271
66	0.7	1984	9	21	13	2.08	6.8	6.53	29	13.5	4
67	0.7	1992	10	07	01	2.08	6.8	5.94	353	15.9	344
68	0.7	1960	9	27	07	2.08	6.8	5.94	9	15.7	352
69	0.7	1994	9	06	01	2.07	6.8	6.53	82	12.8	71
70	0.6	1967	9	19	01	2.03	6.7	6.53	235	15.3	240
71	0.6	1987	8	30	13	2.02	6.6	6.53	107	10.7	110
72	0.6	1997	8	26	01	2.02	6.6	7.18	230	14.4	244
73	0.6	1993	12	30	16	2.01	6.6	5.4	272	17.9	275
74	0.6	1990	9	18	01	2.01	6.6	5.94	237	15.3	250
75	0.6	1990	9	13	01	2.01	6.6	7.9	75	11.2	42
76	0.6	1997	10	04	22	1.99	6.5	7.9	221	11.9	228
77	0.6	1999	9	27	08	1.98	6.5	5.94	166	9.9	171
78	0.6	1989	10	20	16	1.98	6.5	6.53	171	11.2	169
79	0.6	2001	8	13	07	1.97	6.5	6.53	77	11.8	90
80	0.6	1990	9	27	13	1.96	6.4	5.94	101	12.7	104
81	0.6	1992	9	08	01	1.96	6.4	5.94	103	13.1	99
82	0.6	2000	10	02	23	1.96	6.4	7.18	79	11	71
83	0.6	2002	11	30	07	1.95	6.4	5.94	241	15.6	259
84	0.6	2003	10	30	01	1.95	6.4	6.53	52	11.9	25
85	0.6	1984	8	15	01	1.95	6.4	6.53	78	11.5	82
86	0.6	1989	10	12	09	1.94	6.4	6.53	102	10.9	100

4.5 Shallow Water Wave Transformation

The shallow-water wave analysis consisted of numerically modeling the deep-water wave transformation. The deep-water waves were transformed to near-shore waves using the Steady-State Spectral Wave (STWAVE) model.

STWAVE is a steady state finite difference model based on the wave action balance equation. It simulates depth-induced wave refraction and shoaling, current-induced refraction and shoaling, depth- and steepness-induced wave breaking, wind-wave growth, and wave-wave interaction and white-capping that redistribute and dissipate energy in a growing wave field.

The numerical model was used to simulate historical storms forced by offshore wave conditions. Theses wave model results were used as input to the sediment transport calculations and in the development of the coastal protection design alternatives.

Bathymetry. Figure 48 shows a contour plot of the bathymetry for the Barrow STWAVE grid. The grid was developed by merging digital bathymetry from NSIDC (Lestak et.al. 2003) and beach profiles provided by the Alaska District. The grid origin is x = 1,740,000 feet and y = 6,310,000 feet (Alaska State Plane, Zone 6). The grid has 280 rows (south to north, alongshore) and 94 columns (cross-shore), and grid spacing is 300 feet. The grid orientation is 315 degrees meaning that the x-axis points toward land in the cross-shore direction. Depths are relative to Mean Lower Low Water (MLLW). The offshore boundary of the grid is in a water depth of approximately 150 feet.

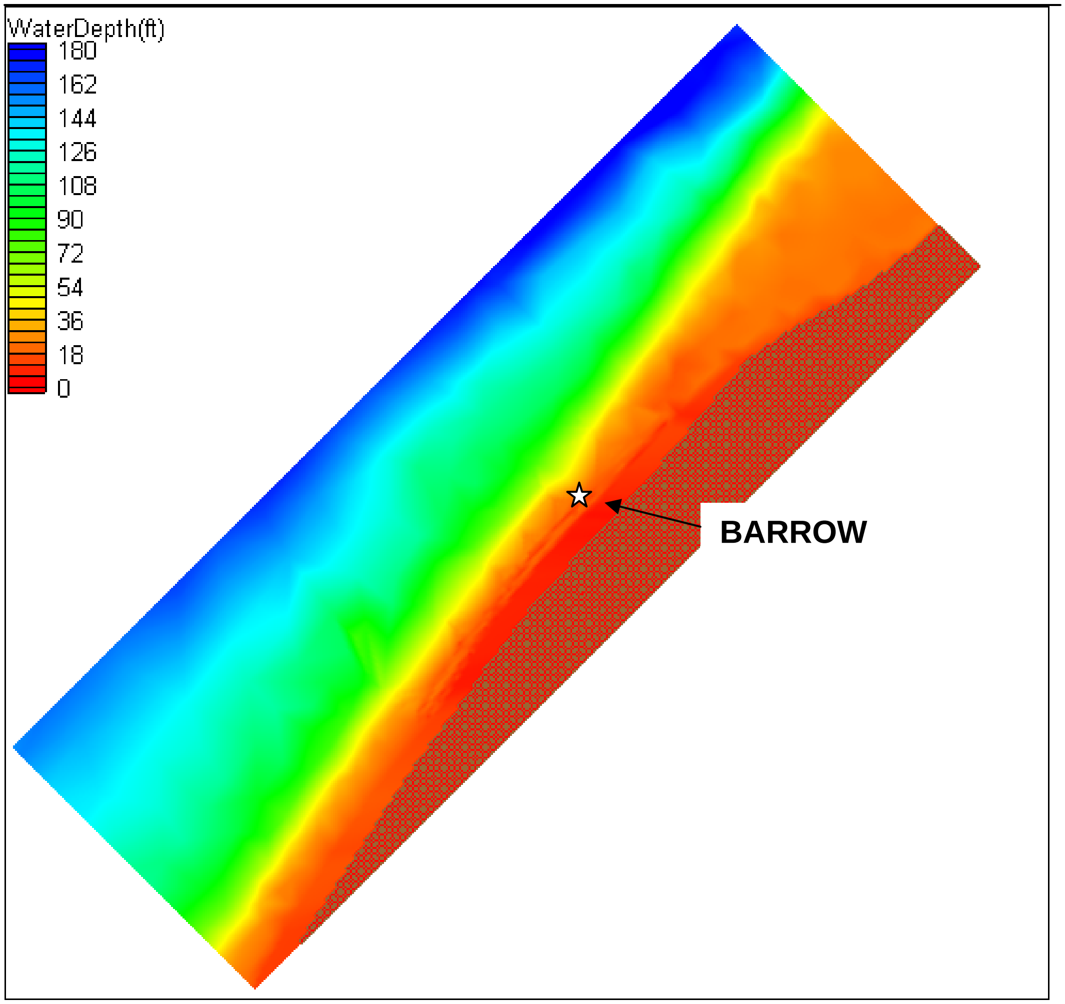


Figure 48. STWAVE bathymetry grid for Barrow, AK (depths in feet). Land area is shown in brown.

Water Level and Wind. Water level variations are a combination of tide and storm surge. Water level is applied in STWAVE as a constant water depth increase, relative to MLLW, over the entire grid. Water levels for typical wave condition simulations were specified as mean tide level. For storm simulations, water levels from the ADCIRC model simulations were used.

Wind input in STWAVE simulates wave growth across the grid domain. Local wind input was not included for the typical wave simulations. Wind speed and direction for the storm simulations were taken from the WAM output station at 71.25 degrees N and 157.25 degrees W and applied to the entire STWAVE grid.

Sample Output. Figure 49 shows example output from STWAVE. The color contours represent wave height. The red contours are areas of local focusing and the yellow are areas of defocusing caused by the near-shore bathymetry. The blue and green represent areas where the waves have dissipated due to depth-limited wave breaking. The incident wave condition for this case is a wave height of 8.9 feet, peak period of 8.7 seconds, and a direction of 275 degrees.

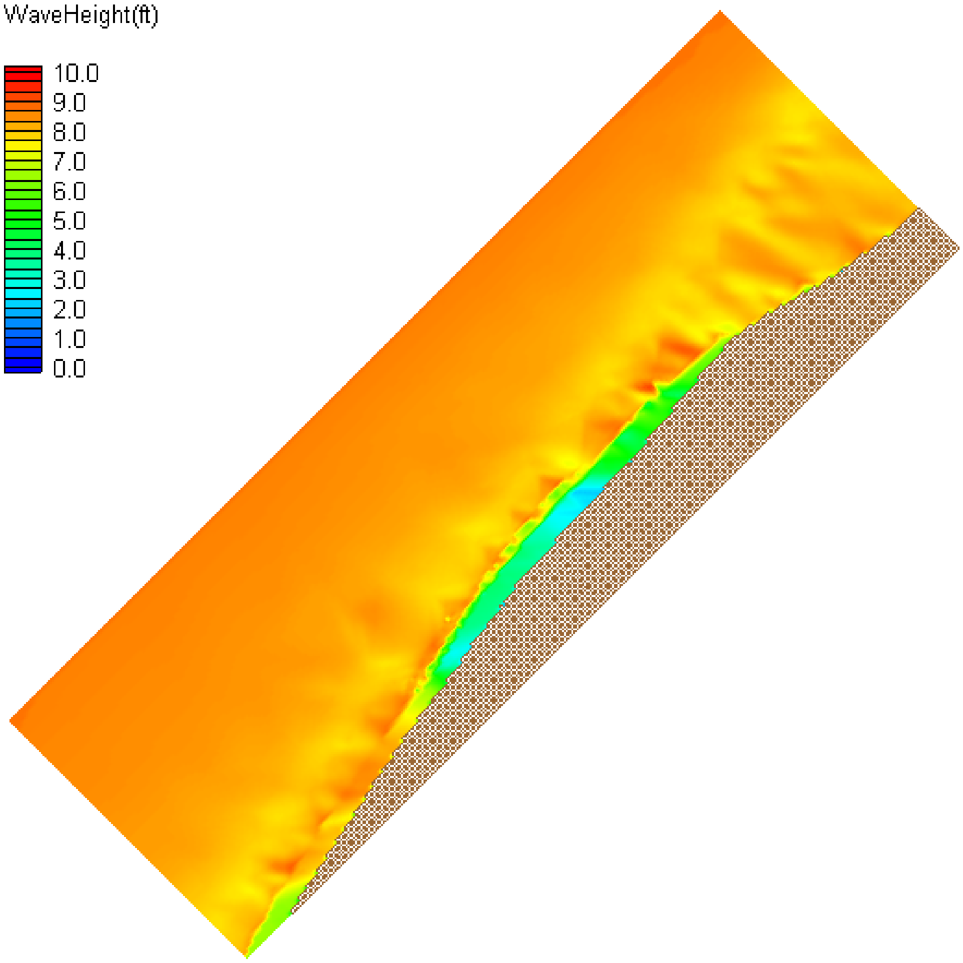


Figure 49. Sample STWAVE transformed wave height field.

4.5.1 Field Data

The model was validated using near-shore wave measurements acquired during the summer and fall of 2003 at depths of 33 and 16 feet. The wave gauges used for this study were RD Instruments Sentinel 1200 kHz Acoustic Doppler Current Profilers (ADCP).The gauges were deployed 12 September to 4 November 2003, with a short gap for servicing on 1-2 October 2003. The gauges were deployed at 71.296341 degrees N, 156.812040 degrees W in a depth of approximately 33 feet and at 71.294176 degrees N, 156.799910 degrees W in a depth of approximately 16 feet (figure 50). Data recovery included a storm event occurring 8-12 September 2003. The peak wave height during the storm was 10 feet with a peak period of 10 seconds. Figures 51 through 53 show the wave height, period, and direction, respectively, for both gauges throughout the deployment period.

An attempt to collect a second season of data was unsuccessful as one gauge was damaged by an ice keel, and ice formation made the collection of the second gauge impossible at the end of the season. Attempts to retrieve the second gauge the following season were unsuccessful.

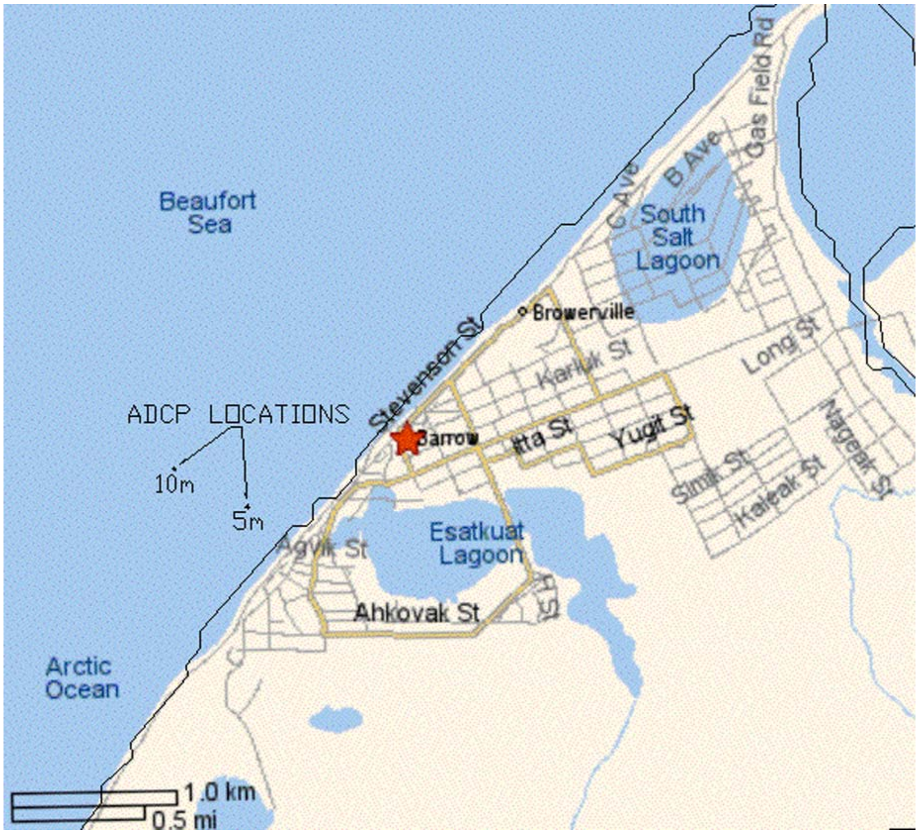


Figure 50. Location of ADCP Instruments

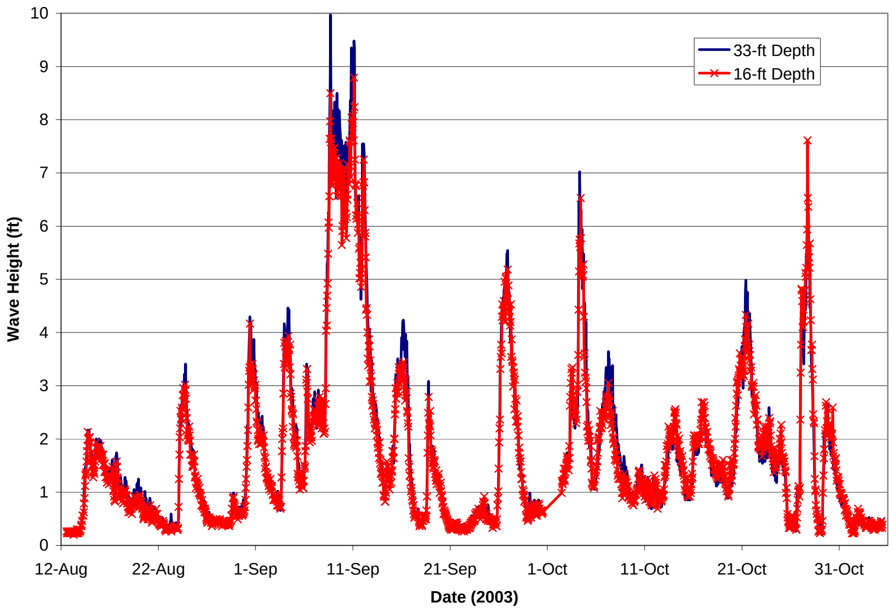


Figure 51. Measured wave height at 33- and 16-foot depths.

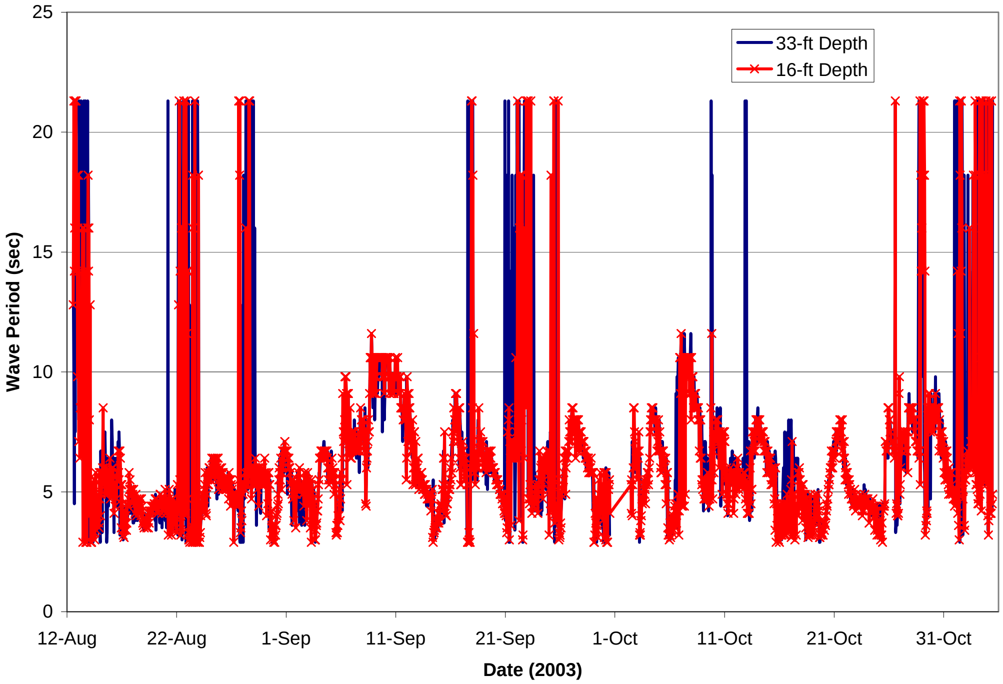


Figure 52. Measured peak wave period at 33- and 16-foot depths.

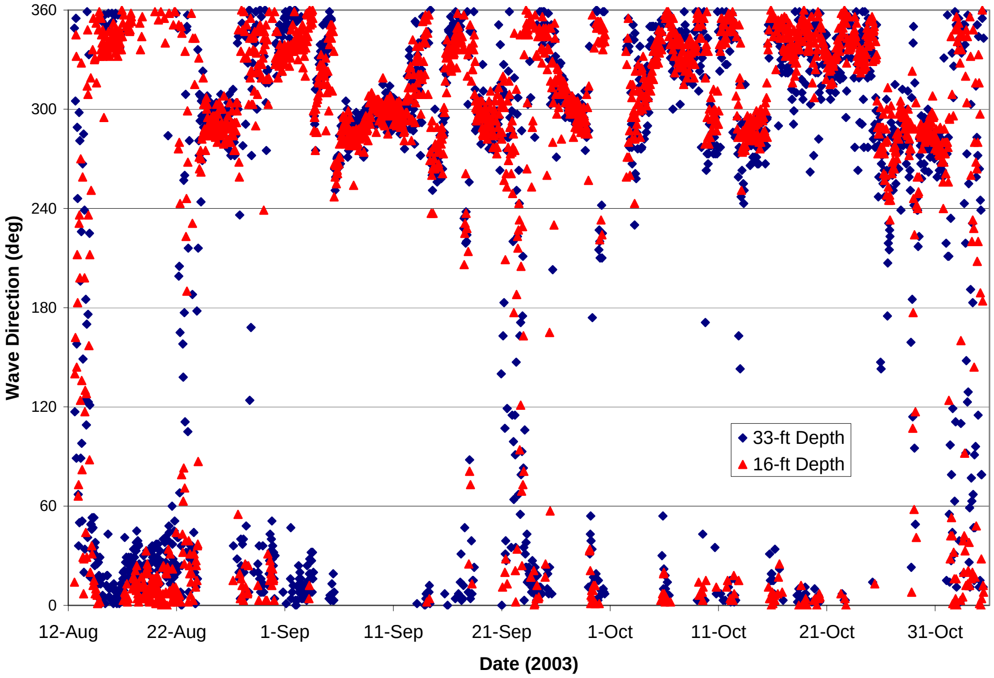


Figure 53. Measured wave direction at 33- and 16-ft depths.

4.5.2 Model Validation

STWAVE was validated for Barrow using the wave data collected at water depths of 33 and 16 feet. Within the August through November 2003 wave record, the largest waves occurred during the period 28 August and 17 September 2003. The measurements include wave height, peak period, and mean wave direction. Figure 54 presents simulated wave heights and periods compared with the data at the 33-foot gauge, and figure 55 shows the mean direction comparisons. The wave heights show good agreement with a mean error of 0.07 foot and a root-mean-square error of 0.69 foot. A positive mean error indicates an underestimate by the model. The comparison of wave periods show differences in the first few days (as the measured period bounces between sea and swell periods), but then track the measurements quite well. The mean error in peak period is 0.5 second and the root-mean-square error is 2.4 seconds. The mean error in direction is 8.3 degrees and the root-mean-square error is 31 degrees. The model and measurements have a slightly different definition of wave direction. The model provides the overall vector mean and the measurements provide the mean direction at the peak frequency. This difference can lead to significant differences when both sea and swell are present. As the waves transform to the shallower gauge in a depth of 16 feet, the wave height error increases slightly, as the period and directional errors decrease. Comparisons with measurements at the 16-foot depth are shown in figure 56 for wave height and peak period and figure 57 for mean direction. The mean wave height error is -0.23 foot and the root-mean-square error is 0.75 foot. The measured periods again jump between sea and swell, but less than at the deeper gauge. The mean error in peak period is 0.3 second and the root-mean-square error is 2.1 seconds. The mean error in mean direction is 0.6 degree and the root-mean-square error is 26 degrees. The validation shows good agreement between the modeling methodology and the measurements.

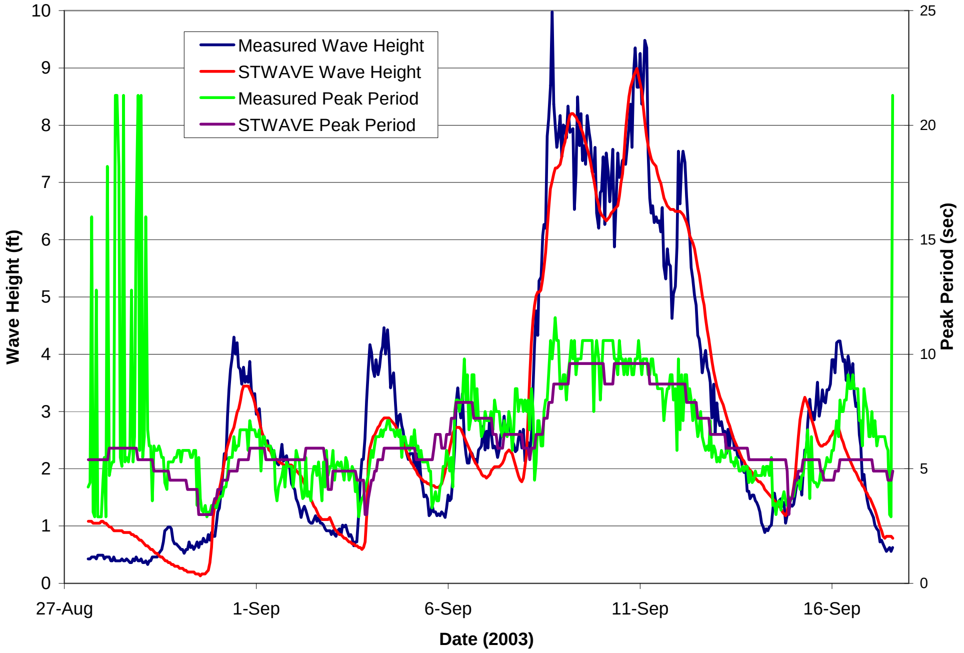


Figure 54. STWAVE validation of wave height and peak period with measurements at 33-foot depth for 27 August – 17 September.

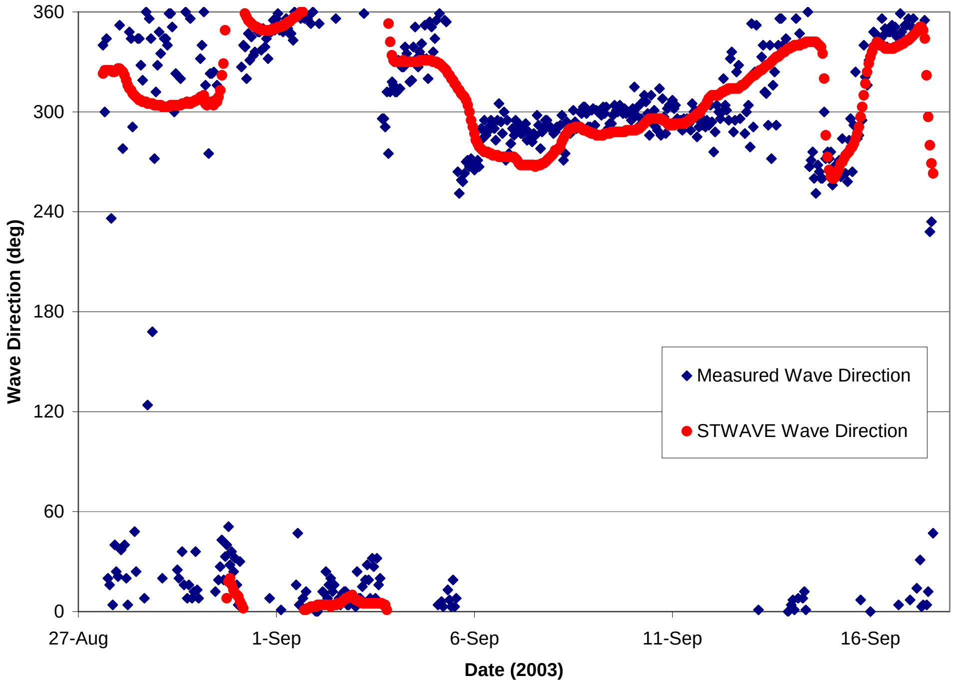


Figure 55. STWAVE validation of mean wave direction with measurements at 33-foot depth for 27 August – 17 September.

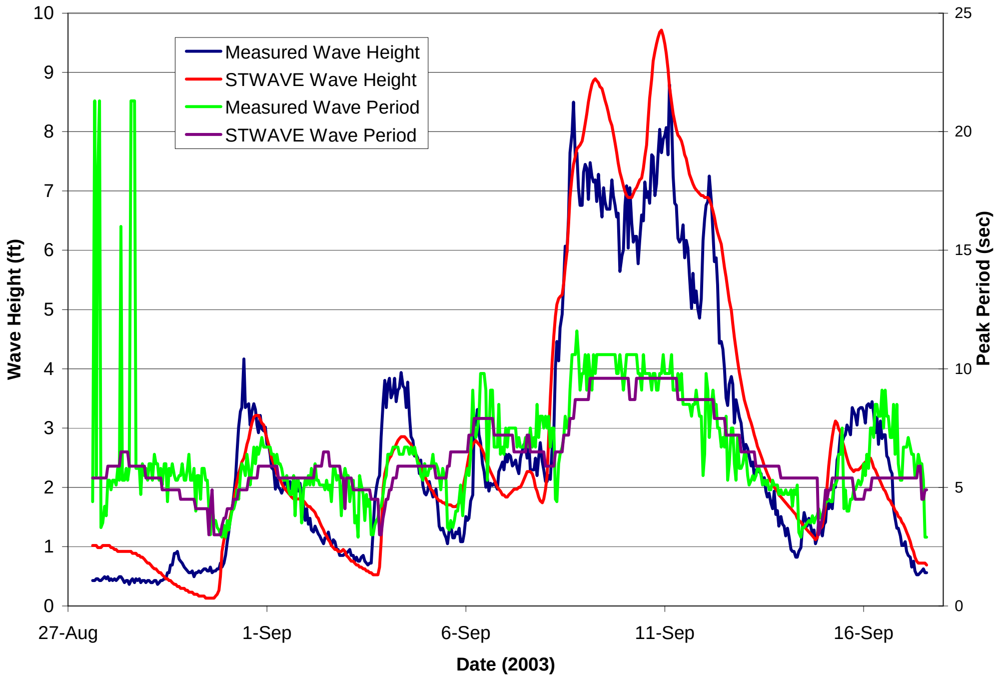


Figure 56. STWAVE validation of wave height and peak period with measurements at 16-foot depth for Julian day 240-260, 2003 (28 August – 17 September).

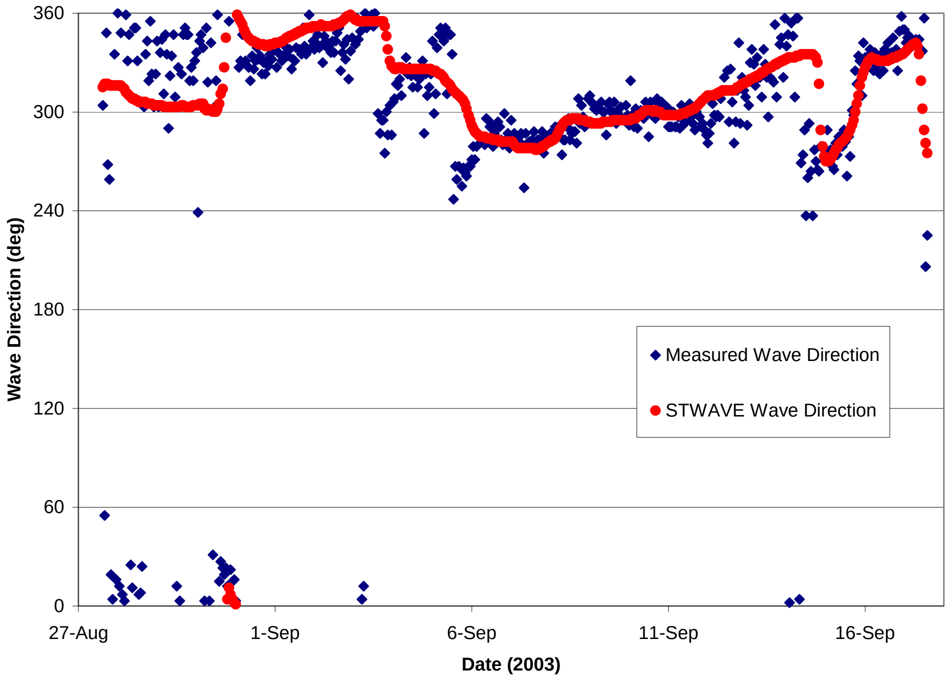


Figure 57. STWAVE validation of mean wave direction with measurements at 16-ft depth for Julian day 240-260, 2003 (28 August – 17 September).

4.5.3 Summary of Results

The wave transformation model STWAVE was used to transform waves from the deep-water wave hindcast boundary output point to the near-shore at Barrow. The modeling simulations included 51 typical waves and 28 storm events. The model was validated using near-shore wave measurements acquired during the summer and fall of 2003 at depths of 33 and 16 feet. The validation shows good agreement between the model and measurements, indicating the deep-water hindcast and near-shore transformation model methodologies are sufficiently skilled to provide design input. Figure 58 provides the near-shore wave height (in 28.5-foot water depth, directly offshore of Barrow) as a function of return period based on the storms simulated between 1954 and 2003.

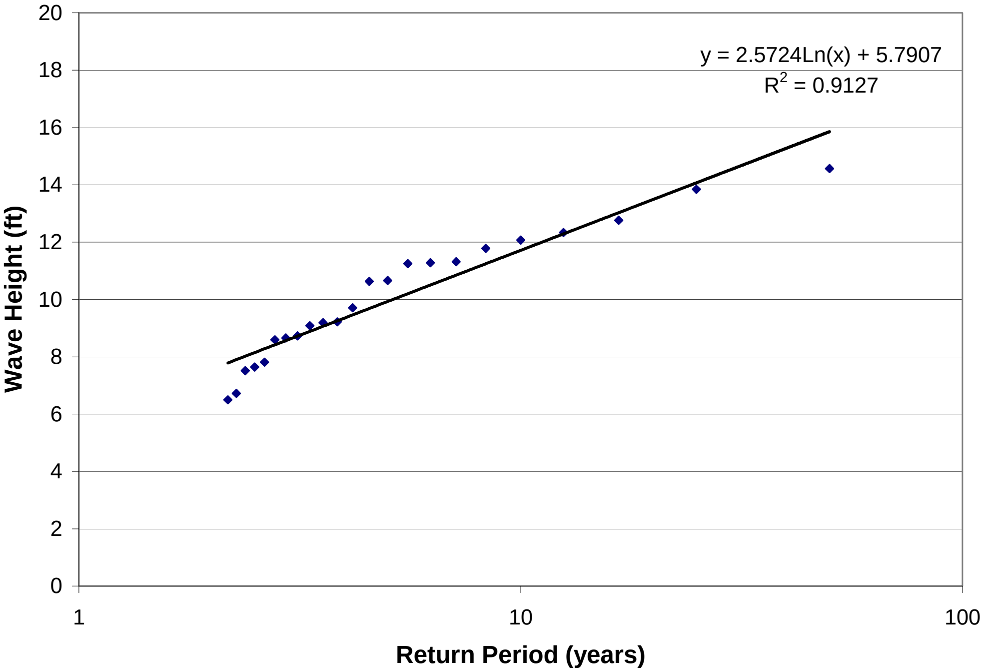


Figure 58. Return period for near-shore storm wave heights (1954-2003).

The percent occurrence table for wave height and period for the STWAVE boundary location is given in table 8. The mean wave height is 2.6 feet and the mean peak period is 5.1 seconds.

Table 8. Percent Occurrence (x1000) 1983-2003 from WAM of Wave Height and Periods for all Directions at Station 71.25 N, 157.25 W

	Peak Period, sec										
H, ft	<5.0	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-12.9	14.0-15.9	16.0 +	Total
0.0-0.3	.	.	.	.	.	.	.	.	.	.	68838
0.4-1.6	6623	3158	827	643	34	1	.	.	.	.	11286
1.7-3.2	8022	1624	808	525	41	4	1	.	.	.	11025
3.3-4.8	2061	1819	627	683	75	18	.	.	.	.	5283
4.9-6.5	74	966	496	556	75	21	.	.	.	.	2188
6.6-8.1	.	74	139	356	99	53	1	.	.	.	722
8.2-9.8	.	8	26	161	80	77	5	.	.	.	357
9.9-11.4	.	.	1	88	35	16	3	.	.	.	143
11.5-13.0	.	.	.	25	40	11	9	.	.	.	85
13.1-14.7	.	.	.	.	18	5	9	.	.	.	32
14.8-16.3	.	.	.	.	1	3	.	.	.	.	4
16.4-18.0	.	.	.	.	.	3	10	.	.	.	13
18.1+	.	.	.	.	.	.	.	.	.	.	0
TOTAL	16780	7649	2924	3037	498	212	38	0	0	0	

5.0 CURRENTS AND WATER LEVELS

Information on currents and water levels was needed to evaluate sediment transport and flooding. Investigation of the water levels and currents consisted of a literature search for information in the area, deployment of instrumentation in 2003 and 2004, and modeling to characterize currents and water levels in the site vicinity.

Historic water-surface elevations and currents for storm events were computed by the CHL using the Advanced CIRCulation (ADCIRC) model (Luettich, Westerink, Scheffner, 1992), a two-dimensional, depth integrated, barotropic-time dependent long wave, hydrodynamic circulation model. The bathymetry used for the ADCIRC model shown is in figure 59. The effect of wave set up and run up on the total water level was computed by the CHL using the SBEACH model (**S**torm-induced **BEA**ch **CH**ange Model). This model simulates cross-shore beach, berm, and dune erosion produced by storm waves and water levels.

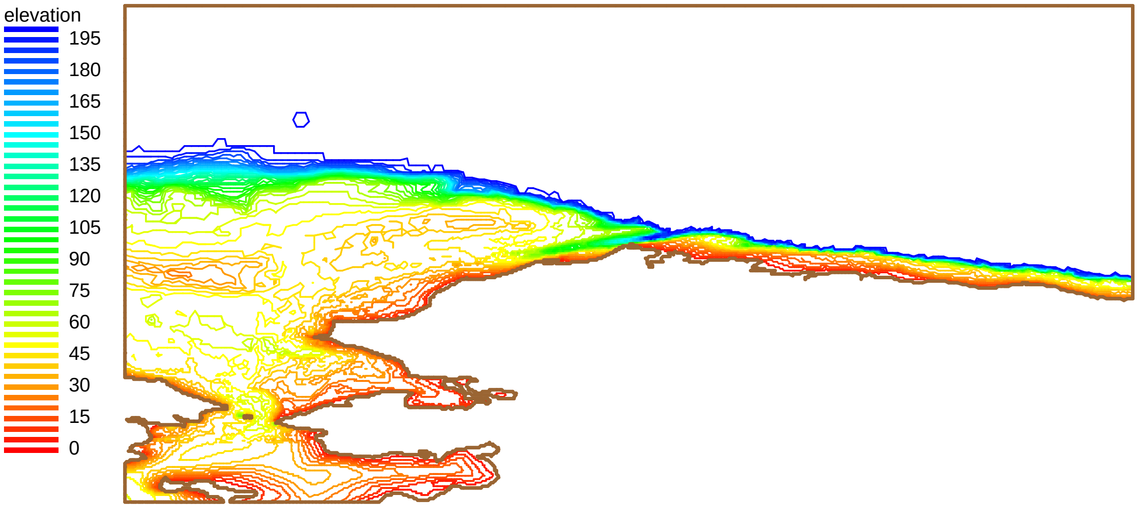


Figure 59. Regional ADCIRC grid bathymetry showing depths less the 200 meters.

5.1 Water Surface Modeling

ADCIRC. Water surface elevations for selected storms were measured and modeled to provide a base storm water elevation for modeling wave set up and run up. The water surface elevation for the storm events included changes in water elevation due to tide, wind stress, and atmospheric pressure.

Model calibration and verification of the water surface elevation was performed with the ADCP data collected in 2003. Initial verification simulations showed that the predicted water surface fluctuations tracked the measurements; however, the maximum positive and negative surge elevations were under predicted due to the neglect of the effects of atmospheric pressure variation.

Much of the variation of water surface elevation at Barrow can be attributed to what is commonly known as the inverted barometer effects. Water surface elevation will increase or decrease 1 foot for each 30 millibar of negative or positive change in atmospheric pressure, respectively.

The inverted barometer correction method was tested via a simulation of the westerly storm event that occurred in early September 2003. A verification simulation was performed, in which the contribution of the inverted barometer effect was included on an hourly basis. Specifically, the inverted barometer contribution was computed by taking hourly atmospheric pressure measurement starting on the first of September and correcting the still water level by 1 foot for every 30 millibar change in the measured atmospheric pressures during the westerly event. The time series of inverted barometer correction was added to the ADCIRC wind driven water levels. Figure 60 presents a comparison of predicted water levels, with and without the inverted barometer correction, and observations of the Barrow ADCP instrument deployed in -33 feet of water. It is seen in figure 60 that the corrected peak water surface elevation tracks well within the observed wind set up and tidal range (days 6 – 10).

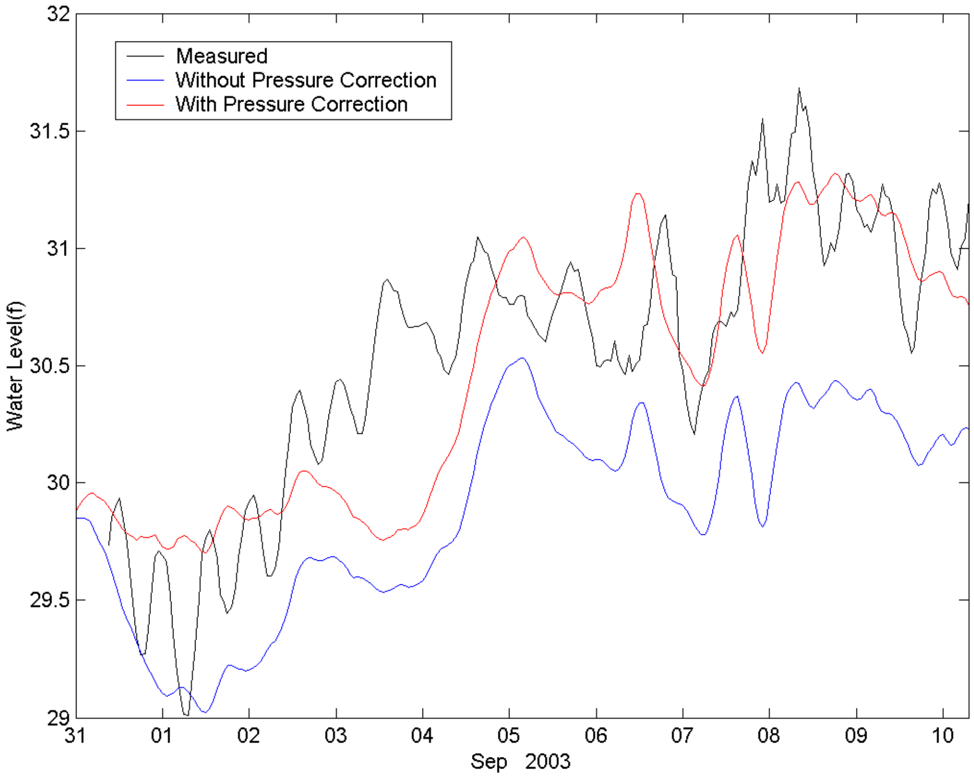


Figure 60. Comparison of predicted water levels with - without the inverted barometer correction and observations at the Barrow ADCP instrument data at the -33 foot site

The effect of free ice concentration was modeled following the work of Birnbaum and Lupkes (2002) and Garbrecht et. al. 2002, in which, it is shown that the maximum transfer of wind energy into water occurs with 50 percent ice coverage. Figure 61 shows the influence of varying degrees of ice coverage.

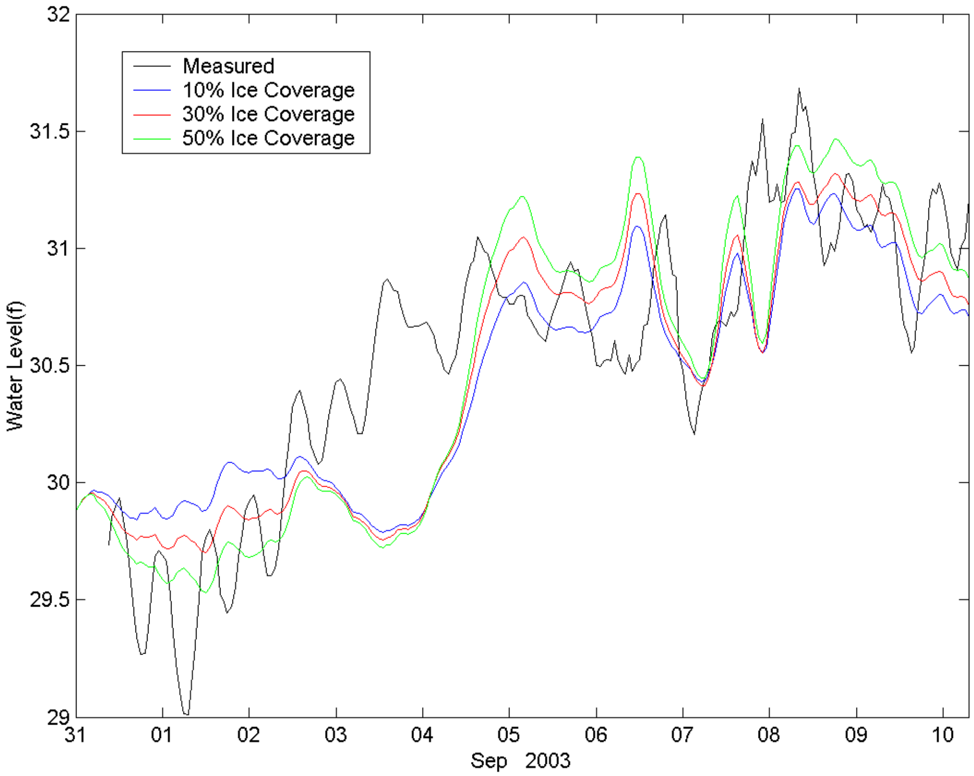


Figure 61. Influence of varying degrees of ice coverage.

Storm events simulated and the date of occurrence are presented in table 9. In most cases, the simulation began when the storm was far to the west of Barrow and ended after its passage. The influence of the tide and atmospheric pressure (inverted barometer) on the resulting peak water surface elevation are included by linearly adding a tidal range of 0.5 foot and the peak inverted barometer displacement as discussed previously. The results of the storm event simulations, including the inverted barometer and tide contribution, are presented in table 9.

Table 9. Summary of peak wind surge, inverted barometer and total surge including tide

Year	Month	Day	Rank	Peak Wind Surge ft	Inverted Barometer ft	Total Surge ft
1954	September	16	25	0.62	0.69	1.80
1954	October	03	4	1.25	1.38	3.12
1955	July	17	13	1.48	0.39	2.36
1960	September	25	12	0.82	1.08	2.39
1961	June	16	20	1.18	0.49	2.16
1962	September	03	7	1.61	0.89	2.98
1963	August	21	22	0.66	0.92	2.07
1963	October	03	1	2.30	1.02	3.80
1968	September	21	24	0.59	0.79	1.87
1973	July	31	11	1.12	0.85	2.46
1973	October	14	2	1.61	1.31	3.41
1975	August	24	10	0.69	1.31	2.49
1978	September	24	28	0.36	0.82	1.67
1983	August	17	19	1.08	0.66	2.23
1985	September	15	15	1.08	0.69	2.26
1986	September	11	21	0.82	0.79	2.10
1986	September	19	8	1.38	0.92	2.79
1987	September	12	14	1.15	0.62	2.26
1988	September	24	6	1.61	0.92	3.02
1992	September	08	26	0.59	0.66	1.74
1993	September	25	18	0.92	0.82	2.23
1993	October	09	17	1.12	0.62	2.23
2000	July	04	27	0.56	0.62	1.67
2000	August	09	23	0.92	0.62	2.03
2002	August	14	9	1.54	0.56	2.59
2002	October	04	5	1.61	0.98	3.08
2003	July	24	3	2.10	0.75	3.35
2003	September	06	16	0.89	0.85	2.23

The Empirical Simulation Technique (EST) was applied to generate stage-frequency relationships for Barrow (Scheffner and Borgman, 1996). Input to the EST model consisted of the estimated peak storm-surge elevations combined with a tidal elevation (0.5 foot and inverted barometer correction, which results in the "Total Surge" presented in table 9. A brief description of EST is presented in Appendix 1. To increase the population within the EST sample, half and then all of the tide range was removed to reflect the fact that the storms are of sufficient duration so that the peak surge can occur at any level within the tide range. Application of the 84-storm population EST analysis resulted in table 10, which presents the stage-frequency distribution and standard deviation for 5 to 100 years.

Table 10. Summary of frequency-of-occurrence relationships with variable tide population.

Return Period Yr	Elevation ft mllw	Std. Deviation ft
5	2.30	0.13
10	2.85	0.16
15	3.05	0.16
20	3.18	0.16
25	3.25	0.20
50	3.58	0.36
75	3.87	0.56
100	4.00	0.72

5.2 Currents

The tidal fluctuations at the site are minimal so the predominant source of currents is wind generation. Current modeling was performed using the ADCIRC model to provide information for the sediment transport.

Calibration and Verification of ADCIRC. Calibration and verification of ADCIRC was performed using the water surface and current measurements collected during the August to November 2003 ADCP deployment (Evans- Hamilton, Inc, 2004). Calibration of the predicted current speed and direction was performed using the August to September field measurements. The calibrated model was then applied to the October 2003 measurement period for purposes of verifying model calibration. Figure 62 presents a comparison of the predicted depth averaged current with surface, mid-depth, and near bottom ADCP current measurements at the 33-foot depth site.

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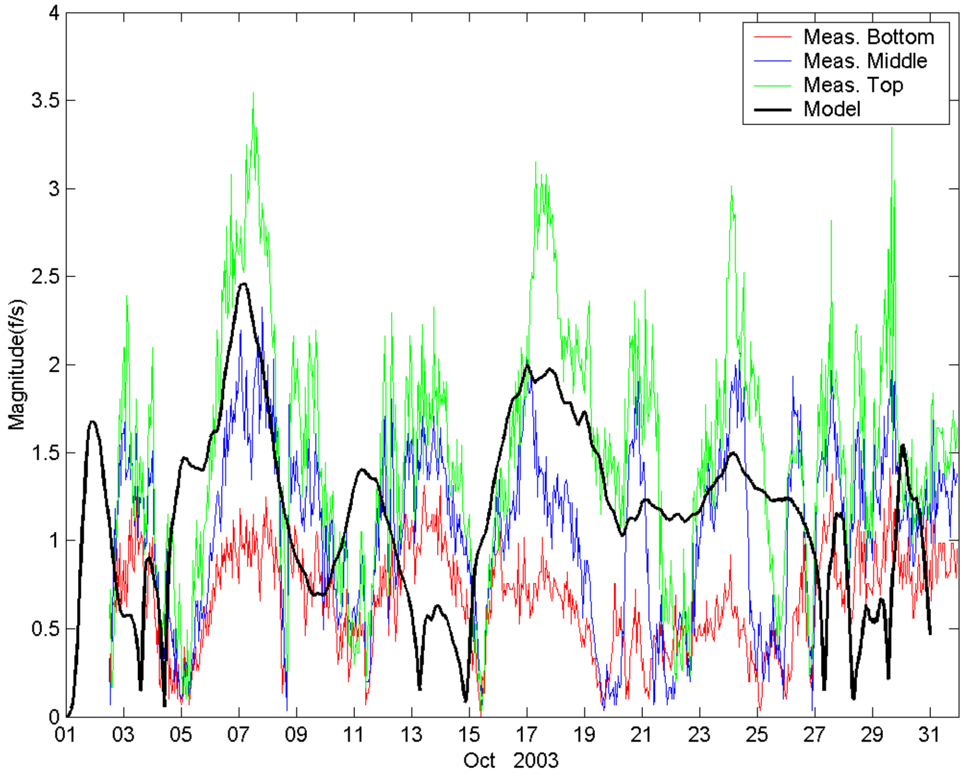

Figure 62. Comparison of predicted depth-averaged current speed and surface, mid-depth and bottom ADCP current measurements at the 33-foot Barrow site.

Satisfactory agreement between predicted and measured current magnitudes is achieved during significant wind events. The discrepancies shown in the predicted and observed current magnitudes result from (1) a persistent northeast coastal current that is observed during periods of light winds and (2) the three dimensional nature of the observed currents. A close examination of figure 62 reveals that there is a factor of three increase in current magnitude from the near bottom to the surface. Furthermore, it is seen in figure 63 that the change in current direction from the bottom to the surface exhibits a lag of more than 2 days during periods where changes in wind direction and strength are significant (days 5-9, 15-19 and 23-26).

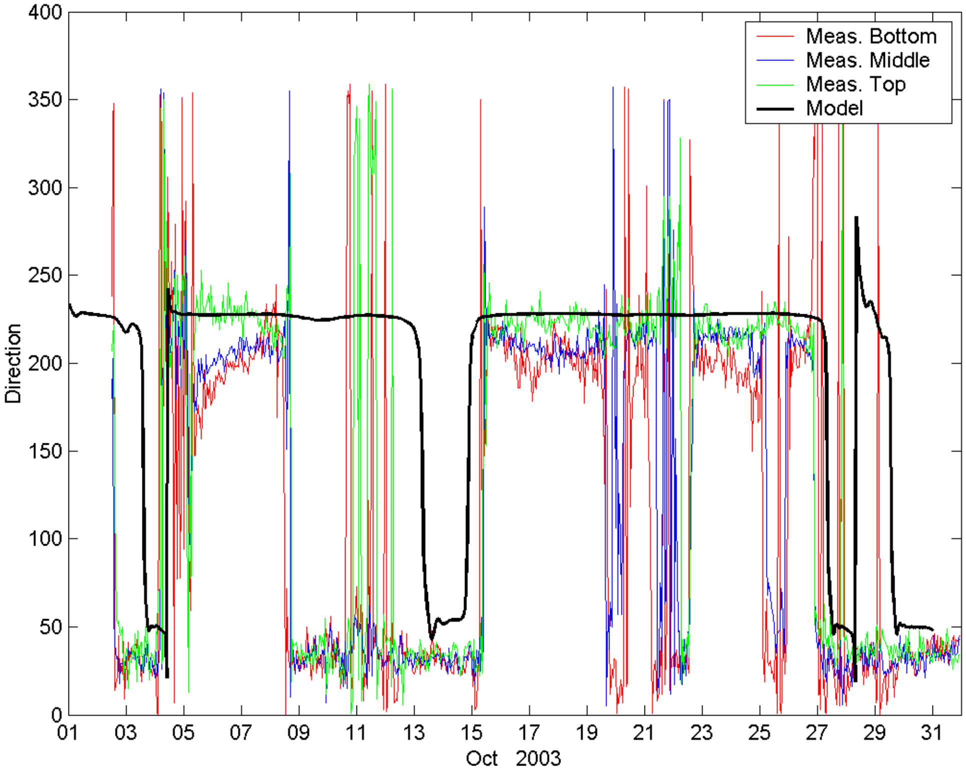

Figure 63. Comparison of predicted depth-averaged current direction and surface, mid-depth and bottom ADCP current direction measurements at the 33 ft Barrow site.

According to model results, depth averaged currents during storm events range between 1 and 1.4 knots. These currents were generally maintained for 12 hours or less. On one occasion these currents were maintained for 24 hours.

For the storm events modeled, the currents predominantly flowed to the northeast along the coast.

5.3 Sediment Transport

5.3.1 Cross Shore Sediment Transport

Beach profile and shoreline data were obtained and a set of profile ranges were established, as shown in figure 64. Profiles on most of these lines were obtained in 1987 and 2003. These profiles were the main ones used to analyze long-term shoreline change and as SBEACH input.

Cross-shore sediment transport mechanisms were evaluated using the SBEACH program and examining changes in cross-shore profiles. Sediment samples were collected for input into the SBEACH model. The D_{50} sediment grain size analyzed for eleven beach samples ranged from 0.3 to 20 mm with an average D_{50} of 3 mm. Model runs with SBEACH indicate that the beach sediments at Barrow generally do not move in the cross shore direction. The threshold sediment size for movement to occur is 0.8 mm, which results in minor changes below the water level only.

Pair wise comparisons of the 1987 and 2003 profiles agree with SBEACH and show the profiles to be remarkably similar in shape and position. The average profile horizontal change of the zero elevation (shoreline) over this 15-year interval is 13.5 feet of accretion, with individual profiles ranging between -62 and +87 feet. Profile 22 is shown as an example in figure 65, and a blowup of the active portion of this range line is shown in figure 66.

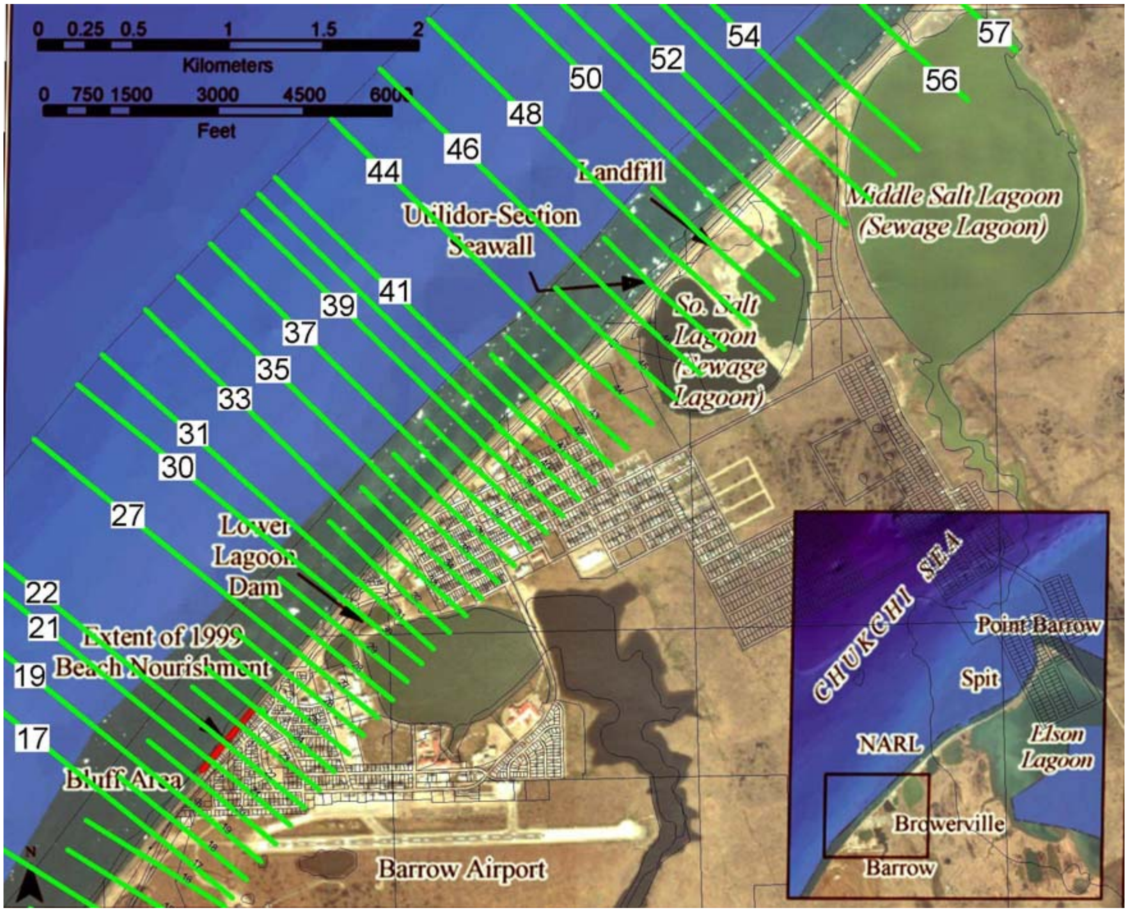

Figure 64. Transect lines along the coast.

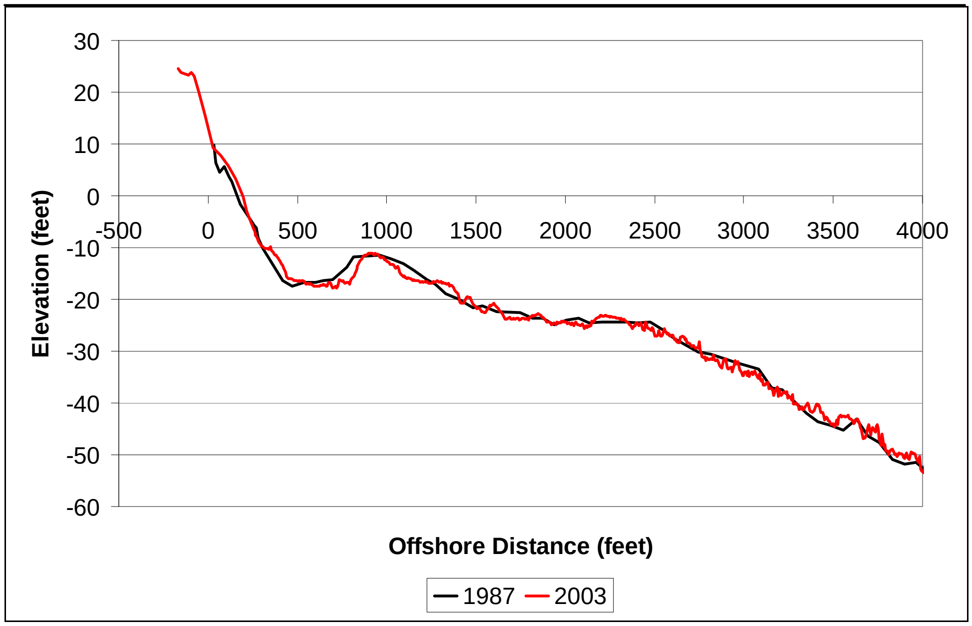

Figure 65. Comparison of 1987 and 2003 Profiles – Transect #22

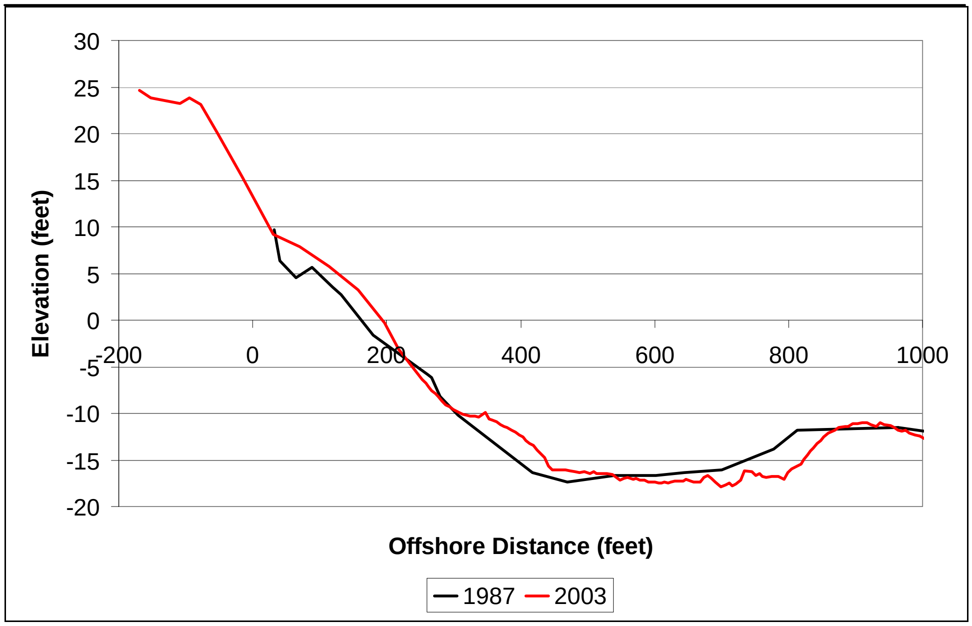

Figure 66. Blowup of Profile 22 comparison showing active portion of the profile.

5.3.2 Longshore Transport

Longshore sediment transport at the site was evaluated using the formula of Soulsby (Soulsby, 1997), one of the few that is considered valid for the coarse beach material found at Barrow. Hindcast data from station 49 were used as model input. The Soulsby formula yielded an average annual gross transport rate of 9,800 cubic yards per year and an average annual net transport rate of 7,300 cubic yards per year to the northeast. This estimate compares well with previous estimates made by researchers at the Naval Arctic Research Laboratory of a net transport of 10,000 cubic yards per year.

Calculation of the longshore sediment transport rate using the CERC formula (Coastal Engineering Manual, 2002, Section III-2-3-a) yielded much larger rates unless the value of the calibration coefficient, K, was reduced. Reducing the value by an order of magnitude to K=0.05 (all CERC formula calculations used significant wave heights) yielded results that compared very favorably with the Soulsby results, as shown in figures 67 and 68. Though this is a much smaller value of the CERC K coefficient that is normally used, it is appropriate, considering the grain sizes involved (King, 2005). Leidersdorf, Gadd, & McDougal (1988) analyzed longshore transport rates on artificial (oil production) islands in the Beaufort Sea. For beach sediment median diameters in the range of 4 to 8 mm, they found that the most appropriate value for the CERC K term was K=0.05.

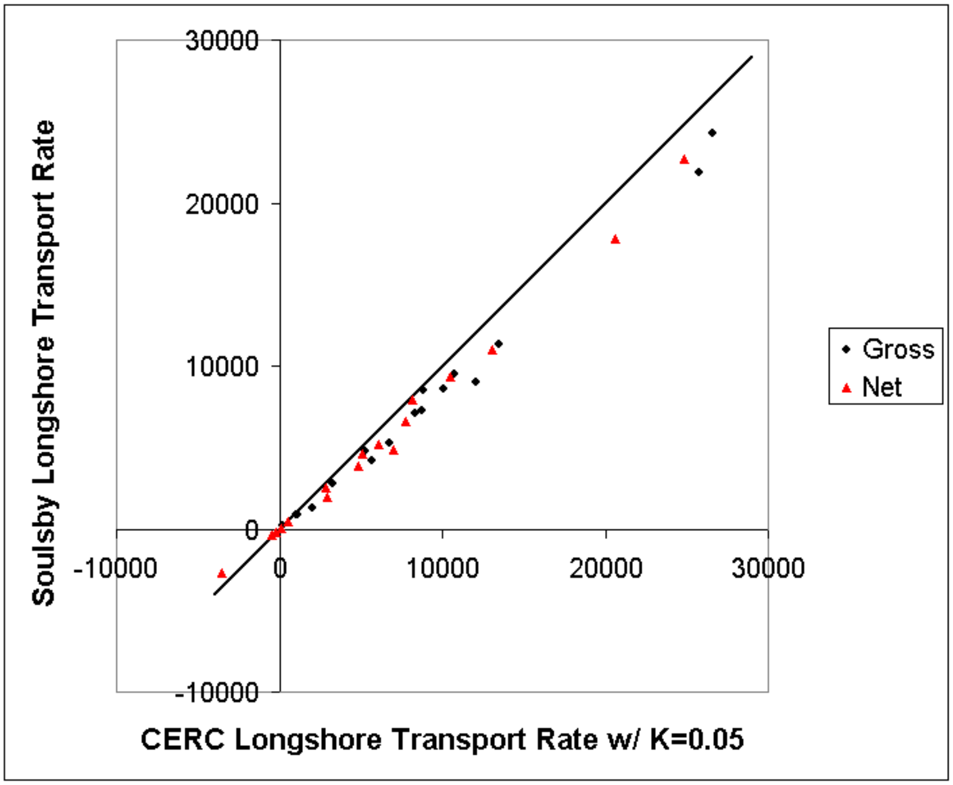

Figure 67. Comparison of yearly sediment transport rates (in yd^3/yr) between the Soulsby and CERC formulas.

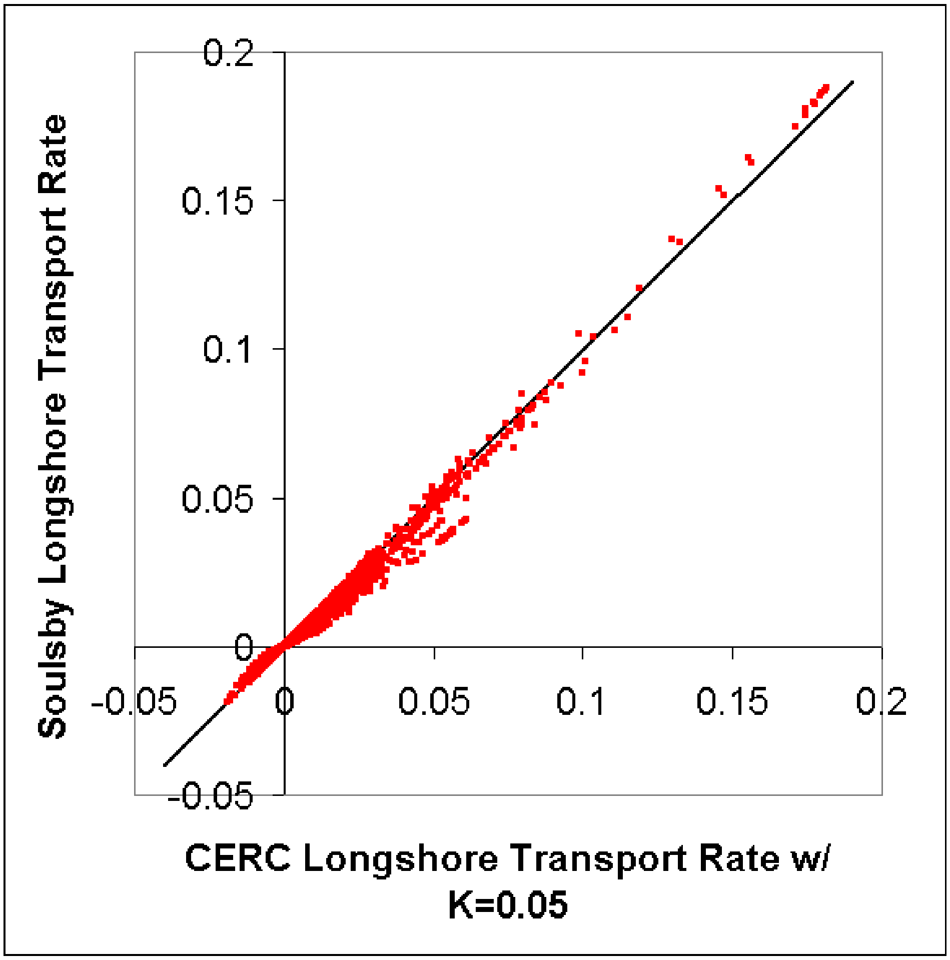

Figure 68. Comparison of hourly sediment transport rates (in yd^3/hr) between the Soulsby and CERC formulas.

6.0 COASTAL EROSION

Analysis of aerial photography from 1948[1] to 2003 was performed by digitizing the shorelines and bluff lines. Location along the shore and bluff lines was identified by transect lines from a 1987 survey. The locations of the transect lines with respect to the study area are shown in figure 64. An example of the digitized shorelines and bluff lines is shown in figure 69. Overall erosion rates based on the aerial photography analysis are listed in table 11. The location of the bluff line in 50 years based on that erosion rate is shown in figure70.

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[1] The 1948 aerial photography was supplemented with the use of 1947 photography.

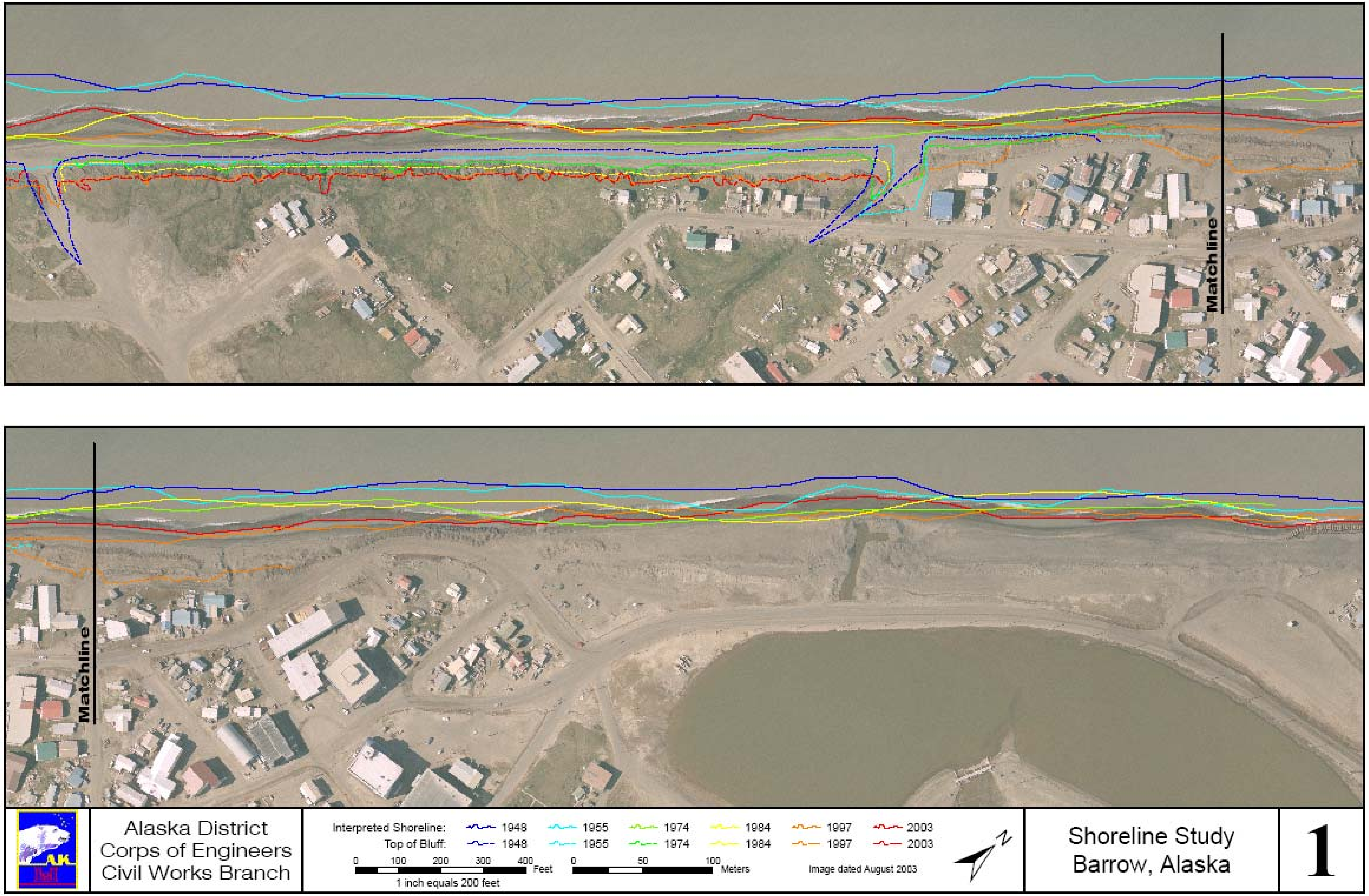

Figure 69. Example of bluff and shoreline analysis.

Table 11. Average Erosion/Accretion Rates

Reach	Bluff[2] [ft/yr]	Shore [ft/yr]
South of Gravel Pit		-1.04
City of Barrow	-1.08	-1.05
Water Supply	NA	-0.72
Browerville	NA	+1.12
Landfill/Sewage Lagoon	NA	-0.61
Erosion noted by – Accretion noted by +		

Figure 70. Location of bluff line in 50 years using the average erosion rate, not the “hot spot” rate.

Coastal erosion is well documented with aerial photography. The differences in the shoreline movement were plotted in time increments to determine if erosion along the coast is episodic or consistent through the years (figure 71). Between 1948 and 1955, the plots indicate typical shoreline behavior with areas of erosion and accretion occurring. Between 1955 and 1974, a large amount of shoreline erosion occurred along the entire study area. The 1974 and 1984 plot shows a predominance of accretion along the coast, and the 1984 and 1997 plot shows the shoreline beginning to return to a typical beach pattern with pockets of erosion and accretion.

A comparison of the overall time period of available aerial photography (1948 and 2003) indicates that there is predominance of erosion that has occurred along the coast. The areas that exhibit the greatest erosion appear to be consistent with the erosion that occurred in the 1955 to 1974 period. The concentration of erosion during one period indicates the erosion that occurs along the coast is episodic, but due to the relatively small volume of sediment transport that typically occurs, the beach is slow to recover when a large volume of material is moved. This leaves the coast after the 1955 to 1974 period

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[2] Bluff erosion was evaluated between Stations 18 and 21. Evaluation of stations south of Station 18 would be subject to interference from gravel pit activities. Aerial photography south of the gravel pit was difficult to interpret, so the bluff lines are questionable. Bluffs are not present beyond Station 21.

with a narrow beach and the bluffs backing the beach in a precarious position of bearing the brunt of storm waves without the dissipative effects of a wide beach.

The years 1955-1974 cover the period with the highest storm water levels and when there were a number of major construction projects. The 1963 storm, discussed earlier in this report, is reported to have transported a large amount of beach and bluff material. Reports have put the net estimated amount of material transported during that storm as high as 200,000 cubic yards of material. In addition to the biggest storm event, this period saw road, airport, and building construction requiring foundation material. To facilitate construction associated with this development, a great deal of material was borrowed from the beach.

Shoreline Mining History. At the start of the Cold War the United States government rapidly developed a large presence at Barrow. Part of the reason for this was to help give early warning to a ballistic missile attack from the Soviet Union. Along with a DEW line station, the Naval Arctic Research Laboratory (NARL) was established and a large, all-weather, airplane runway was built. Barrow’s permafrost soils were far from ideal for supporting large structures, so the beach was heavily mined to supply gravel for runway and building foundations. Figure 72 shows a dragline at the shoreline by the NARL. This borrow activity appears to have been limited to the NARL camp area, although the effects of sediment removal would spread out along the beach.

Evidence of beach mining closer to Barrow was found in search of the NARL archives at the University of Alaska Fairbanks. A 1963 photograph shows trucks moving material along the beach in front of the City of Barrow and a haul road that leads to the new airport that is under construction (figures 73 and 74). In the same set of photos, an oblique photo shows a scalloped coastline that looks as if it had been subject to borrowing activities (figure 75). It was during this period that the Wiley Post-Will Rogers Memorial Airport and the Samuel Simmonds Memorial Hospital were built. A comparison of aerial photographs from 1962 and 1964 shows the rapid growth that was experienced during that period (figures 76 and 77).

Dr. Max Brewer, the head of the Naval Arctic Research Laboratory, estimated that the mining operation removed approximately 1.1 million cubic yards of material from the beach (Brigham, 1968). Also, for many years, local residents took beach gravel for their use on personal property until this practice was banned, first by the Bureau of Indian Affairs, and later by the North Slope Borough (Lynch, et al., 2004).

It appears that the combination of mining of the beach for gravel and the occurrence of the largest storm on record resulted in an extreme retreat of the shoreline during the 1955-1974 period. The effects of that shoreline retreat are being experienced today through bluff erosion and flooding during storms.

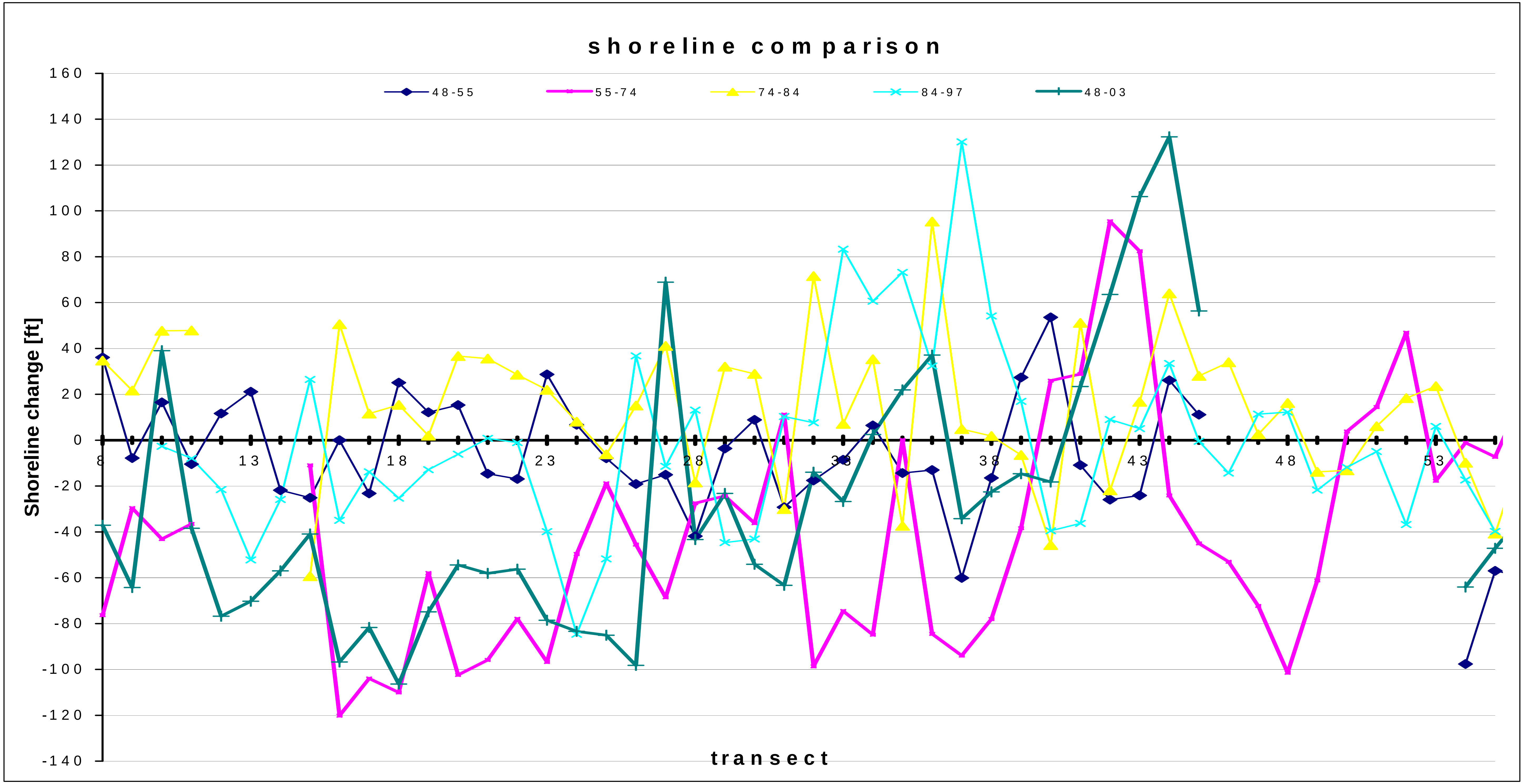

Figure 71. Differences in the shoreline movement plotted in time increments to determine if the erosion along the coast is episodic or consistent through the years.

Figure 72. Drag line at NARL.

Figure 73. Haul road from the beach leading to the airport during construction.

Figure 74. Close up of haul road.

Figure 75. Scalloped shoreline consistent with beach borrowing.

Figure 76. 1962 Aerial photograph. (National Snow and Ice Data Center photo)

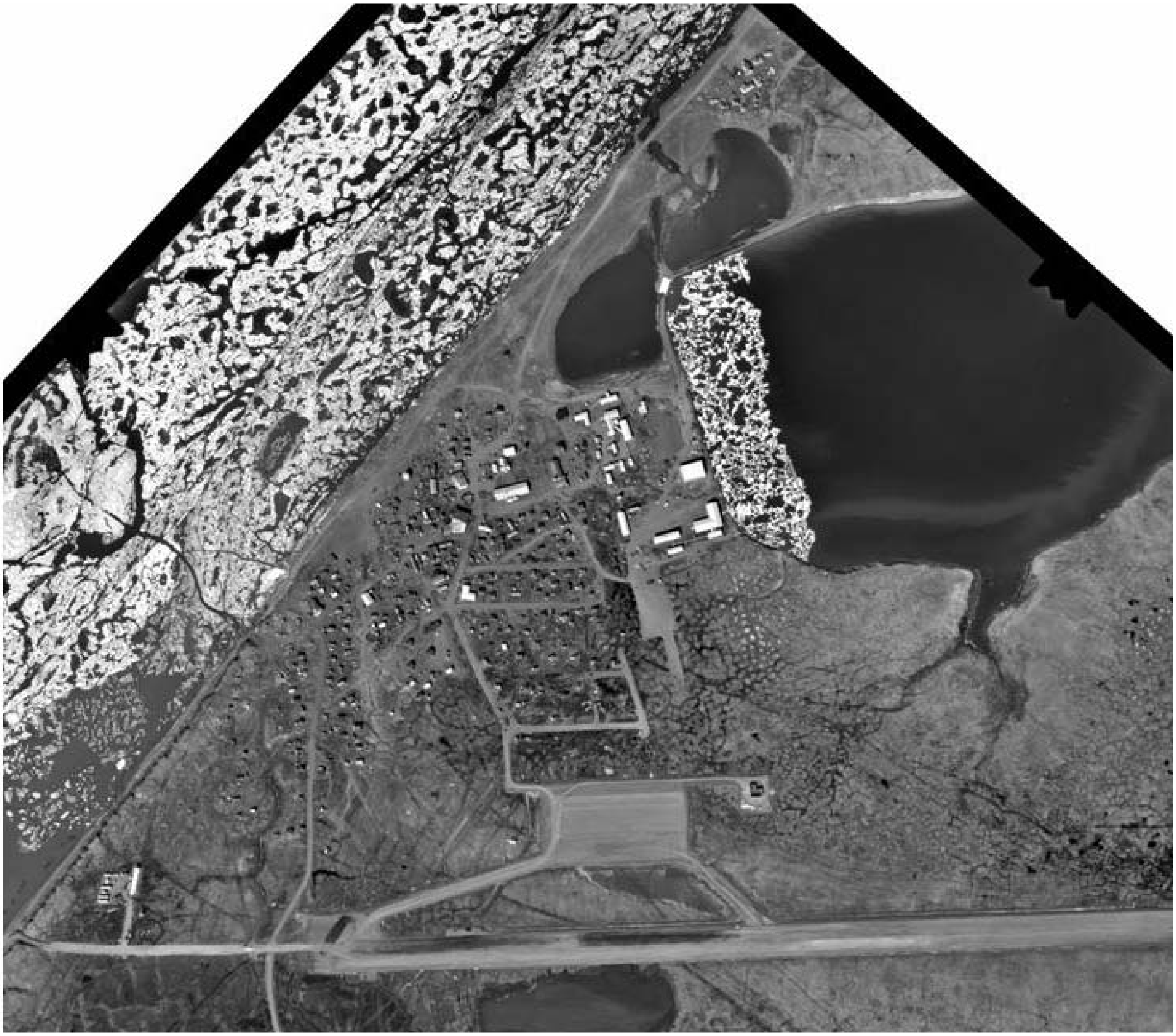

Figure 77. 1964 Aerial Photograph (National Snow and Ice Data Center photo)

Evaluation of the shoreline as a whole unit may be appropriate when looking at the entire north coast, but when evaluating the effects of erosion on a community, local erosion rates that would adversely affect the community need to be isolated and evaluated. Local “hot spots” where the shoreline continues to erode instead of experiencing the erosion/accretion cycle typical along a coast need to be evaluated. Locations that experience chronic erosion or erosional “hot spots” in the vicinity of Barrow were identified at transects 18-20, 23-27, and 29-30. Of these identified “hot spots,” the coast between transects 23 and 27 was identified as the most critical location because it covers the most shoreline and fronts the most densely populated coast (figures 78 and 79). Evaluation of the historical coastline in this area shows a coast that has not stabilized from the initial material loss in the 1955-1974 time frame. Comparing the 1948 and 1955 beach shorelines, the beach appears to be relatively stable, and since then, the beach and low-lying bluffs/dunes have yet to reach equilibrium. Isolating the erosion along that section of coast for the years 1984 to

2003 shows a shoreline erosion rate of 2.2 feet per year. This is less than the erosion rate of 4 feet per year experienced between 1984 and 1997, but slightly higher than the overall rate of 1.5 feet per year for the years 1948 to 2003. If allowed to erode unchecked at the lower rate of 2.2 feet per year, and assuming the bluff/dunes will try to maintain the existing beach width, the structures along this section of coast will be impacted within the 50-year life span. The predicted beach line is shown in figure 79. This “hot spot” section of coast is also the area of transition from a narrow beach backed by bluffs to a wide beach backed by tundra. The bluff/dune erosion is linked to the shoreline erosion since a wider beach would dissipate wave energy before it could impact the bluffs.

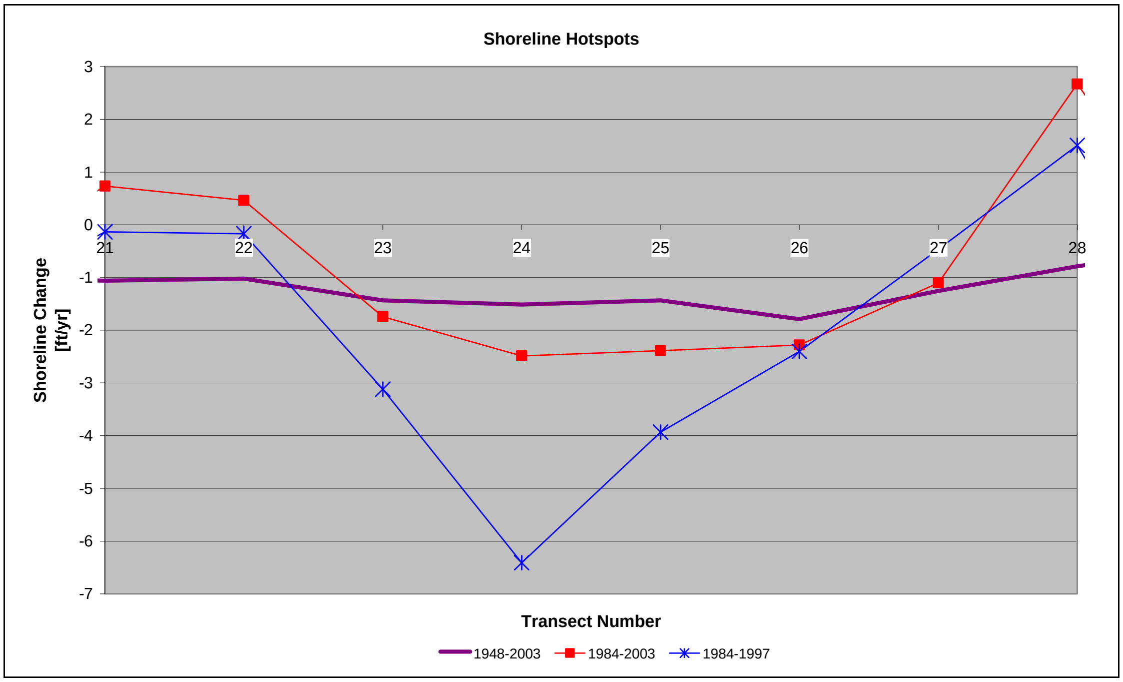

Figure 78. Plot of “hotspot” area of persistent erosion.

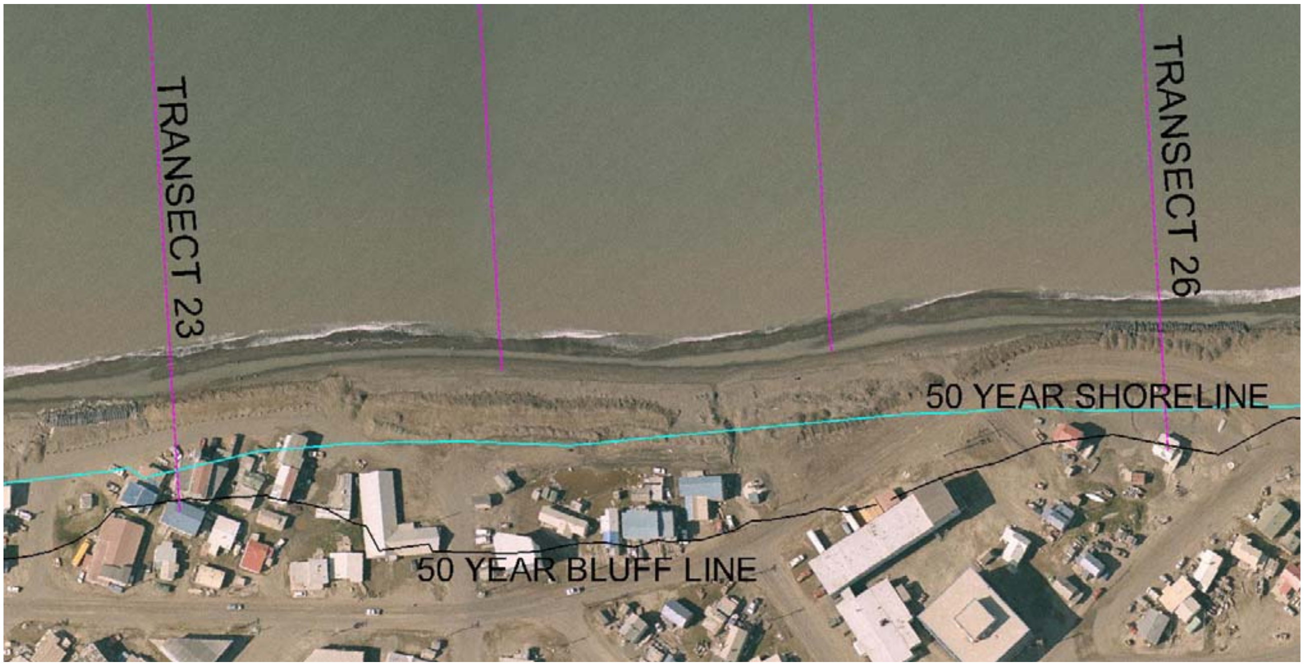

Figure 79. Aerial photograph of “hotspot.”

7.0 COASTAL FLOODING

Coastal flooding at Barrow results from wave run up over the beach and into the upland areas. Flooding elevations were estimated with a modified version of the SBEACH model (Larson and Kraus 1989, Larson et al. 1990, and Wise et al. 1996) using a volume flux approach, as described below. Fourteen damage reaches (figure 80) were established and a representative profile was developed for each reach based on measured profile data from 1987 and 2003. The profiles on which the storms were simulated in SBEACH are provided in figures 81 to 84. (Note the variation in berm crest between the various profiles, which influence the volume of water washed over the crest. Coastal flooding results from wave run up and is topographically controlled.) Storm data from the wave (WAM/STWAVE) and surge (ADCIRC) hindcasts for 28 historical events, described previously, were used as input. Twelve water level curves were generated for each storm by taking the ADCIRC predicted values and combining them with three barometric and four tide curves, for a total of 336 historically based plausible storms, which when combined with the 14 profiles, resulted in 4,704 SBEACH simulations.

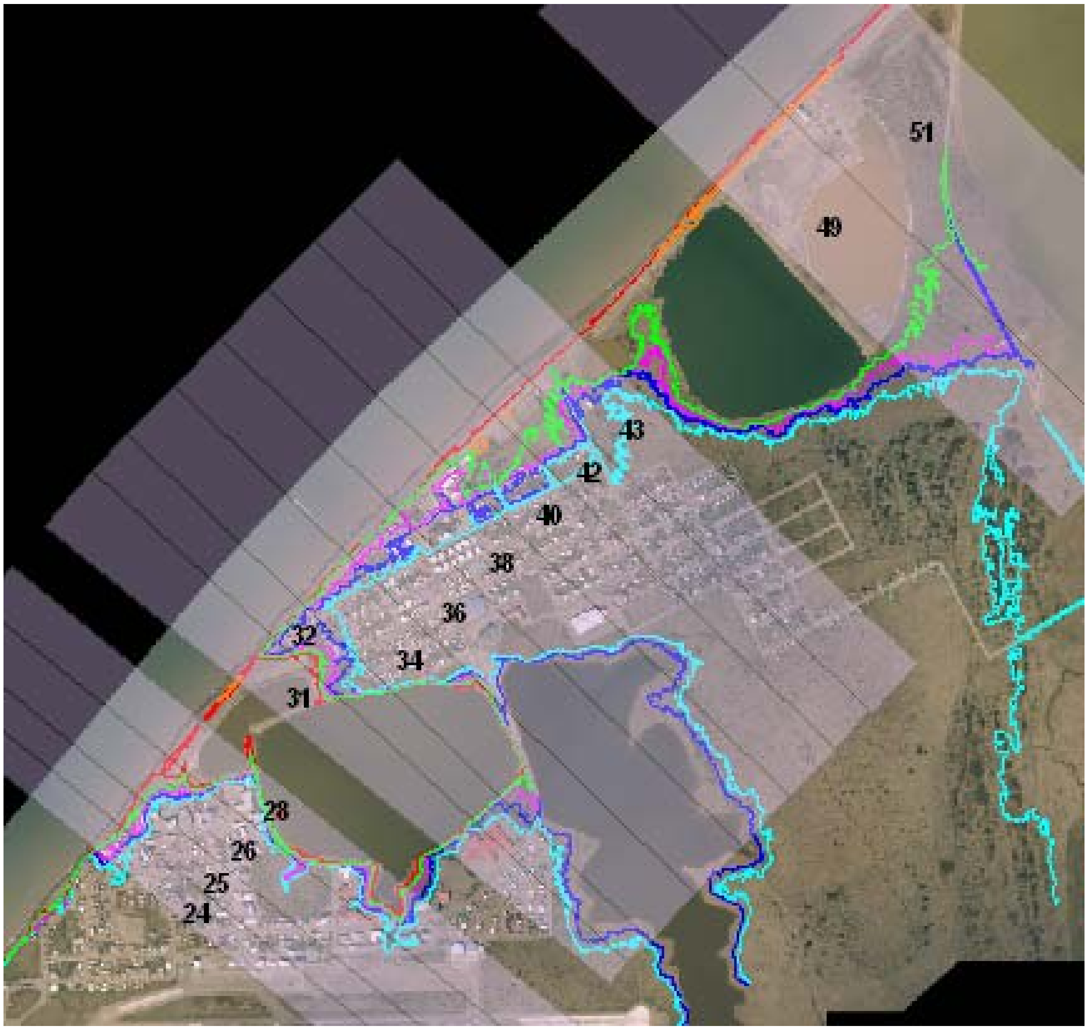

Figure 80. Study area with reaches 24-51 shown identified and elevation contours (red=8ft, green/orange=10ft, pink=12ft, blue=14ft, cyan=16ft).

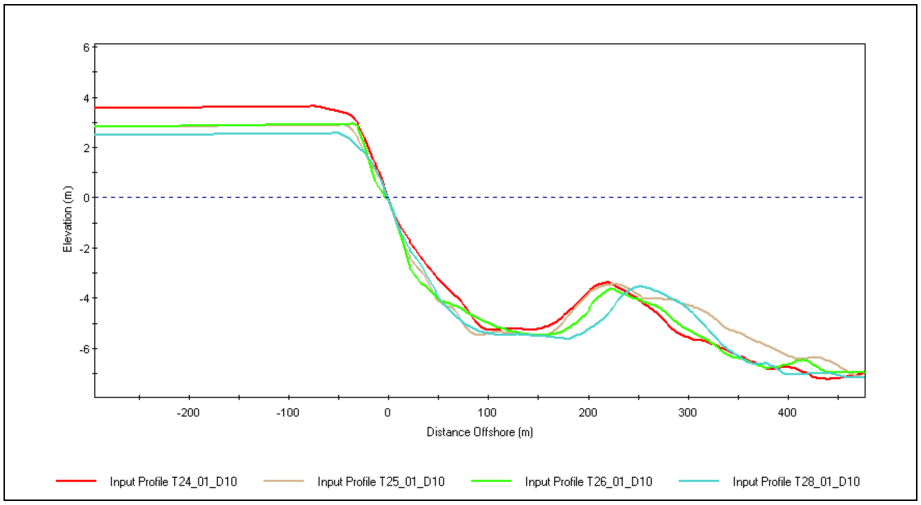

Figure 81. Beach profiles for Reaches 24, 25, 26, and 28.

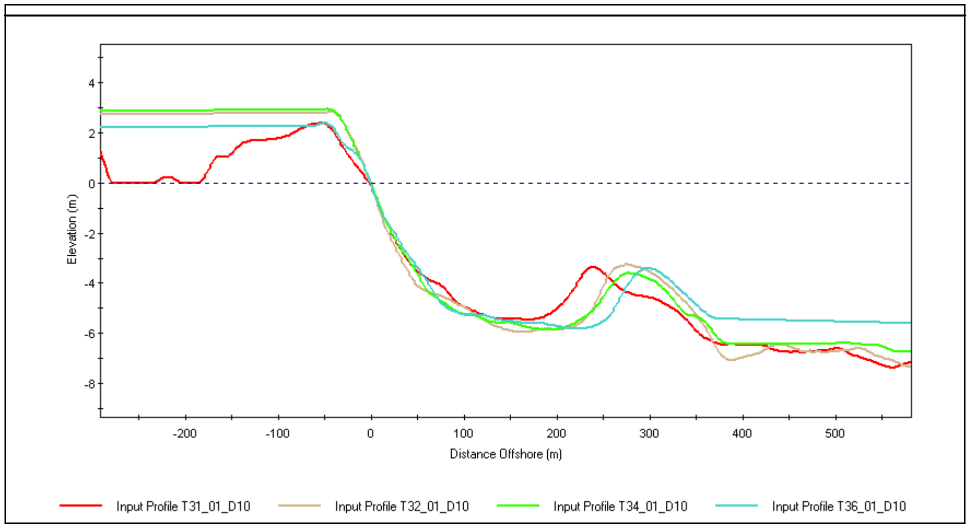

Figure 82. Beach profiles for Reaches 31, 32, 34, and 36.

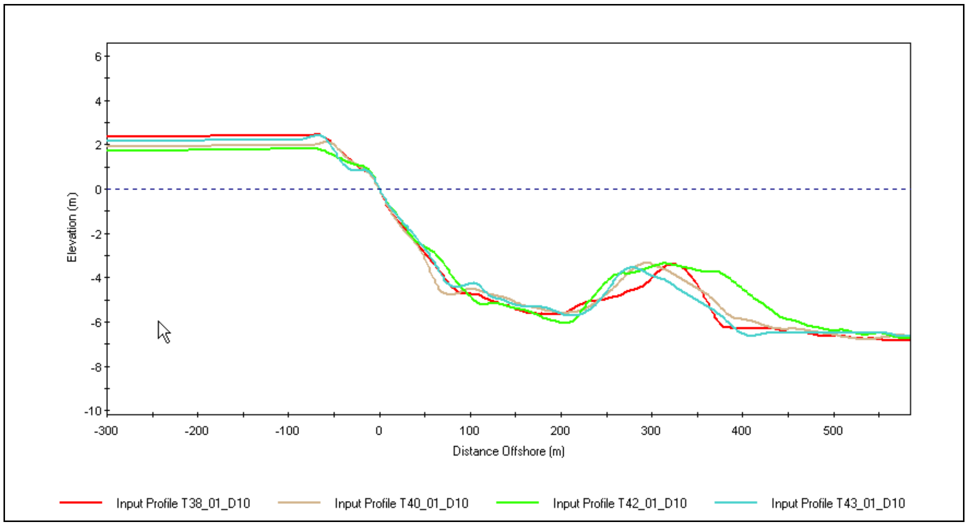

Figure 83. Beach profiles for Reaches 38, 40, 42, and 43.

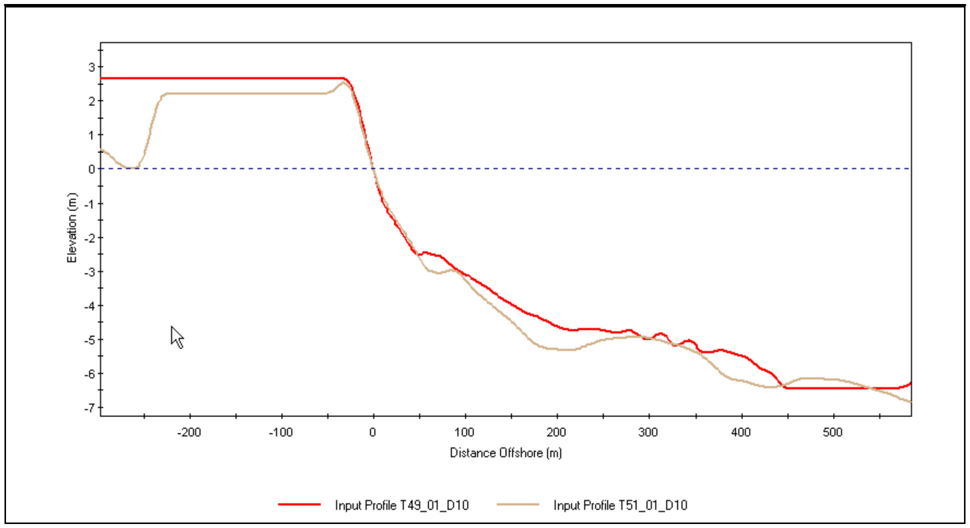

Figure 84. Beach profiles for Reaches 49 and 51.

SBEACH does not model wave run up on complex upland areas. To estimate run up flooding, a modified version of SBEACH was applied to estimate the volume of water that is pumped past the berm/dune crest for each storm simulation. Estimates of volumes of water overtopping the crest were calculated using time histories of profile and hydrodynamic output from SBEACH. The modified SBEACH considers three mechanisms of flooding: (1) profile overwash, (2) profile inundation, and (3) wave propagation. Profile overwash is defined here as water overtopping the dune due to calculated wave run up that exceeds the dune crest. For the case of overwash, the total water level (tide + surge + wave set up) remains below the dune crest elevation, but wave run up exceeds the dune crest. Profile inundation occurs when the total water level exceeds the dune crest. Wave propagation occurs during profile inundation and accounts for the volume of water transmitted across the barrier island through volume flux produced by breaking waves. At Barrow, the tide + surge + wave set up never exceeds the berm/dune crest, so only profile overwash is invoked.

The method for estimating volume of water due to overwash was formulated based on the sediment transport overwash algorithm included in SBEACH. First, the depth of the overwash bore at the dune crest was estimated by linearly interpolating between the depth of water at the surf zone/foreshore boundary in SBEACH and a depth of zero at the maximum extent calculated by the model. With this approach, the bore depth at the dune crest is zero when the maximum run up elevation is less than or equal to the dune crest, and increases as the calculated run up elevation exceeds the dune crest elevation.

As a first approximation, overtopping volume due to overwash was estimated according to the broad-crested weir formula:

$$q = g^{1/2}\left(\frac{2}{3}h_{bore}\right)^{3/2} \qquad \text{Equation 1}$$

where q is flow rate per unit width, g is acceleration of gravity and h_{bore} is the depth of the bore at the dune crest. This approach has some limitations. For example, the weir formula assumes steady state conditions, whereas wave run up is periodic. However, because rms run up is employed in the model as an estimate of the time-averaged run up condition from which bore depths are computed, the steady state approximation given by Equation 1 is reasonable.

Applying Equation 1, the total volume of water overtopping each reach was estimated for each storm. The total volume of flow for each representative profile represents the volume calculated over the duration of each storm. The volume for each reach is based on a single representative profile for that reach, which can result in unrealistic discontinuities in overtopping volumes. To account for the alongshore variation across a reach and blend and the volume fluxes in the longshore direction, a three-point smoothing was applied. The total volume for a given transect was calculated based on the volume calculated by SBEACH for that reach and the two adjacent SBEACH profiles according to the following formulation:

$$V_x' = (V_{x-1} + 2V_x + V_{x+1}) / 4 \qquad \text{Equation 2}$$

where V_x' is the smoothed overtopping volume for profile x, V_{x-1} is the SBEACH calculated overtopping volume for the profile immediately to the south of x, V_x is the SBEACH calculated overtopping volume at profile x, and V_{x+1} is the SBEACH calculated overtopping volume for the profile immediately to the north of x. Figure 85 shows an example of the calculated and smoothed volume fluxes for the 1986 storm.

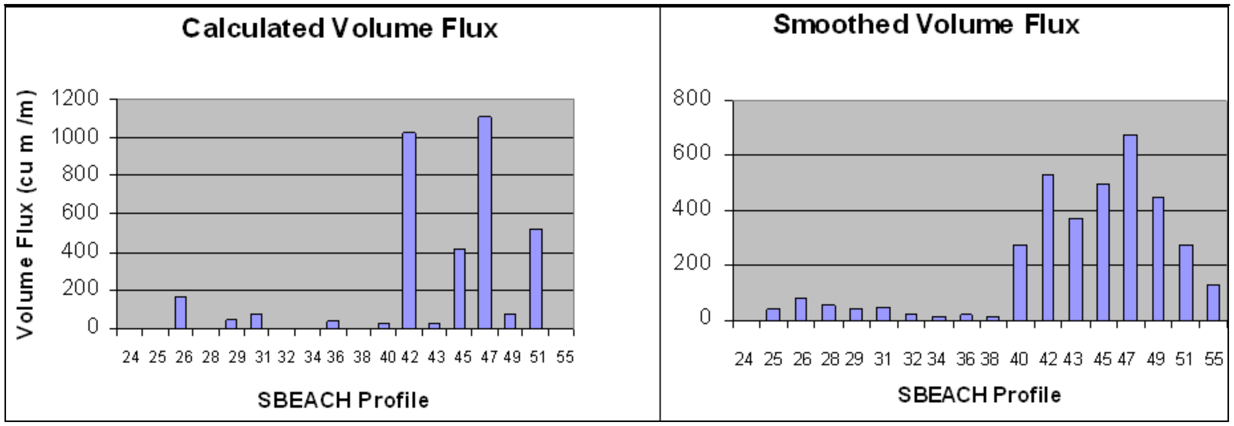

Figure 85. Volume fluxes for September 19, 1986 storm.

The volume computed by Equation 2 is used to calculate the total volume of water that overtops the berm crest at each reach. From this volume flux, flooding elevations are calculated based upon the topography landward of the berm crest. Topographic data was analyzed in GIS to compute the storage capacity between upland contours, based on the area between those contours. The analysis assumes that the water pumped above the berm crest by wave action does not have time to drain due to irregularities in the upland profile (e.g. low areas and gullies) and the continuous overflow of water during the peak of the storms. A step function was developed for each reach, which utilized topographic characteristics and storage capacity calculations for each reach to compute the flooding elevation. Flooding elevations were capped at 0.25 foot above the highest contour in the reach.

The calculated flood exceedance probabilities are presented in table 12. The table presents the probability that the flooding level will exceed a given level for each reach. Stage-frequency curves were developed with the statistical Empirical Simulation Technique (EST) model (Scheffner 1999). The EST assumes that past storm frequency and intensity is an accurate predictor of future storm activity. The last decade has seen an increase in storm activity along with more ice-free days each year and the permanent icepack being farther offshore. This adds an additional level of uncertainty to the EST results, and consideration of global climate change could result in more frequent flooding predictions. Because run up flooding is topographically controlled, the stage-frequency curve is reach-dependent. Separate curves were generated for each reach and are given in figures 86 to 99. The EST extrapolates from input data and can therefore produce results that are physically unrealistic at the upper end of the curve. Therefore, the EST results have been capped at the upper end to reflect physical constraints introduced by the topography of each reach. The bottom of each curve coincides with the beach berm crest, and no flooding occurs below this level. So, on reach 24 for example, flooding is not expected to occur for storms with a return period below approximately 20 years.

Table 12. Flood Exceedance Probabilities

Reach	Berm Elev (ft)	>7ft	>8ft	>9ft	>10ft	>11ft	>12ft	>13ft	>14ft	>15ft	>16ft
24	11.99475						0.0357	0.0022			
25	9.547244				0.1741	0.0893	0.0513	0.0179	0.0067		
26	9.616142				0.1741	0.0982	0.067	0.0513	0.0223	0.0089	0.0067
28	8.458005			0.0826	0.0089						
31	7.877297		0.0938	0.0938	0.0714	0.0647	0.0625	0.0603	0.0402		
32	9.284777				0.0938	0.0714	0.0625	0.0536	0.0179		
34	9.744094				0.0558	0.0179	0.0067				
36	7.903543		0.0558	0.0558	0.0402	0.0179	0.0156				
38	8.136483			0.0558	0.0201	0.0112					
40	6.961942	0.0446	0.0313	0.0268	0.0246	0.0156	0.0089	0.0067	0.0022		
42	6.036745	0.0313	0.0268	0.0268	0.0246	0.0201	0.0134	0.0112	0.0089	0.0067	0.0045
43	7.96916		0.1607	0.0848	0.0491	0.0268	0.0246	0.0179	0.0179	0.0045	
49	8.704068			0.2946	0.0938	0.0357					
51	8.287402			0.096	0.0268						

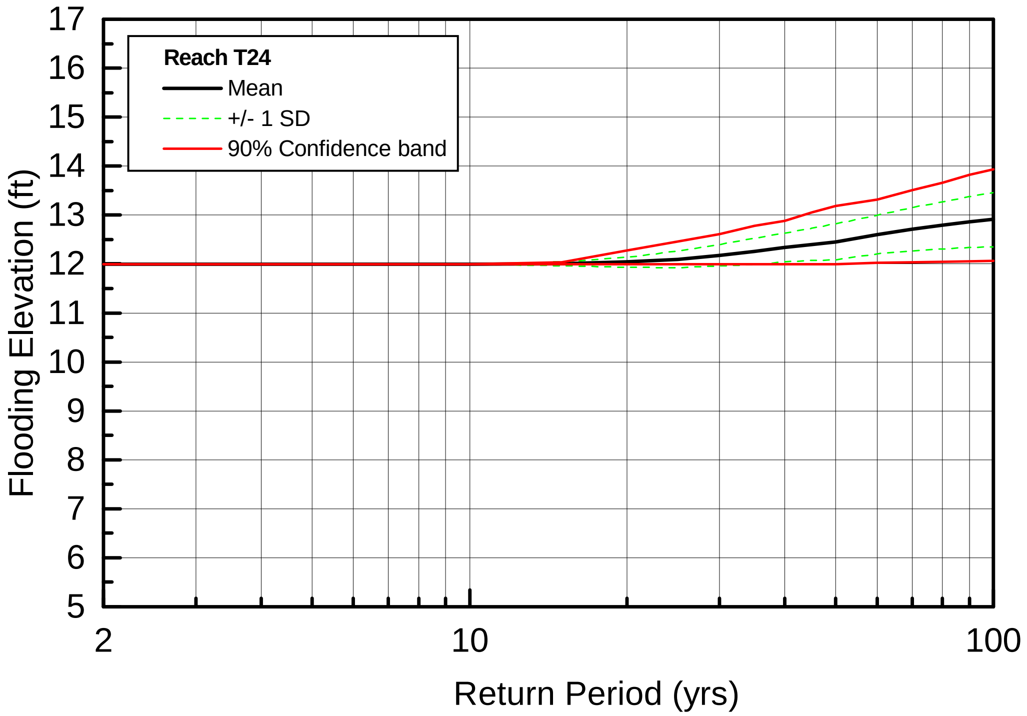

Figure 86. Stage-frequency curve for damage reach 24.

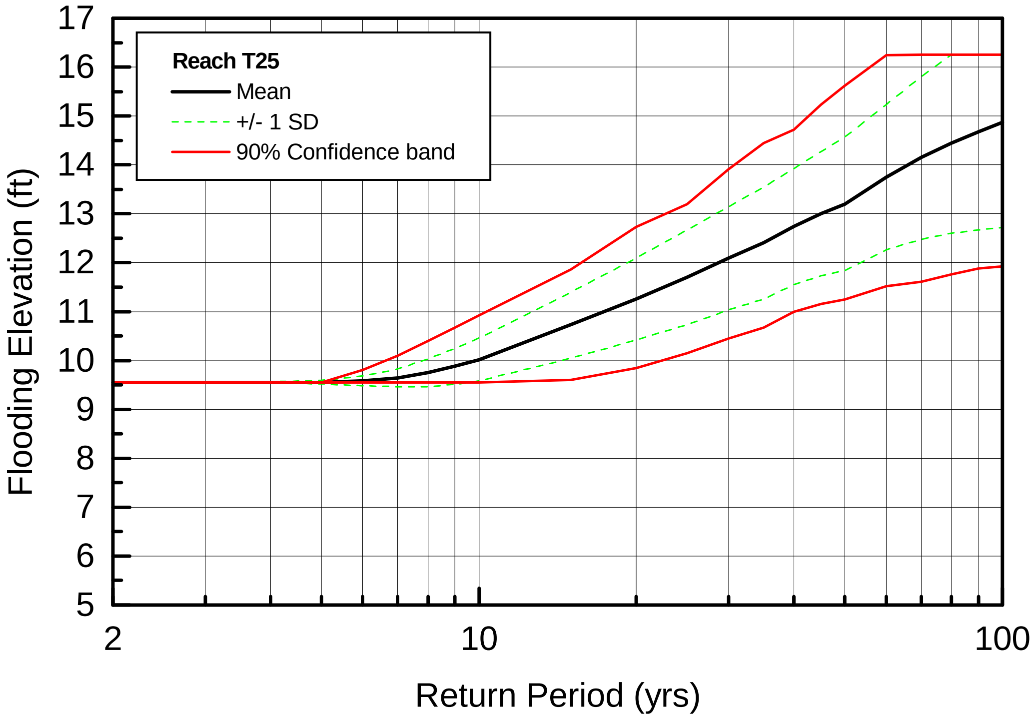

Figure 87. Stage-frequency curve for damage reach 25.

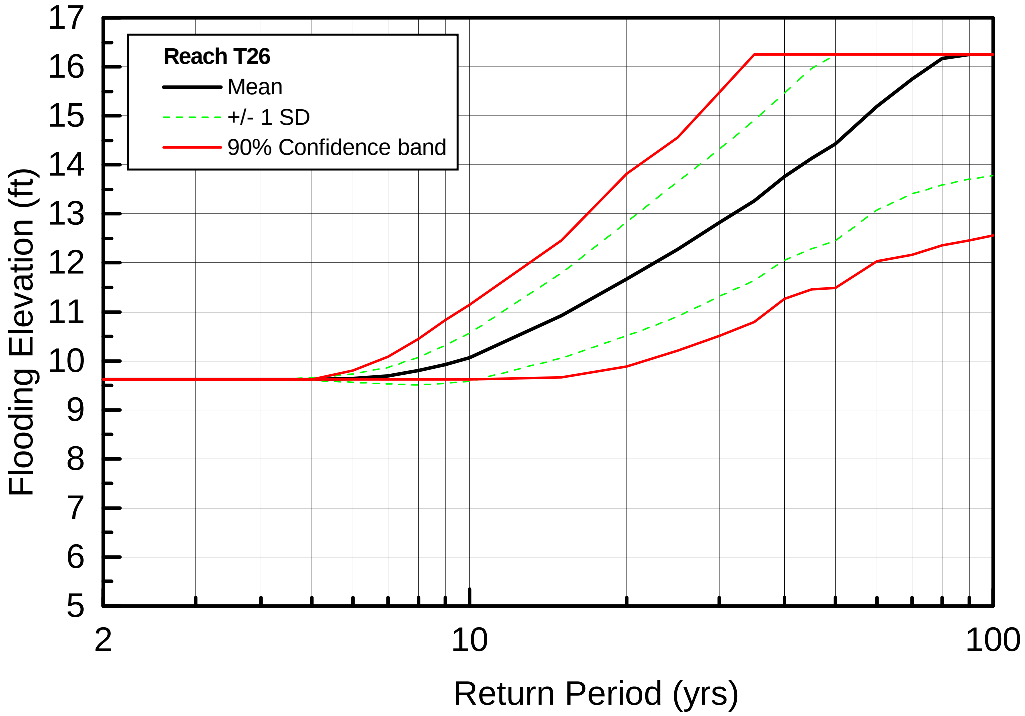

Figure 88. Stage-frequency curve for damage reach 26.

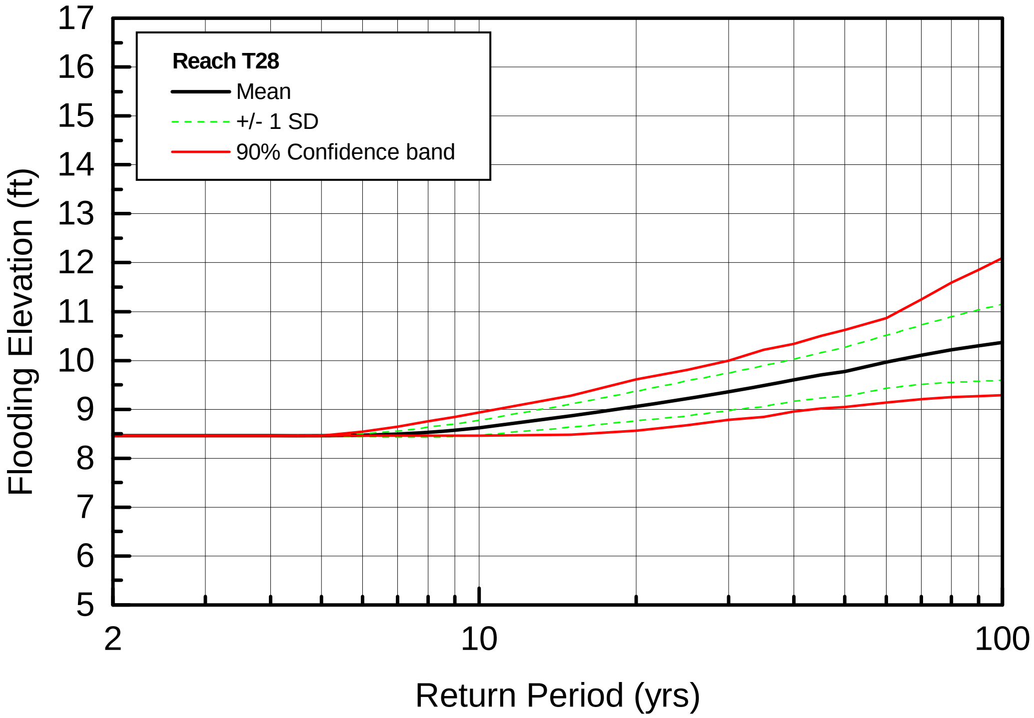

Figure 89. Stage-frequency curve for damage reach 28.

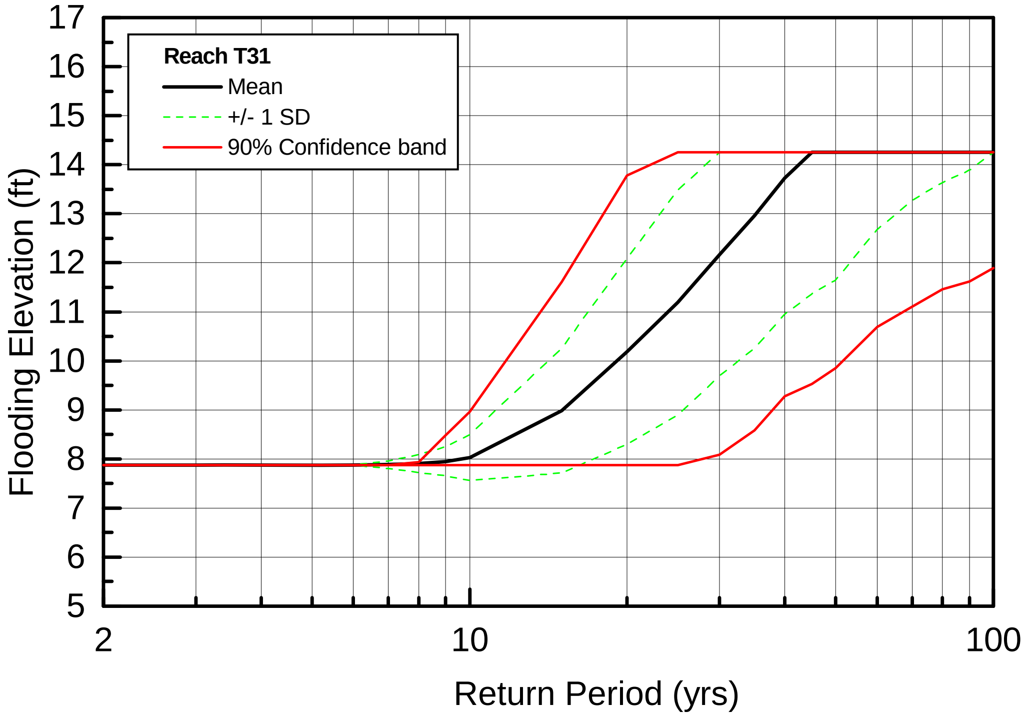

Figure 90. Stage-frequency curve for damage reach 31.

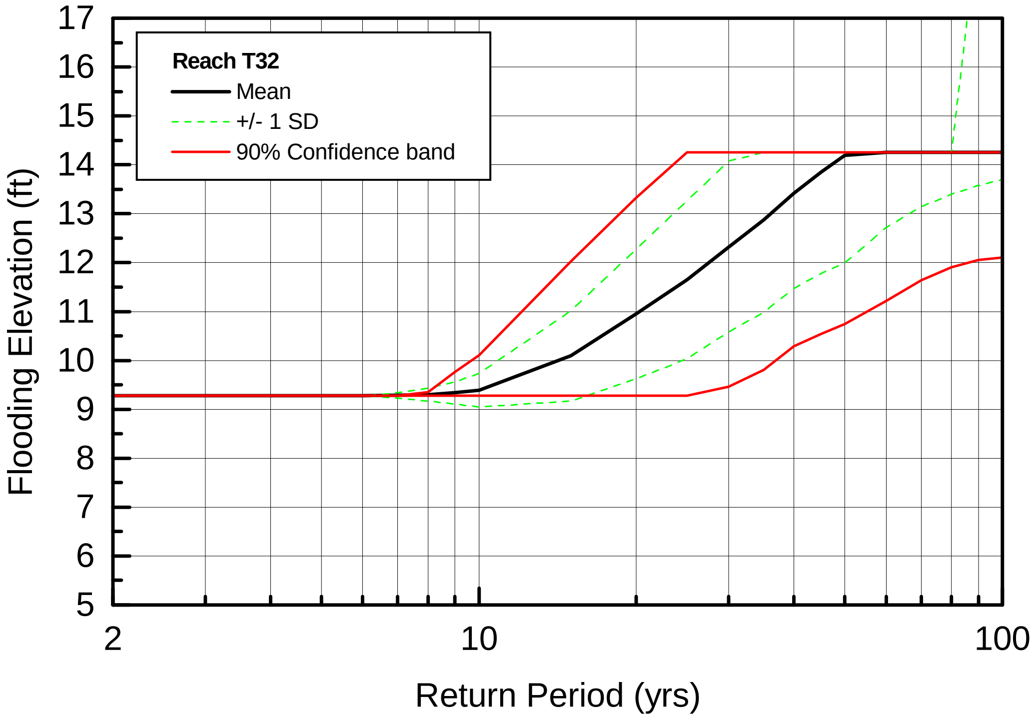

Figure 91. Stage-frequency curve for damage reach 32.

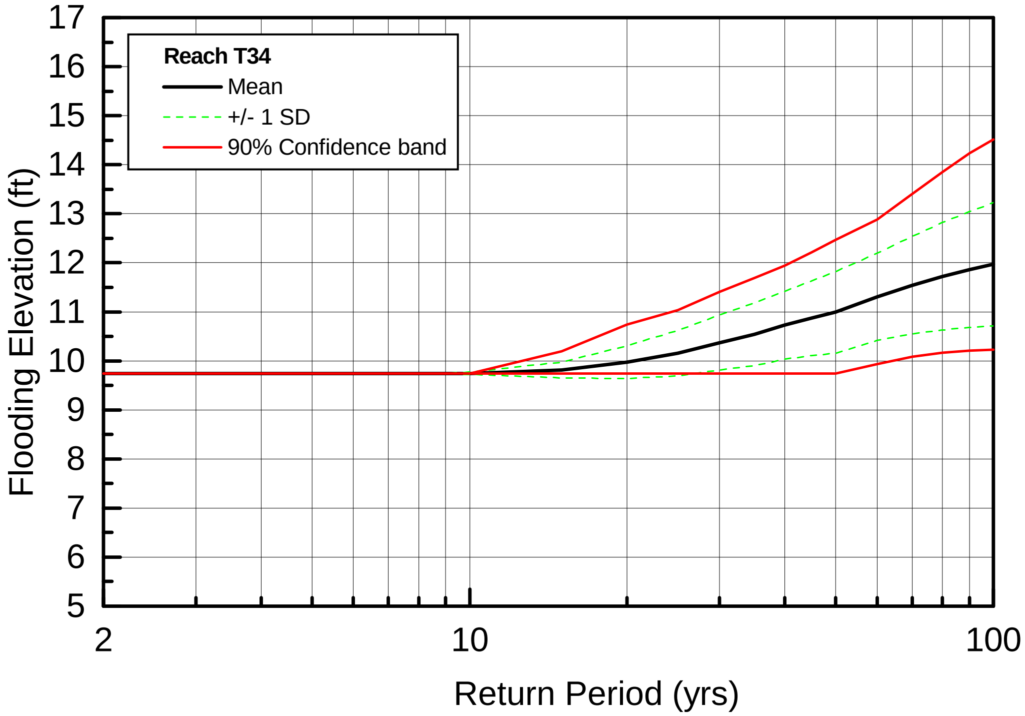

Figure 92. Stage-frequency curve for damage reach 34.

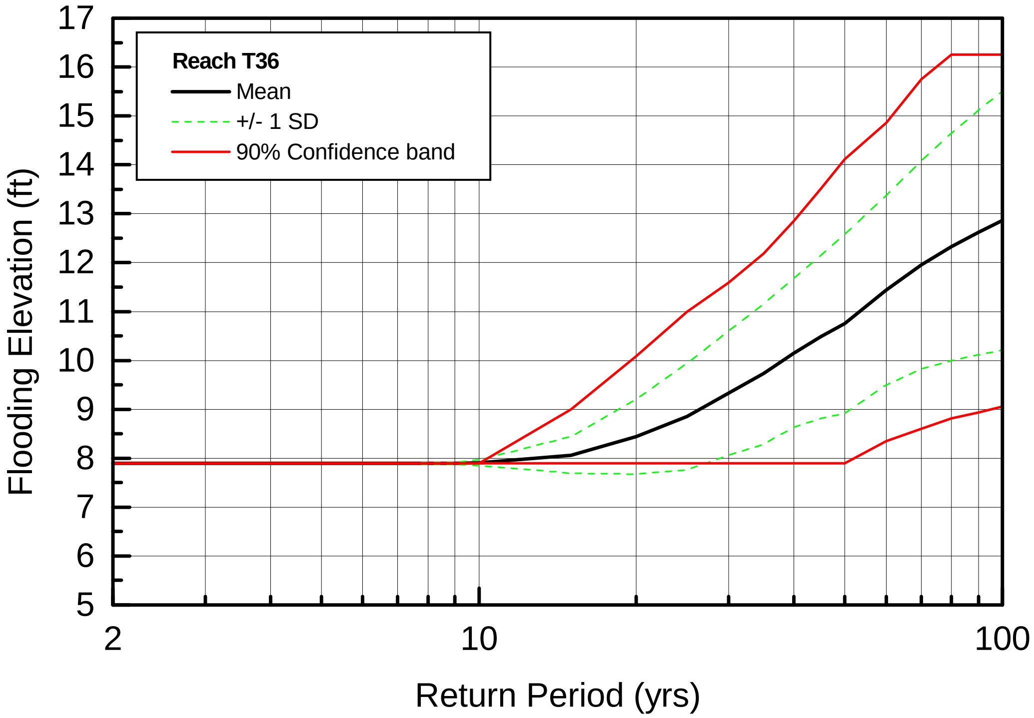

Figure 93. Stage-frequency curve for damage reach 36.

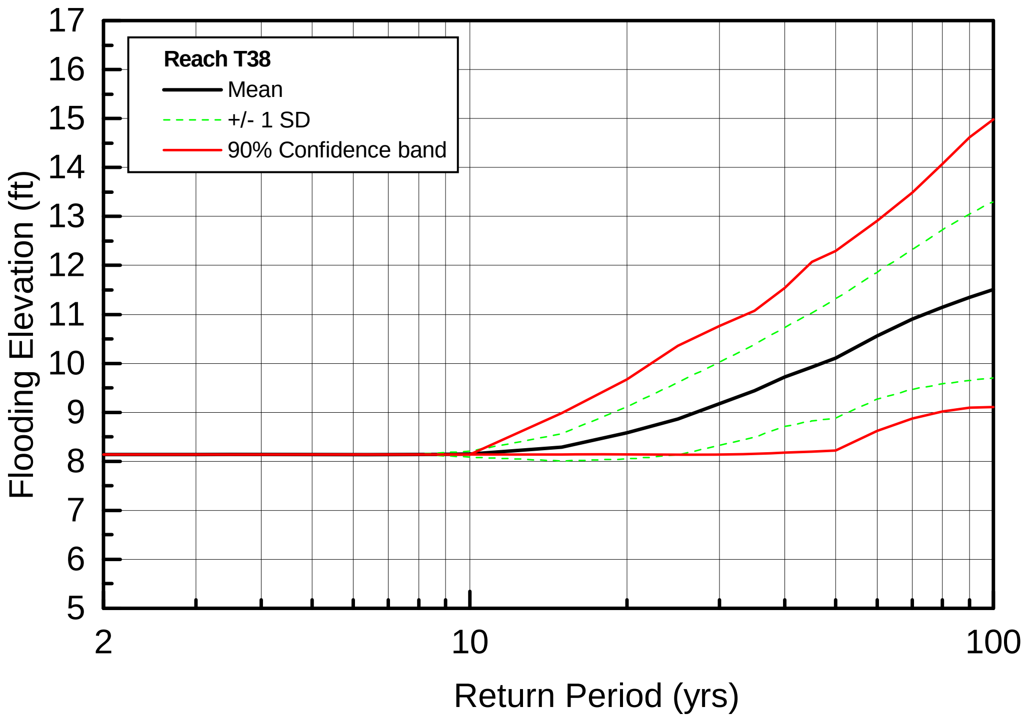

Figure 94. Stage-frequency curve for damage reach 38.

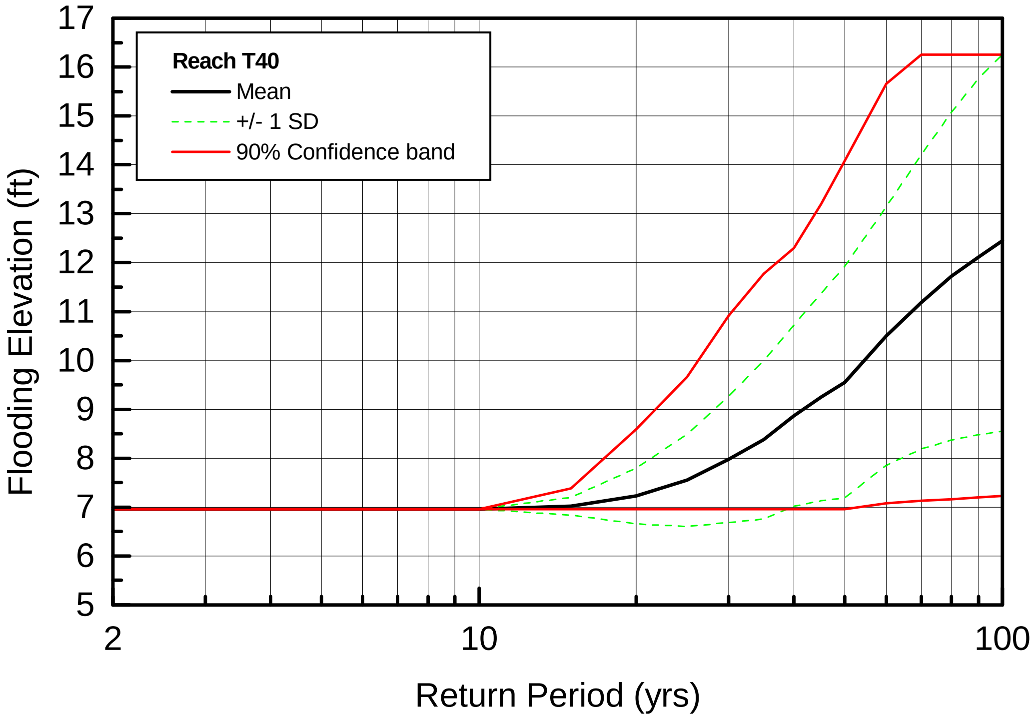

Figure 95. Stage-frequency curve for damage reach 40.

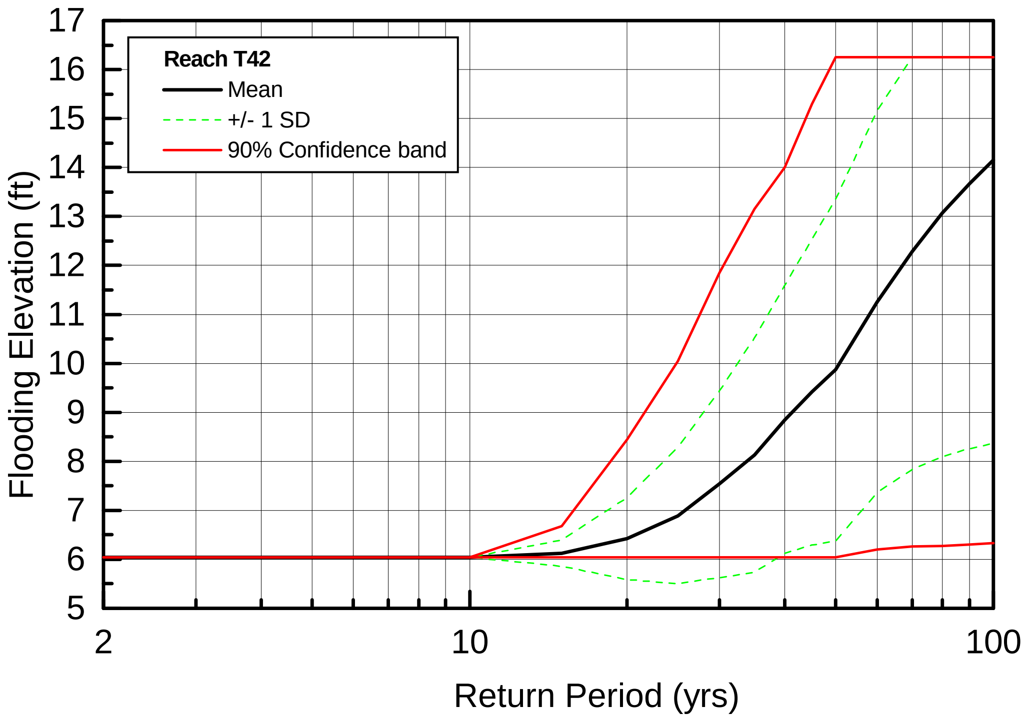

Figure 96. Stage-frequency curve for damage reach 42.

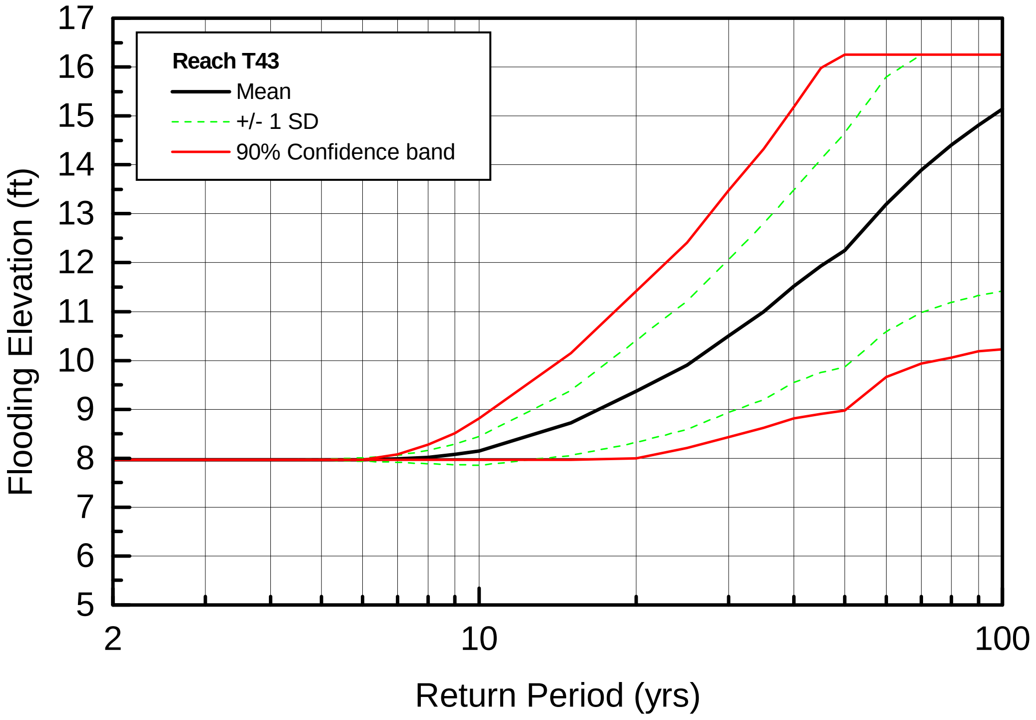

Figure 97. Stage-frequency curve for damage reach 43.

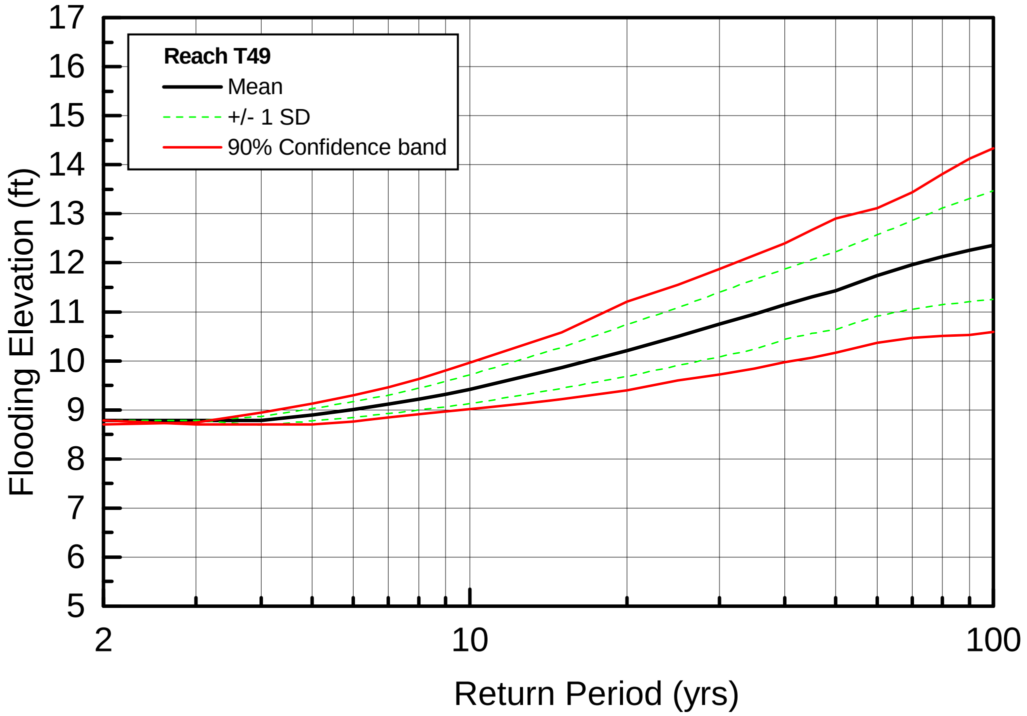

Figure 98. Stage-frequency curve for damage reach 49.

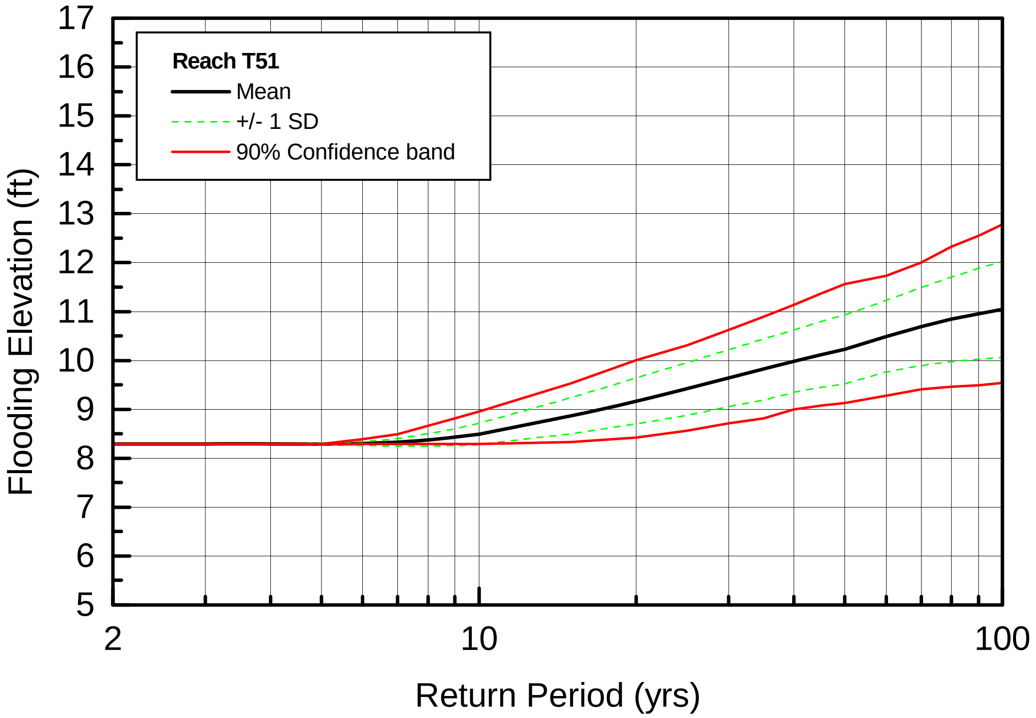

Figure 99. Stage-frequency curve for damage reach 51**.**

For reaches evaluated south of the sewage lagoon in Barrow and Browerville, a storm with a return period of 5 to 20 years, depending on the reach, is required to induce flooding. For the reaches near the sewage lagoon, model results indicate a 3-year storm will produce some flooding. The calculated 50-year flooding elevation across the study area is approximately 10 to 14.5 feet. These calculation estimates do not include any flood protection berm feature such as the temporary ones that the city puts in place before and during a storm or any proposed structure.

Model Verification. Water level measurements during storms against which the model results could be checked were limited because of the proactive nature of the community during storm events. The North Slope Borough actively combats flooding before and during every threatening storm by placing sacrificial berms along the low lying coastal areas and pushing beach material up to a higher elevation during storm events. These berms are generally composed of fine material and are easily washed away, but they last long enough to provide temporary protection and are constantly being rebuilt during storms.

Prior to the procurement of heavy equipment to actively combat coastal flooding, the community of Barrow was highly susceptible to damages from coastal flooding as seen in the damages experienced in the 1963 storm. Evaluation of the flood potential along the coast could not account for the flood fighting activity along the coast during the storms. Papers written on the effects of the 1963 storm that impacted the coast cite debris lines measured at the 12-foot elevation at the former Naval Arctic Research Laboratory site north of Barrow. This debris line is outside the project area, but the topography is similar to that in the Browerville area. The stage frequency curves indicate that a flood elevation of 12 feet is possible during an extreme storm event.

8.0 STORM DAMAGE REDUCTION OPTIONS

Storm damage reduction can be categorized into three options:

- options that modify existing structures or practices to prevent storm damage (also known as non structural measures)
- options that protect the bluff from erosion, and
- options that protect low areas from flooding.

Some of these options may serve the same purpose, but for this analysis they are considered separately.

8.1 Protection From Erosion

The bluff at Barrow is composed of fine sand, silt, and organic material that is bound by permafrost. Wave action on the face and at the base of the bluffs causes localized melting of the permafrost and niching at the toe of the bluffs. Once the permafrost melts, the bluff material has no inherent strength, which leaves the bluff susceptible to two potential failure modes: slumping or block failure. Slumping occurs when permafrost is exposed and the subsequent melting produces localized mud flows of unstable material down the face of the bluff. This material is then washed away during high water events. Block failure occurs when the base of the bluff has eroded to the point where the ice is no longer capable of supporting the weight of the bluff and a large block of bluff collapses and is washed away by high water events. Block failure can be quite large if the failure plane is along the ice wedge of a polygon.

Options considered for erosion protection include:

- Non structural measures
- Revetment
- Beach nourishment
- Seawall
- Breakwater
- Groins

Non Structural Measures. This alternative would allow the natural erosion process to take place, and structures, roads, and utilities that would be impacted by erosion would be relocated. Alternative land parcels would need to be available for structure relocation and utilities would need to be rerouted. No provision would be made for the preservation of archaeological remains in the bluff.

Revetment. A revetment would protect the bluff from niching during storm events. Revetments in many locations throughout Alaska have successfully protected eroding bluffs. The limiting factors when considering a revetment along the bluffs at Barrow are: cost of the revetment material, the resistance of the revetment material to ice forces, and the ease of construction and maintenance. Material options being considered for revetment include rock, supersacks, and articulated concrete mats. This option would not address slumping issues associated with melting permafrost. It would protect the bluff toe and not harm the existing beach, so it was retained for further consideration.

Beach Nourishment. The use of beach nourishment to protect eroding bluffs has not been used widely in Alaska. Beach nourishment had been tried at Barrow, but the dredge used to perform beach nourishment was heavily damaged during a storm in 2000 prior to the completion of the nourishment project. The nourishment program was discontinued with the loss of the dredge. Early feasibility study efforts focused on a beach nourishment alternative and finding a source of nourishment material. Three potential sources for nourishment material were identified and preliminary cost estimates were developed. The potential gravel sites identified were Point Barrow, Cooper Island, a site know as the Bureau of Indian Affairs (BIA) site, and a submerged spit off Point Barrow (figure 100).

All the potential sites except for the submerged spit had sand and gravel that was comparable in size to the beach material at Barrow and Browerville. The success of a beach nourishment alternative at Barrow is the ability to constantly renourish the beach if beach material similar to the existing beach is used or less frequent nourishment if material coarser than the existing beach material is used. This option would not address the slumping issues associated with melting permafrost. It would protect the bluff toe and not harm the existing beach, so it was retained for further consideration.

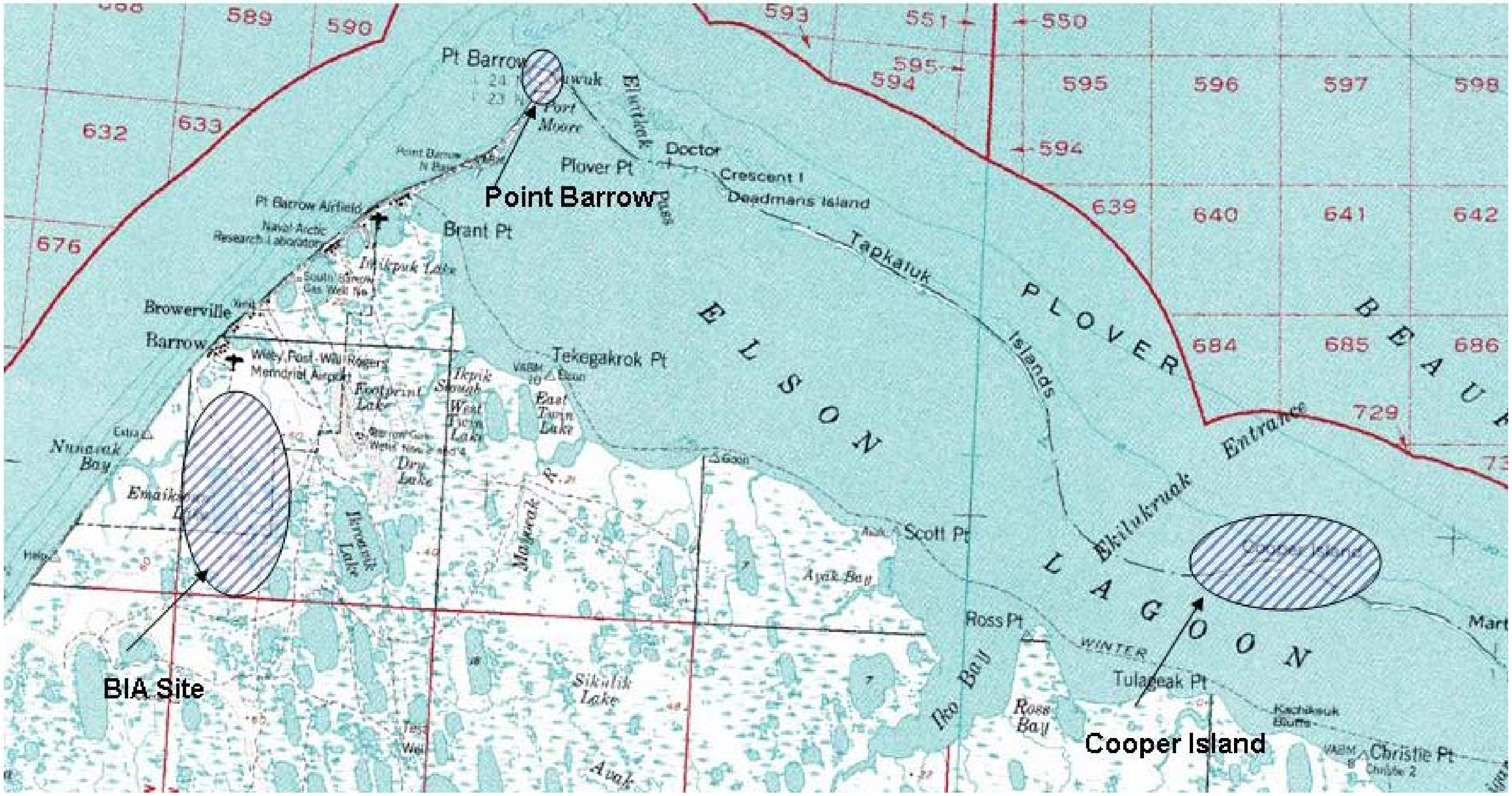

Figure 100. Potential gravel sites from geotechnical investigation.

Seawalls. The purpose of a seawall is to protect the land and developments behind it (figure 101). The beach at Barrow is important to the way of life in the Arctic. Boats are launched on the beach for subsistence activities, and goods and supplies are landed on a barge at the beach, so it is important that the beach be maintained. The effect of a seawall and particularly the shoreline in the zone of the reflected wave is often damaging. A number of studies have found that scour tends to develop on the beach fronting a seawall. The coastal condition at Barrow is extremely fragile since the major source of natural renourishment has been removed from the system and only a small amount of material is transported along the shoreline each year. A large storm event could take many decades of recovery in front of a seawall at Barrow. The sustained narrowing of the beach as a result of removing borrow material is evidence that the beach can obtain equilibrium, but not recover to previous widths. Taking a chance on a protective measure that could possibly reduce the beach width is a risk that could result in damage to the beach from which it will not recover. A number of seawall structures in Alaska have caused scour to develop on the fronting beach. Because this option could harm the coastal environment, it was dropped from further consideration


'04 7 13

Figure 101. Seawall at Barrow

Offshore Breakwaters. Intermittent offshore breakwaters could be used to lessen the wave energy impacting the beach and the base of the bluff. Typically, offshore breakwaters provide a quiet area where sediment accumulates and a tombolo forms, giving the shoreline a scalloped appearance. Due to the small amount of sediment transport, the formation of a tombolo would be a very slow process. Materials that could be used in the construction of a breakwater include rock or concrete armor units similar to dolosse. The construction costs for this option would be higher than other options since work would need to be performed from a barge, inspection and maintenance would be more difficult, and it would likely lead to erosion outside the project area due to the interruption of the natural sediment transport system. Therefore, it was dropped from further consideration.

Groins. Groins are typically placed to limit the movement of longshore sediment and build up a beach. Due to the limited longshore transport of beach material, groins would be marginally effective. Materials that could be used in the construction of a groin system include rock, steel piles, timber piles, and sacrificial supersacks. Groins would take a long time to build up sediment to increase the beach width and would limit the amount of material being transferred outside the project area, resulting in increased erosion outside the project area. This option was dropped from further consideration.

Evaluation of the options considered for erosion protection are presented in table 13.

Table 13. Erosion Protection Option Matrix

Protection Type	Advantages	Disadvantages
Non Structural Measures	No maintenance costs associated with relocation. Technically easy to implement. Allows bluffs to find natural equilibrium.	There is likely local resistance to relocation. Need alternate land parcels available for relocation. Does nothing to preserve artifacts from eroding bluffs
Revetment	Provides protection of the entire bluff face. Easy construction with land based equipment. Easy access to inspect for damages	Susceptible to ice damage. Depending on material used, could have high maintenance requirements.
Beach Nourishment	Returns beach material that had been lost during storm events and borrow activities. Will reduce wave impact at the base of the bluff. Maintains a usable beach for community activities and shipping and receiving goods.	Will require periodic maintenance. No nourishment material with significant gravel locally available.
Seawall	Provides protection of the entire bluff face.	Will protect the bluffs, but possibly erode the fronting beach.
Breakwater	Will reduce the wave climate at the base of the bluff. Maintains a usable beach for community activities and shipping and receiving goods.	Susceptible to ice damage. More complex construction. Need offshore equipment. More difficult to inspect and maintain.
Groins	Will build up sediment and eventually raise beach elevation resulting in milder wave climate at the base of the bluffs. Maintains a usable beach for community activities and shipping and receiving goods.	Susceptible to ice damage. Will produce a sediment deficit downdrift of the groins. Sediment transport is minimal, so beach buildup will take a considerable amount of time.

8.2 Flooding Protection

The bluff at the southwestern end of Barrow provides elevation to protect that part of the coast from flooding associated with storm events. The terrain elevation decreases to the northeast, and at Isatkoak Lagoon, no bluffs exist and the coast is a low-lying beach. The area of Isatkoak Lagoon and the low-lying beach along the coast are susceptible to flooding during storms. Flooding occurs during storms with high wave run-up elevations that exceed the elevation of the berm fronting the coast. The construction of a well-engineered flood protection structure could significantly reduce the coastal flooding risk at Barrow.

Options considered for flooding protection include:

- Non structural measures
- Revetted berm structure
- Beach nourishment, or a
- Seawall

Non Structural Measures. Homes impacted by flooding could be raised to avoid flood damage. Raising impacted homes would preserve the structure and interior; however, property kept outside such as boats, four wheelers, or snow machines would not be protected. An alternative to raising homes above the flood level would be to relocate homes outside the flood area. This alternative would require that parcels be available for the structure relocation. Flood damage at the lagoon could be addressed by raising the height of the spillway.

Revetted Berm Structure. A revetted berm structure that would dissipate the energy associated with wave run-up could be constructed on the seaward side of the coastal road. The revetted berm would be susceptible to damage from ivu events and could be designed to withstand ice forces, but this would require a significant increase in the size of the armor stone, and due to a lack of information on the frequency and severity of these episodes, the associated maintenance due to ivu events is unknown. A revetted berm structure sized to address the wave run-up and not ice forces would use considerably smaller armor stone, but would have increased maintenance requirements. The North Slope Borough currently uses a sacrificial berm system to protect the low lying areas from flooding, which is effective, but susceptible to wave and ice damage. The revetted berm option would protect the low-lying coastal area from flooding and not harm the existing beach, so it is retained for further consideration.

Beach Nourishment. The use of beach nourishment as a flood protection measure has not been used in Alaska. Beach nourishment would raise the beach elevation to move the wave run up away from Isatkoak Lagoon and Browerville. The beach fill and bluff fill would be a continuous project, so the preliminary project attributes discussed in the beach nourishment for erosion protection apply to the beach nourishment for flood protection alternative.

Seawall. As discussed in the erosion protection option, the effect of a seawall on the fronting beach is uncertain. Because of the importance of the beach to the activities at Barrow and the potential damage to the beach, this option was dropped from further consideration.

Evaluation of the options considered for flood protection is presented in table 14.

Table 14. Flood Protection Option Matrix

Protection Type	Advantages	Disadvantages
Non Structural Measures	No maintenance costs associated with relocation. Technically easy to implement	There is likely local resistance to relocation. Need alternate land parcels available for relocation.
Revetted Berm Structure	Straightforward construction and maintenance. Proven success in Alaska Easy access for inspection	Susceptible to ice damage. Depending on material used, could have high maintenance requirements.
Beach Nourishment	Aids in returning the beach to its original state. Will reduce wave run-up with increased beach elevation.	Will require periodic maintenance. No economical, archaeologically, and environmentally acceptable location to provide adequate amount of material.
Seawall	Provides a large area of flood protection.	Will protect the low lying areas from floods, but erode the fronting beach.

8.3 Selected Features

8.3.1 Bluff Protection

Revetment. A rock revetment to protect the toe of the bluff has a proven history of use in Alaska for coastal protection. Several materials were evaluated to construct the revetment including the HESCO concertainer system that is currently being used at two locations in Barrow, articulated concrete mats, and rock. The HESCO system, while successful at Barrow to date, has not proven reliable at other locations during storm events, so it was dropped from consideration. Personal correspondence with oil company personnel on the success of concrete armor units on offshore islands in the Beaufort Sea indicates that the articulated concrete mats experience chipping and breaking from ice forces and that the mats need a well-drained underlayer to dissipate uplift forces. Articulated concrete mats are generally costly to install and maintain, and to date, they have not had a good history of protection at coastal sites in Alaska. Rock revetments have been used successfully at sites throughout Alaska. A revetment sized for waves would be susceptible to ice damage, but could be repaired easily if a maintenance stockpile were kept at Barrow. Due to the unreliability of the HESCO system and the articulated mat, these materials were dropped from further consideration.

Beach Fill. Beach fill has not been used in Alaska to prevent erosion, but it is a viable solution in Barrow. Erosion that is being experienced along the bluffs/dunes at Barrow appears to be linked to borrow activity from the beach and a severe storm event. The beach has tried to stabilize itself, but its main source of renourishment has been removed from the system as a borrow source. The use of a beach fill would inject a supply of gravel to the beach system that is still trying to stabilize itself.

8.3.2 Flood protection

Revetment. A revetted berm structure to provide a raised shore elevation to dissipate run up energy provides a solution for coastal flooding at Barrow. The structure would not need to be impermeable as with a typical dike, but it would need to intercept the run up and dissipate its associated energy. Several materials were evaluated to construct the revetted berm structure including the HESCO concertainer system that is currently being used at two locations in Barrow and rock. The HESCO system, while successful at Barrow to date, has not proven reliable at other locations during storm events, so it was dropped from consideration. Maintenance and costs associated with each of the materials was evaluated, and it was determined that rock would provide the most reliable, easiest to maintain, and least cost material.

Beach Fill. Beach fill has not been used in Alaska to prevent flooding but it is a viable solution in Barrow. The flooding at Barrow is associated with the shallow beach slope and low-lying tundra. Raising the beach elevation would dissipate the wave energy and associated run up on the beach and keep the input of water from run up from making its way inshore. The use of beach fill would also have the added benefit of injecting a supply of gravel to a beach system that is in a deficit.

8.4 Design Parameters

8.4.1 Water Level

The coastal flooding at Barrow is the result of the combination of tide, surge, wave set up, and wave run up, and it is only the addition of run up that introduces flooding along the coast. As a result, the flood protection structure elevation is based on the run up elevation. The base water elevation used in the design is the ADCIRC elevation and the wave set up, and the run up elevation used in the design is the SBEACH elevation.

A hand calculation check on SBEACH elevations for wave set up and run up for the 20, 50, and 100-year events was performed using two different wave set up equations: a method by Komar in Beach Processes and Sedimentation and a method shown in the Coastal Engineering Manual (CEM). The base elevation for all calculations is the tide plus surge water level obtained from ADCIRC modeling for the 20, 50, and 100-year event.

SBEACH generated output to predict return frequency intervals using the EST model. This model makes the assumption that past storm frequency and intensity is an accurate predictor of future storm activity. The last decade or so has seen an increase in storm activity along with more ice-free days each year and the permanent icepack being farther offshore. This adds an additional level of uncertainty to the EST results. The return frequency interval for storm set up (combined elevation of tide plus storm surge, plus wave set up) is shown in figure 102.

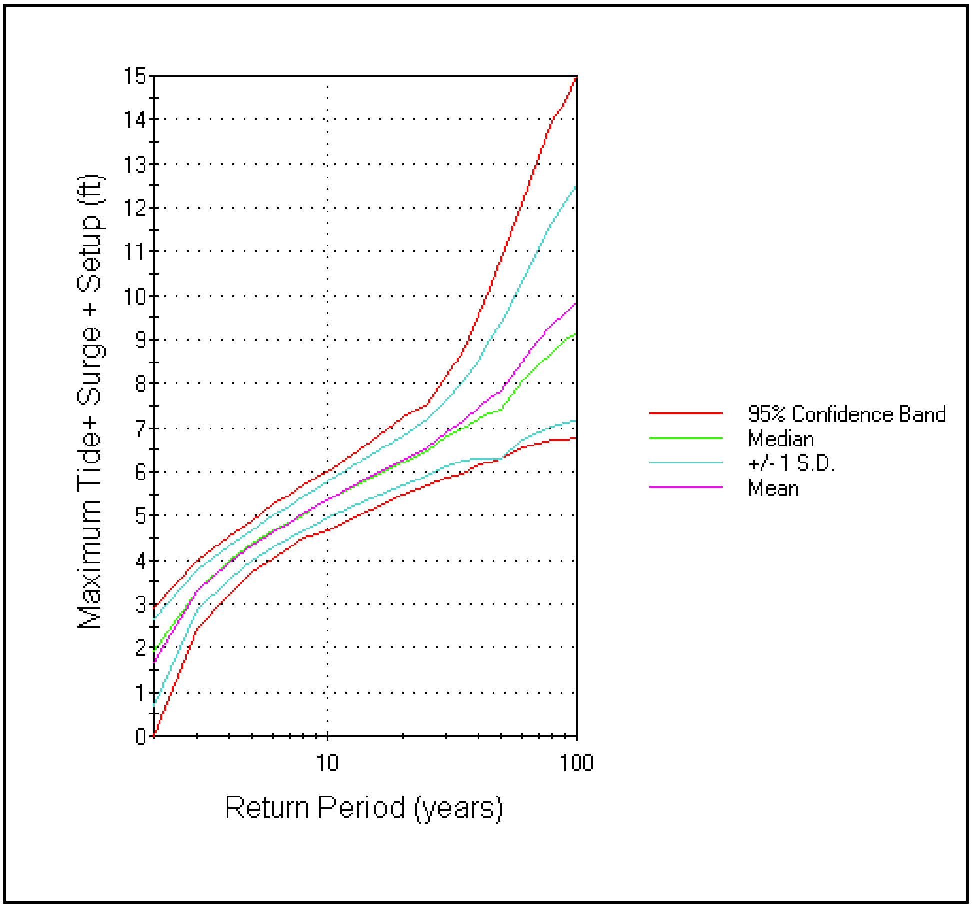

Figure 102. Stage frequency curve for setup elevation.

A comparison of the two hand calculated results is shown in table 15. The set up elevation with the base elevation from ADCIRC added in is shown in table 16 and compared with the SBEACH results. The calculated difference in water elevation between SBEACH and the hand calculations for the 20, 50, and 100-year events varies between 5 and 23 inches.

Table 15. Comparison of the two hand calculated results.

Equation	**20-Year Wave Set Up [feet]**	**50-Year Wave Set Up [feet]**	**100-Year Wave Set Up [feet]**
CEM	3.3	3.7	4.0
Komar	4.26	4.5	4.7

Table 16. Set up elevation with the base elevation from ADCIRC added in

Water Elevation ADCIRC + Wave Set Up	**20-Year Water Elevation [feet]**	**50-Year Water Elevation [feet]**	**100-Year Water Elevation [feet]**
CEM	6.5	7.5	8.0
Komar	7.4	8.1	8.7
SBEACH	6.5	7.9	9.9

8.4.2 Run-Up For Flood Protection Structure

The run up associated with the natural beach slope was presented earlier as part of the SBEACH analysis for coastal flooding. SBEACH is not able to calculate run up associated with a permeable stone structure, so hand calculation methods were used to determine the run up on a stone structure. The run up associated with a permeable coastal protection structure was calculated using methods described in the Coastal Engineering Manual.

Shore protection for flooding is set back from the near-shore environment, so the calculation of run up was made using shallow water assumptions. The larger waves will have broken by the time they reach the toe of the structure, so the significant wave height used for calculations was the maximum wave height that could be sustained at the toe of the structure with the associated water level described above using the relationship:

$H_{b/}h_b = 0.78$

Where H_b = breaker height

h_b = water depth below the still water line at the wave crest at incipient breaking.

Run up was calculated using methods for a rock armored surface shown in the Coastal Engineering Manual. The run up elevation was added to the SBEACH water elevation in table 16 to obtain a minimum structure elevation for the 20, 50, and 100-year flood event. The minimum elevations necessary for flood protection are presented in table 17.

Table 17. Total Water Level in the Low Lying Area (Tide + Surge + Set Up + run up)

Equation	20-Year Wave Run Up [feet]	50-Year Wave Run Up [feet]	100-Year Wave Run Up [feet]
CEM	9.5	12.5	14.0

8.4.3 Run Up For Revetment

Although the bluff area is not susceptible to flooding because of the natural elevation, wave run up is equally important in the protection of the bluff from erosion. The fine material that comprises the bluff is extremely susceptible to erosion from wave action and run up that could remove the fine material.

The revetment elevation to protect from tide + surge + set-up + run up was calculated in the same manner as for the flood protection elevation described above. The profile used for this analysis was transect 18. The results of this analysis are shown in table 18.

Table 18. Total Water Level in the Bluff Area (Tide + Surge + Set Up + run up)

Equation	20-Year Water Level [feet]	50-Year Water Level [feet]	100-Year Water Level [feet]
CEM	14.5	18.5	20.0

Total water elevation on the structure in the bluff area is generally higher than the total water elevation on the structure in the flood protection area. The beach is generally narrower in the bluff area, which results in a structure that is closer to the shoreline; therefore, larger waves can reach the bluff with an accompanying higher run up. This is why the water elevations for the bluff area are higher than the elevations for the low-lying area.

8.4.4 Design Wave

The armor stone was sized for a depth-limited wave impacting the toe of the structure. To accommodate the uncertainty associated with a decreasing ice season and a potential increase in storm activity, the 95 percent Confidence Interval associated with the 50-year water level that included the tide + surge + wave set up from SBEACH was used for the water level rather than the mean water level. This was superimposed on the 2003 transect survey elevation to determine the maximum wave height that could impact the structure. The water depth at the toe of the structure yields a maximum potential breaking wave at the toe of the structure of 8 feet.

8.4.5 Revetment Design

The revetment design for shore protection uses a multilayer design with two layers of armor stone, and under layers of B stone, core, gravel, and filter fabric to obtain the proper filtering so beach material will not pipe through the structure.

Armor Stone. Using Hudson’s equation for the largest breaking wave of 8 feet and a Kd of 2 results in armor stone size of 2.7 tons. In addition to wave forces, any structure placed along the coast at Barrow is also going to be subject to ice forces. The survivability of a rock structure along the coast during an ivu event was studied using a physical model at the Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire.

A series of four model tests was conducted in the Test Basin of the Ice Engineering Facility at CRREL to simulate the impact of ice shoves from the Arctic Ocean on the proposed coastal protection structure. Ice shoves originating from the Arctic Ocean have long been observed to occur along the shoreline at Barrow, Alaska. The objective of the model tests was to assess the integrity of the proposed structure under the impact of the ice shoves by determining the stability of the stones. A review of available data on ice conditions in the Arctic Ocean off Barrow indicated that representative ice covers are on the order of 5 feet thick and have a flexural strength of 600 kPa.

A 20:1 undistorted model of the proposed armor stone revetment and the immediate shoreline was constructed. The model reproduced approximately 394 feet of shoreline and covered the distance from the mean water line to the back of the revetment.

The model was supported on a rolling platform with eight wheels and was pushed by the test basin carriage (figure 103) against the stationary ice. Each test represented approximately 1,968 feet of prototype ice being driven up the shoreline against the structure. Elevation profiles of the revetment were measured before and after each test. To increase the number of variations that could be evaluated, the revetment length was split in half so that one configuration could be built on one half and a second configuration could be built on the other side. To enable the tests to be independent of each other, the ice sheet was cut down the middle prior to testing, and an aluminum template extended out from the center of the structure to ensure that each half of the ice sheet was separate before impacting the structure. The stone placement method: random or selective, the size of the stones, and the toe configuration were varied between tests. Selective placement of the stones to interlock and support each other provided a much greater degree of stability during ice shoves than random placement. The size and placement of the stones at the toe of the revetment was also found to be important in the survivability of the revetment.

Figure 103. Revetment test section being pushed by carriage.

The first test was a test of armor stone sized for wave action. The armor stone was randomly placed. Results of the test indicated that the armor stone sized for waves was under sized to withstand damage during an ice shove event. The armor was heavily damaged during testing.

The second test conducted compared the survivability of 8-ton stone with selective versus random armor placement. The selective placement survived with some damage, while the random placed armor suffered heavy damage. The damage appeared to start at the toe and once the ice sheet was flexed, the damage was minimal.

The third test was conducted to determine if the stone size could be decreased if heavy toe stones were incorporated into the structure to flex the ice sheet. This test evaluated selectively placed 4-ton stone slopes with 8-ton and 13-ton toe stones. A single layer of 13-ton and 8-ton toe stones were used for this test. The revetment with the 8-ton toe stones sustained heavy damage during the test while the revetment with the 13-ton toe stones was damaged, but survived.

The fourth test evaluated 4-ton stone and 8-ton stone on the structure slope with four different toe configurations. To look at more toe stone variations, each half of the revetment slope was built with two different toe stone configurations, so a total of 4-toe stone configurations were examined (8-ton, 13-ton, and 20-ton toe stones). The revetment slope section with the best survivability during the tests was the selectively placed 8-ton stone slope with a 13-ton toe. The 8-ton stone slope with an 8-ton toe sustained damage that would require slope repair. The 8-ton stone slope with the 13-ton toe stone sustained damage to a section of the toe that would need repair, but the bottom layers of the toe stone stayed in place and there was minimal movement on the revetment slope. The entire 4-ton stone slope survived, but experienced movement and dislodged stones. None of the revetments tested in the fourth tests were considered failures; however, when the results are translated to prototype, three of the revetments would require extensive maintenance, and the fourth would require minor maintenance (replacement of top toe stone layer). The idealized cross section that had the best survivability and least subsequent maintenance is shown in figure 104. Before and after pictures from the testing are shown in figures 105 and 106.

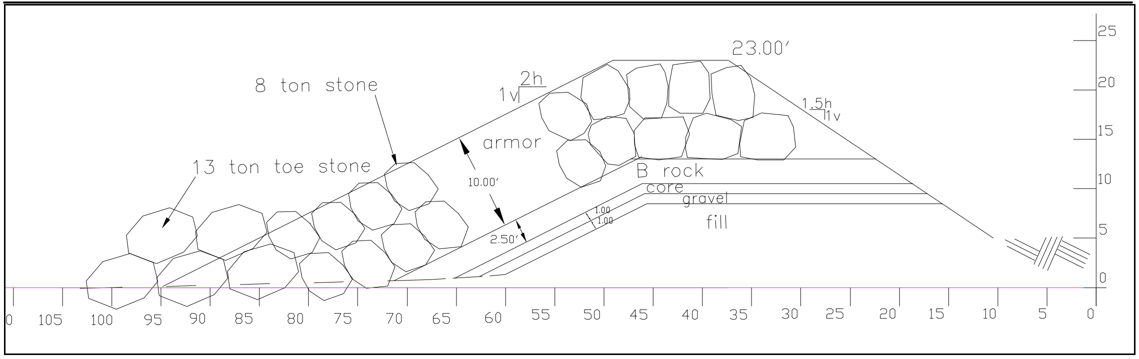

Figure 104. Idealized cross section from ice tests with best survivability from physical model.

Many uncertainties were associated with ice testing. The recurrence interval of ivus and ice strength during an ivu are major variables. The length, speed, and duration of an ivu are also not well documented. The tests were designed to impact the ice with a uniform strength for the entire length of the ice sheet; however, this was difficult to achieve as the far end of the cold room was generally cooler than the front end. Random tests indicated that the ice at the back of the cold room was stronger than the front.

The results of the physical model testing provided data to size the armor stone for minimum maintenance due to ice impact. Test results highlighted the importance of the structure toe when it is set back from the beach. The toe is the first element to be impacted by the ice and to cause significant ice deflection. Because of the critical nature of the toe, the smaller stone comprising the filter layers under the armor are to be buried to prevent them from being gouged out by the ice. Burying the filter layers leaves the armor toe stone as the initial impact surface with the ice to begin flexure.

Sizing the stone to withstand ice impact results in an armor layer that is oversized for waves. It also set the minimum structure height. Armor stone thickness is two stone widths, which results in a revetment elevation higher than the 50-year run up elevation along the low lying coast. In an effort to minimize the stone quantity and elevation, the B stone layer was reduced from two layers to one.

Figure 105. 8-ton armor stone (blue slope) with 13-ton toe (red toe stone) revetment before ice testing.

Figure 106. 8-ton armor stone (blue slope) with 13-ton toe (red toe) stone revetment after ice testing. Some toe stone moved during test, but the revetment slope stayed intact.

8.5 Structure Design

Three designs were pursued to determine which was most advantageous for coastal protection. A structure designed to withstand most ivu events was designed as well as a structure with armor stone sizing governed by wave height. A beach nourishment alternative was also evaluated assuming that gravel for nourishment would be imported.

8.5.1 Bluff Protection Governed By Ice

The revetment along the bluff area would consist of two layers of armor stone on the structure slope (figure 107). The stone size was obtained from ice testing. The toe of the structure would consist of five 13-ton stones that transitioned into an 8-ton stone slope. The B rock would be a single layer sized to filter 13-ton stone on the toe and 8-ton stone on the slope. The B rock, core, and gravel filter layers would be buried to match the existing beach elevation. The crest height was set 0.5 foot higher than the 50-year run up to keep the run up from impacting the backing bluff. The bluffs would not be excavated to provide a uniform slope on which to build; rather they would be dressed with fill material to achieve a uniform slope. The bluffs are archaeologically rich, so no excavation would be permitted on the bluff face.

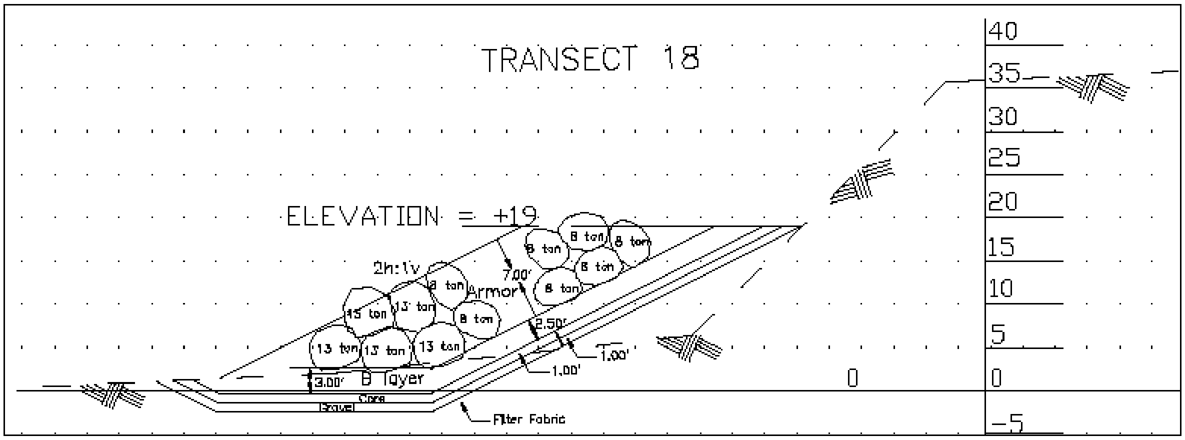

Figure 107. Bluff erosion protection with armor sized for ice protection.

8.5.2 Bluff Protection Governed By Waves

Revetment. The revetment along the bluff area would consist of two layers of 2.7-ton armor stone on the structure slope and two layers of B stone (figure 108). The B rock, core, and gravel filter layers would be buried to match the existing beach elevation. Similar to the revetment design for ice, the crest height was set at 19 feet, which is 0.5 foot higher than the 50-year run up. The bluffs would not be excavated to provide a uniform slope on which to build, rather they would be dressed with fill material to achieve a uniform slope. The bluffs are archaeologically rich, so no excavation would be permitted on the bluff face.

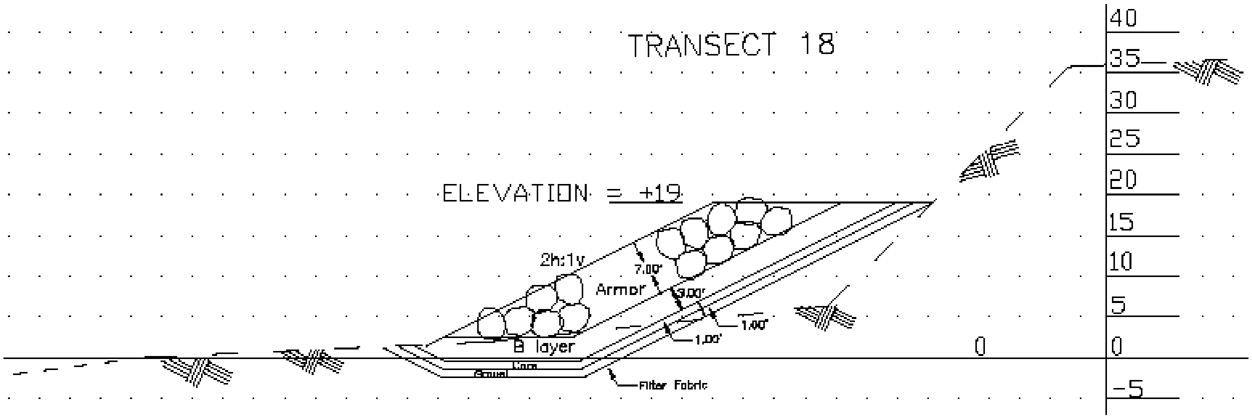

Figure 108. Bluff erosion protection with armor sized for wave protection.

Nourishment. Figure 109 shows a design for beach nourishment in the bluff area. The fill would extend to a maximum height of +19 feet or the top of the bluff/dune, whichever was higher. The volume of fill would be dependent on the length of bluff/dune to be protected. The cross section is based on the fill needed to raise the beach 5 feet with a depth of closure assumed at -17 feet for the high bluff area. This is the depth at which the bathymetry begins to increase and an offshore bar is present. The depth of closure is assumed to be -19.5 feet based on interpretation of the offshore cross sections as the bluffs reduce in elevation to dunes to the northeast and the offshore bar moves deeper. Alternatives for different lengths of protection and the associated initial nourishment and renourishment intervals are shown in table 19. The renourishment interval is based on the gross sediment transport estimates for the length of beach proposed for protection. This conservative renourishment estimate was used because of the narrow beach, shoreline analysis indicating that this area has not stabilized, the unknown effects on sediment transport of ice reworking the beach, and the transport associated with ice freezing to the beach material. The initial nourishment to increase the beach elevation 5 feet and the associated renourishment intervals are shown in table 19.

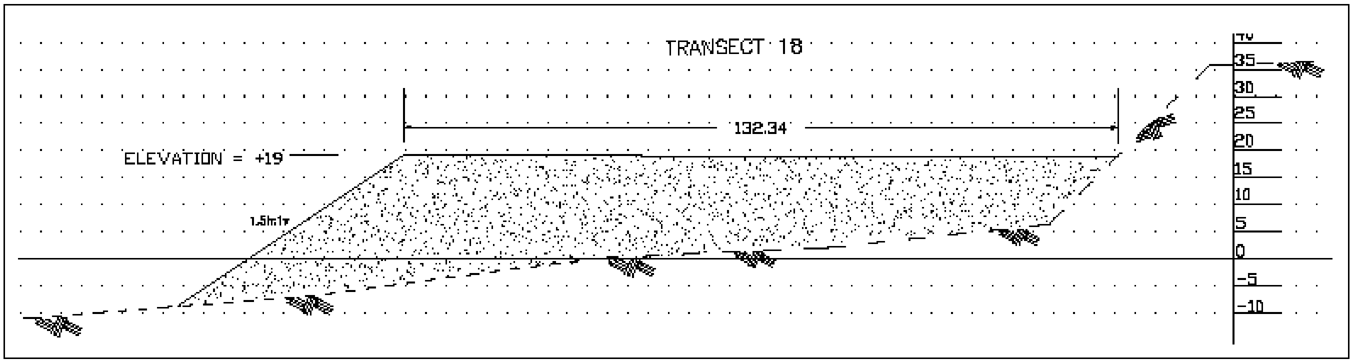

Figure 109. Preliminary beach fill design for bluff area.

Table 19. Nourishment Scenarios

Transects	Initial Nourishment Volume [cy]	Renourishment Interval [yr]	Renourishment Amount [cy]
17-22	191,000	5	91,000
22-24.625	139,000	2	39,000
22-27	265,000	8	165,000

8.5.3 Low Lying Coast Protection Governed By Ice

Revetted Berm Sized for Ice Impact. Coastal flooding at Barrow is the result of the combination of tide, surge, wave set up, and wave run up, with wave run up being the water level increase that results in flooding. The coastal flood protection revetted berm is designed to address flooding by reducing wave run up energy.

Wave run up elevations associated with a porous structure were calculated and described previously. The 50-year run up elevation is 12.5 feet and the 100-year run up elevation is 14 feet, but the crest height of the revetted berm is determined by the average stone diameter (figure 110). Because the structure is set back from the beach, a two-armor-stone thickness would result in a 15-foot crest elevation. The filtering B layer, core, gravel, and fabric would be placed below the natural beach line for ice survivability. The stone size was obtained from ice testing; however, the structure design is smaller than the physical model tested. The seaward side of the structure would consist of five 13-ton stones that transition into an 8-ton stone backside. The reduced size of the structure would likely result in increased maintenance due to extreme ice impact events, but the reduced size would make the structure easier to maintain. A stockpile of replacement stone would be kept at Barrow for maintenance activities. The B rock would be a single layer that is sized to filter 13-ton stone on the front of the structure and 8-ton stone on the back. The B rock, core, and gravel filter layers would be buried to match the existing beach elevation.

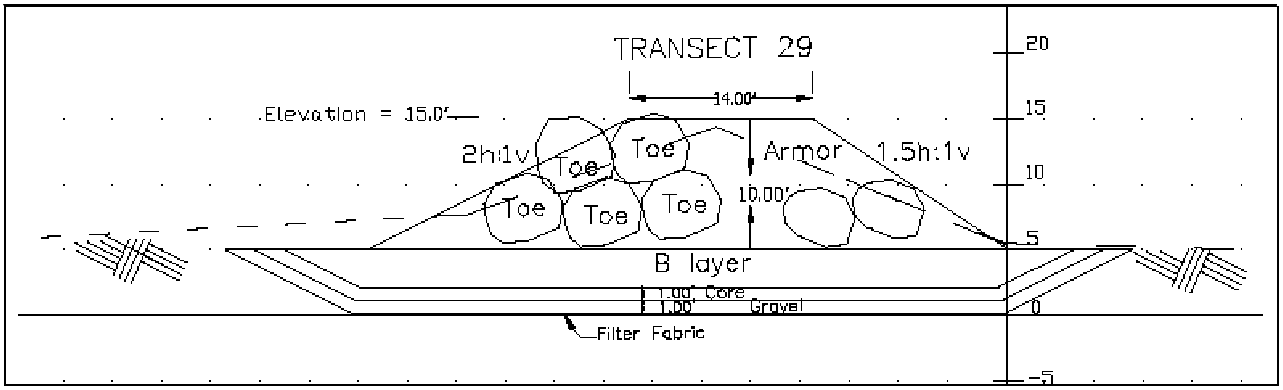

Figure 110. Flood Protection revetted berm sized for ice.

8.5.4 Low Lying Coast Protection Governed By Waves

Revetted Berm Structure. The structure described above could be reduced in size if it was sized to withstand wave, but not ice impact (figure 111). The structure would have higher maintenance associated with ice shove events, but would have a smaller footprint. The wave run-up on a porous structure along the coast was calculated as described previously and the 50-year and 100-year run up elevations are 12.5 feet and 14 feet, respectively. As with the design for ice, the crest elevation of the structure is determined by the average stone diameter. A two-armor stone and B layer thickness results in a 14.5-foot crest elevation. The structure will consist of two layers of 2.7-ton stones with a 2 horizontal on 1 vertical seaward slope and 1.5 horizontal on 1 vertical landward slope. The reduced size of the structure will likely result in increased maintenance due to ice impact, but the reduced size would make the structure easier to maintain, and a stockpile of replacement stone would be kept at Barrow for maintenance activities. The B rock would be a double layer placed on a 1-foot layer of core, 1-foot layer of gravel, and an underlayment of filter fabric. The B rock, core, and gravel filter layers would be buried to match the existing beach elevation.

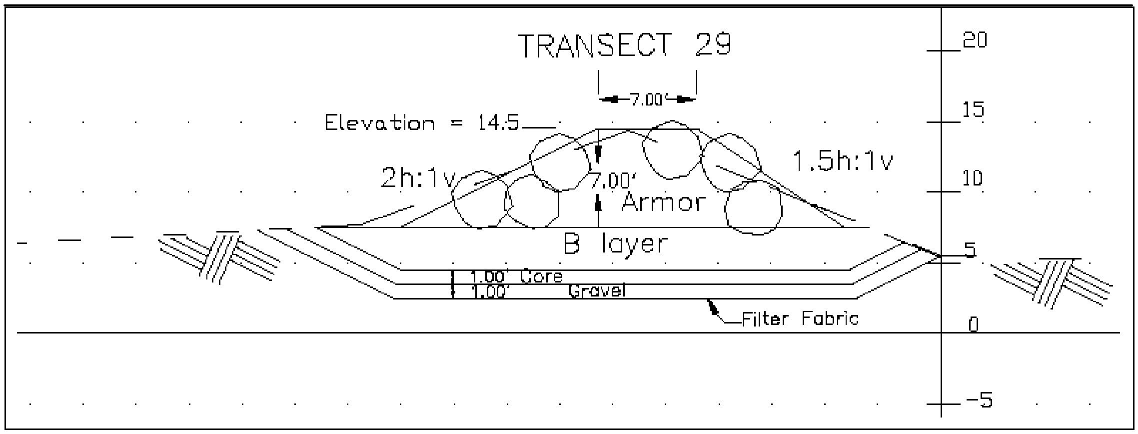

Figure 111. Flood Protection Structure sized for waves.

Nourishment. Figure 112 shows a design for beach nourishment. The fill would extend to the height required for flood protection. The length of beach fill and the associated height of fill for different levels of protection are shown in table 20. The volume is based on the fill needed to raise the beach 1 foot, 3 feet, 5 feet, and 7 feet. The cross section shown in figure 111 is the profile for raising the beach 3 feet. The depth of closure is assumed to be -19.5 feet. This is the depth at which the bathymetry begins to increase and an offshore bar is present. The renourishment interval is based on the gross sediment transport estimates distributed over the entire length of beach proposed for flood protection and is triggered when the nourishment volume left on the beach is equal to 5 years of transport. This estimate is less conservative than the beach nourishment estimate for the bluff area because the beach is wider in this area and the wave energy would be dissipated more effectively over a wide beach. The effects on sediment transport of ice reworking the beach and the transport associated with ice freezing to the beach material are unknown. The initial nourishment to increase the beach elevation 5 feet and the associated renourishment intervals are shown in table 20.

An alternative to the 8-foot protection level between transects 27 and 31.5 is to fill in the lagoon fronting the beach and relocate farther inland the road fronting the lagoon. Filling in the lagoon had been proposed as a drainage solution by the North Slope Borough when looking at drainage issues associated with a beach structure. Currently, a channel is created every spring to allow excess melt water to drain from the middle lagoon. Once the lagoon is drained, the road is rebuilt to cover the channel. The North Slope Borough proposed filling the front lagoon and indicated they would pump the middle lagoon to achieve the desired water level in the spring. Filling in the first lagoon to an 8-foot elevation would remove the flooding issues associated with run up in that area. Assuming that the bottom of the lagoon is at 0 feet, an 8-foot fill in that area would require approximately 250,000 cubic yards of material (includes 25% for fluff). Since this would not be beach fill material, local material sources could be used for the fill and road construction.

Table 20. Nourishment Scenarios

Transects	Protection Level [feet]	Initial Nourishment Volume [cy]	Renourishment Interval [yr]	Renourishment Amount [cy]
27-31.5	8	48,000	6	26,000
24.6-31.5	10	218,000	27	184,000
22-33	12	581,000	48	526,000
22-43	14	1,553,000	69	1,448,000

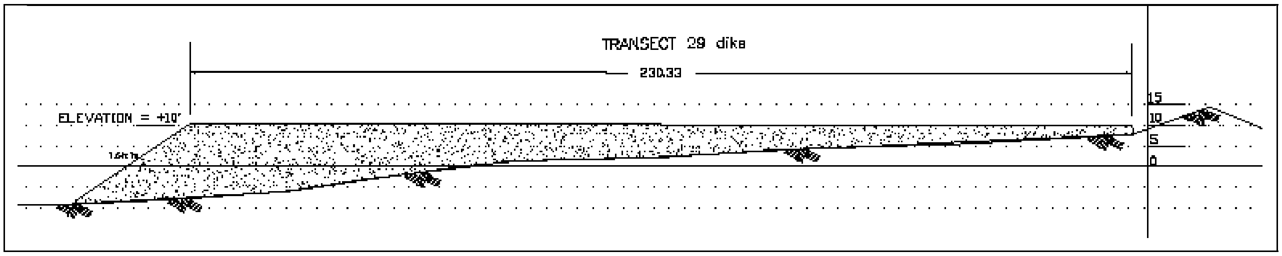

Figure 112. Preliminary beach fill on low lying beach.

8.5.5 Drainage

Upland runoff drainage is currently accomplished by diverting water runoff through pipes that end on the beach and by naturally cut drainages through the dunes. The selected alternative would maintain the current drainage pattern and drain the runoff through the coastal structure using a culvert. Naturally cut drainage swales would be filled with coarse gravel and be allowed to gravity drain.

The beach fronting Isatkoak Lagoon would require special consideration. Current practice is to open a channel from the lagoon to allow overflow water from the lagoon to drain. This is done in the spring when water from melting ice and snow run into the lagoons. Construction of a project across the beach would impede the current drainage practice. Discussions with the North Slope Borough indicated that a culvert with a valve to release the water is impractical because the pipe and valve would likely be frozen when it is time to drain. A heat traced pipe would be subject to maintenance requirements. The North Slope Borough proposed filling in Isatkoak Lagoon and pumping the second lagoon to reduce the water elevation. An evaluation of that alternative found it to be simplest and least prone to failure. It is estimated that 250,000 cubic yards of fill material would be needed to fill to first lagoon.

A coastal protection structure north of the lagoon would be higher in elevation than the road. In this area the structure could impede the existing drainage pattern. This section of project would incorporate a drainage system into the project that would consist of construction of a drainage swale to a culvert that penetrates the structure.

9.0 ALTERNATIVES CONSIDERED IN DETAIL

9.1 General

Alternatives that provided different levels of protection were considered for storm damage reduction at Barrow. The extents of the structural alternatives considered are shown in figures 113 through 115. Material volumes and maintenance intervals associated with each alternative are shown in table 22. Along the low-lying area, the levels of protection were based on the elevation of the structure and where it tied into existing contours. Along the coastal bluff section, the levels of protection were based on the length of coastline to be protected.

Sections of the revetment structure get very close or into the water edge due to the narrowed beach. In these areas it is possible that sediment would accrete around the toe of the structure. Once the accretion at the base of the structure reached an equilibrium point, the normal sediment transport process would continue.

9.2 No Action

This alternative would leave the city susceptible to the effects storms. The bluff would continue to erode, the low-lying areas would continue to flood, and the city would continue to fight to save the shoreline during storm events.

9.3 Non Structural

The non-structural alternative would consist of relocating buildings and utilities away from the eroding bluff line for erosion protection. The distance back from the eroding bluff should be based on social, local, and economic considerations. Set back distances for 10, 25, and 50 years is shown in table 21. The “hot spot” erosion rate of 2.2 feet/year was used as a chronic erosion rate since it not possible to accurately characterize the episodic erosion that is experienced by the coastal bluffs. An example of the 50-year erosion line is shown in figure 79.

Table 21. Bluff erosion distances.

10 Years	22 feet
20 years	44 feet
50 years	110 feet

Flood protection could be achieved by raising or relocating lower elevation buildings and utilities. This would not protect property stored outside on the ground such as boats, snow machines, ATVs, cars, and/or trailers. The minimum elevation to raise the structures and utilities should consider the social, local, and economic issues associated with any action and be based on the flood exceedence probabilities and stage frequency flood plots in table 12 and figures 86 to 99.

9.4 Bluff Protection

This alternative would reduce the effect of erosion on the bluff during storm events but would not alleviate the damages incurred from flooding. It could protect the bluff with the highest concentration of structures and the bluff with the archaeologically significant house pits from wave erosion. There would be no insulation of the upper bank.

9.5 Flood Protection

This alternative would reduce the effect of flooding on the low lying areas during storms. This alternative would not protect the bluff with the archaeologically significant house pits.

The availability of material to construct a storm damage reduction structure is the limiting factor with those two options. Stone is not available locally. Gravel is available locally but is mixed with a large amount of sand and fines. It is assumed that all construction material, with the exception of the fill, will be imported. The fill material can be supplied by local sources.

The volume of material needed for flood protection is directly related to the area selected for storm damage reduction. Protection from flooding due to run up corresponds to shore elevation. The proposed flood protection project would raise the lower shore elevation and tie into the higher corresponding shore elevation. Four levels of shore protection were evaluated based on increasing the shore side elevation to tie into existing contours: protection to 8 feet, 10 feet, 12 feet, and 14 feet. The protection consists of a revetted berm structure that would dissipate the wave run up and prevent flooding due to run up.

9.6 Maintenance

The frequency and severity of ivu events is generally limited to photographs and personal accounts. Statistics on the frequency of occurrence and associated ice strength, length of ice impact, and duration of shove events has not been developed, and currently, there is not enough data to develop these statistics. Ivu events will be the primary reason for revetment and/or revetted berm maintenance. In the absence of statistical information, an assumption was made that regardless of the alternative chosen, maintenance in the form of rebuilding a section of revetment or revetted berm would occur every 5 years and a stockpile of stone would be maintained at Barrow to support the maintenance. For the armor stone sized for ice, the maintenance length was assumed to be 1,200 feet. For the armor stone sized for wave, the maintenance length was assumed to be 2,000 feet.

Figure 113. Extents of alternatives.

Figure 114. Close Up of Erosion Protection Extents.

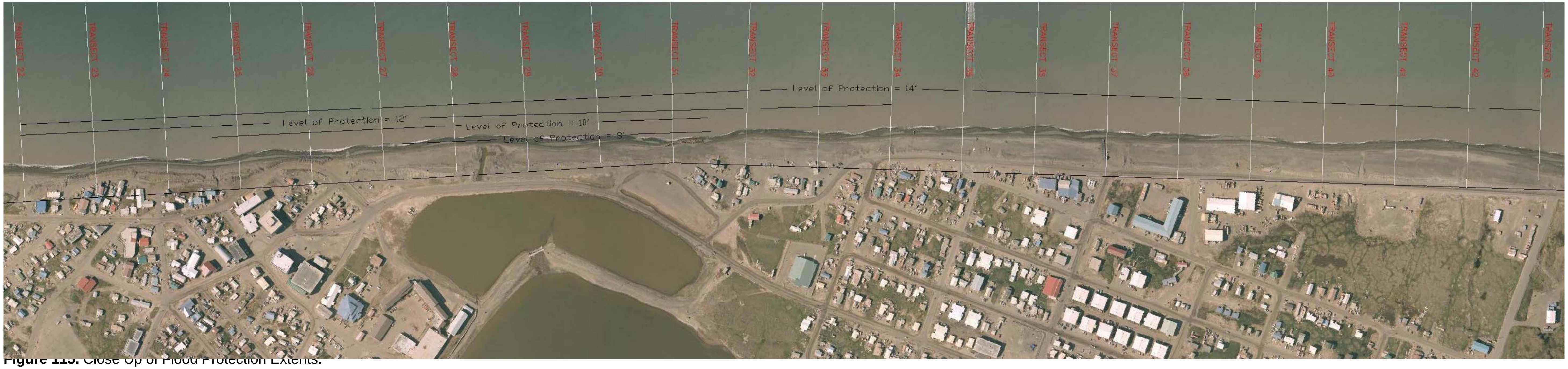

Figure 115. Close Up of Flood Protection Extents.

Table 22. Erosion Alternative Summary.

Armored Revetment Coverage Area	Type of Protection	Armor [cy]		B Rock [cy]		Core [cy]	Gravel [cy]	Filter Fabric [sy]	Fill [cy]	Maintenance Interval / Length	Maintenance Armor [cy]	Maintenance B Rock [cy]	Maintenance Core [cy]
Transects 17-22	Armor sized for waves	15,800		12,400		4,700	5,100	15,600	4,800	5 years / 2000 feet	8,700	7,900	3,500
Transects 22-24.625	Armor sized for waves	7,100		5,900		2,300	2,500	7,700	1,600	5 years / 2000 feet	7,100	5,900	2,300
Transects 22-27	Armor sized for waves	11,200		9,600		4,400	4,100	13,300	1,600	5 years / 2000 feet	8,700	7,900	3,500
Transects 17-22	Armor sized for ice	*8 ton*	*13 ton*	*1,600 lb*	*2,600 lb*	4,900	5,200	16,400	4,800	5 years / 1200 feet	14,000	6,700	2,800
		12,600	10,100	6,200	5,600								
Transects 22-24.625	Armor sized for ice	*8 ton*	*13 ton*	*1,600 lb*	*2,600 lb*	2,600	2,800	8,800	1,600	5 years / 1200 feet	11,800	5,800	2,600
		6,400	5,400	3,200	2,600								
Transects 22-27	Armor sized for ice	*8 ton*	*13 ton*	*1,600 lb*	*2,600 lb*	5,000	5,200	17,500	1,533	5 years / 1200 feet	14,000	6,700	2,800
		13,100	11,200	6,000	5,400								

Beach Nourishment Coverage Area	Type of Protection	Initial Nourishment [cy]	Assumptions	Maintenance Interval	Maintenance Nourishment [cy]	Maintenance Assumptions
Transects 17-22	Beach Nourishment	190,400	All beach nourishment scenarios assume raising the beach 5 feet and depth of closure at -17 feet in bluff area and -19.5 feet where bluffs reduce to dunes	5 years	90,400	Maintenance is triggered when 5 years of nourishment is remaining on the beach
Transects 22-24.625	Beach Nourishment	138,700		2 years	38,700	
Transects 22-27	Beach Nourishment	264,100		8 years	164,100	

Table 21. Flooding Alternative Summary

Revetted Berm Extent	Type of Protection	Armor [cy]		B Rock [cy]		Core [cy]	Gravel [cy]	Filter Fabric [sy]	Excavation [cy]	Maintenance Interval / Length	Maintenance Armor [cy]	Maintenance B Rock [cy]	Maintenance Core [cy]
Transects 27-31.5	Armor sized for waves; protection level* = 8 feet	7,800		7,100		3,100	3,400	11,000	4,800	5 years / 2000 feet	8,700	7,900	3,500
Transects 24.625-31.5	Armor sized for waves; protection level* = 10 feet	12,000		10,900		4,700	5,100	16,900	21,652	5 years / 2000 feet	8,700	7,900	3,500
Transects 22-33	Armor sized for waves; protection level* = 12 feet	22,000		19,200		8,100	8,800	26,900	37,700	5 years / 2000 feet	8,700	7,900	3,500
Transects 22-43	Armor sized for waves; protection level* = 14 feet	39,400		34,900		14,900	16,200	51,400	69,100	5 years / 2000 feet	8,700	7,900	3,500
Transects 22-43	Armor sized for ice shove (ivu); protection level* = 14 feet	*8 ton*	*13 ton*	*1,600 lb*	*2,600 lb*	19,800	21,000	70,000	90,900	5 years / 1200 feet	11,800	5,800	2,600
		48,000	51,400	22,800	23,200								
		13,100	11,200	6,000	5,400								

Beach Nourishment Coverage Area	Type of Protection	Initial Nourishment [cy]	Assumptions	Maintenance Interval	Maintenance Nourishment [cy]	Maintenance Assumptions
Transects 27-31.5	Beach Nourishment raise beach 1 foot; protection level 8 = feet	47,600	All beach nourishment scenarios assume depth of closure at -19.5 feet	6 years	25,100	Maintenance is triggered when 5 years of nourishment is remaining on the beach
Transects 24.625-31.5	Beach Nourishment raise beach 3 feet; protection level = 10 feet	217,900		27 years	183,500	
Transects 22-33	Beach Nourishment raise beach 5 feet; protection level = 12 feet	581,000		48 years	526,000	
Transects 22-43	Beach Nourishment raise beach 7 feet; level of protection 14 feet	1,552,800		69 years	1,447,800	

*Protection level refers to the increase in shoreside elevation to provide protection from flooding due to run-up to the referenced elevation.

10.0 CONSTRUCTION CONSIDERATIONS AND MAINTENENCE

Construction of a storm damage reduction structure would rely heavily on imported material. Armor stone, B rock, core, and gravel would be imported. There is a limited window during the ice-free season in which barges are able to access the site. All work would need to be performed from the beach. Archaeologically significant sites are located in the construction area so no shore side construction would be allowed, and excavation into the bluffs would be prohibited. All slope grooming would need to be performed using fill material to achieve a desired slope. There would be some excavation into the beach for construction that would have to be supervised by an archaeologist.

The project would need to be inspected for damage at least twice annually. One inspection would need to occur after the snow and ice melts and a second in the fall before freeze up. There would also need to be post storm inspections to check the condition of the structure toe and any displaced material. It is imperative that these inspections be performed to have adequate time to repair damage before winter. Because of the short window in which material can be brought to the site, a stockpile of armor stone, B rock, and core would be left at Barrow to have material on hand should repairs be necessary. The beach fill options assume that renourishment would take place when there is 5 years of nourishment material left.

11.0 RISK AND UNCERTAINTY

The analysis performed for this appendix used historical information to assess wind, waves, currents, sediment transport, and ice development at Barrow. Risk and uncertainty that directly affect this project are annual maintenance requirements due to increased storm frequency. The information gathered and analysis presented is the best data available.

In recent years evidence has suggested that the Arctic environment is experiencing a warming trend. The magnitude, duration, and effect of a warming trend is not known; however, the Office for Naval Research, the Naval Ice Center, the Oceanographer of the Navy, and the Arctic Research Commission held a conference in 2002 that discussed the shrinking polar ice cap. They even indicated that the polar ice pack is projected to retreat to the extent that a new shipping route may be opened. While this would reduce the effect of ice on the coastal structure, it could result in an increase frequency of the large storms experienced in the Chukchi Sea. Waves impacting the structure would continue to be depth limited unless there is significant sea level rise. The proposed rock structure would be above the water line and available for visual inspection for damage from storms or ice.

Much of Alaska is undergoing a drop in sea level due to glacial rebound, but specific information on sea level at Barrow is lacking. A study of sea level change in the Russian sector of the Arctic Ocean indicates that sea level is rising at a rate of approximately 0.07 inch/year. Over a 50-year period that would contribute 3.5 to 4 inches of elevation. This would have a slight impact on the wave heights that could be supported and the anticipated flood elevation. This would be the lower range of sea level rise that could be experienced at Barrow. The Corps of Engineers has chosen to follow the recommendations of the National Research Council (NRC) as described in the publication *Responding to Changes in Sea Level: Engineering Implications* (NRC, 1987). This publication assumes three possible scenarios for eustatic sea level rise to the year 2100. These scenarios are described by the equation

$$E(t)= 0.0012t+bt^2$$

In which t represents years, starting in 1986, b is a constant, and E(t) is the eustatic sea level rise, in meters as a function of t. For the three scenarios proposed by the NRC, b is equal to 2.854E-5 for Curve 1, 6.770E-5 for Curve 2, and 1.069E-4 for curve 3. For a 50-year project life, a project at Barrow could see sea level as high as 2.1 feet. The upper level of sea level rise and the associated increase in depth limited wave height is accommodated by using the water level that corresponds to the 95 percent confidence interval when sizing the armor stone for waves.

The associated increase in run up due to sea level rise was not calculated, but with a stockpile being maintained on site, stone would be readily available to increase the structure height should an increase in water level be realized along the coast of the magnitude predicted by the NRC equations.

U.S. Army Corps of Engineers
Alaska District

Barrow, Alaska

Coastal Storm Damage Reduction Technical Report

Appendix B – Real Estate Plan

March 2007

Technical Report
Barrow, Alaska, Storm Damage Reduction

Appendix B – Draft Real Estate Plan

NOTE:

This Appendix was originally created as the Draft Real Estate Plan (REP) for an early version of the Draft Integrated Interim Feasibility Report and Environmental Impact Statement for Coastal Storm Damage Reduction at Borrow, Alaska. That document underwent Independent Technical Review. As a result of that review, basic hydraulic and economic analyses were redone, with the result that no alternative yielded positive National Economic Development benefits greater than the costs of implementing that alternative. Since there is no Federal action proposed in this Technical Report, there is no need for a formal Real Estate Plan. However, since the draft REP had compiled information on real estate, it is included for information only

REAL ESTATE PLAN
BARROW STORM DAMAGE REDUCTION PROJECT
BARROW, ALASKA
26 March 2007

1. Purpose

This study was authorized by a resolution adopted 2 December 1970 by the House Public Works Committee. The resolution, known as the "Rivers and Harbors in Alaska" resolution, reads in part:

> *Resolved by the Committee on Public Works of the House of Representatives, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the reports of the Chief of Engineers on Rivers and Harbors in Alaska, published as House Document Numbered 414, 83rd Congress, 2nd Session…and other pertinent reports, with a view to determining whether any modifications contained herein are advisable at the present time…*

The purpose of this study is to determine the Federal interest in providing storm damage reduction, flood damage reduction and navigation improvements at Barrow, Alaska; to identify a non-federal sponsor willing to share in the cost of the feasibility study; and to develop a Project Management Plan (PMP) for a feasibility-level study.

Barrow, the northern most community in North America and the economic center for the North Slope Borough, is located on the Arctic Ocean about 750 miles (mi) north of Anchorage, Alaska. Barrow is a first-class city with about 4,400 residents. The North Slope Borough, which includes almost all of Alaska north of the 68th Parallel, has a population of about 9,600 persons spread over 95,000 mi^2, an area about the size of the state of Oregon. The majority of residents are Inupiat Eskimos. Barrow is located on a southwest-northeast coastline of the Chukchi Sea about 10 mi southwest of Point Barrow, the northernmost point of land in Alaska (Figure 1). Point Barrow is located on a spit fronting Elson Lagoon and marks the boundary between the Chukchi Sea on the west and the Beaufort Sea on the east.

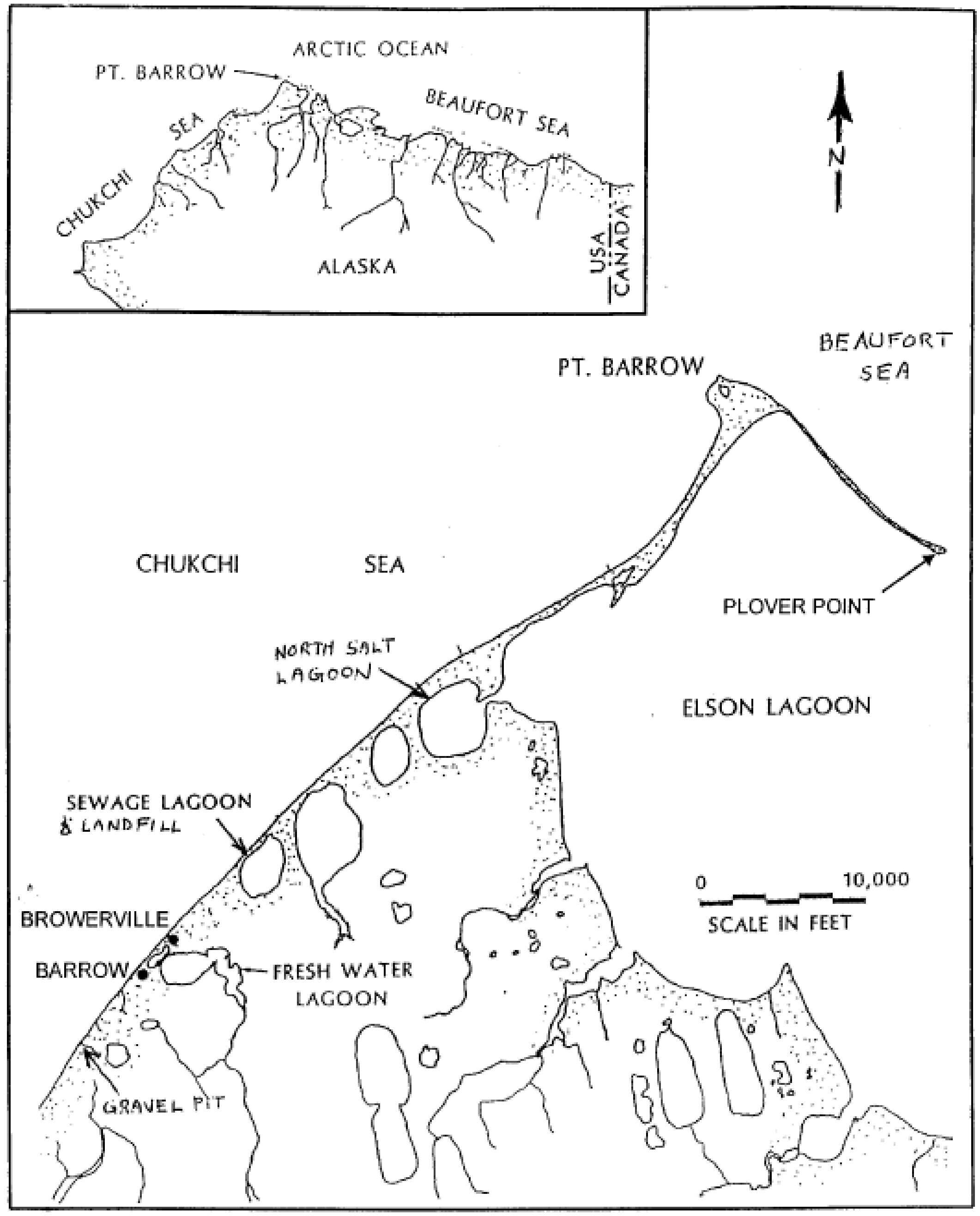

FIGURE 1. LOCATION MAP

2. Project Description

For the purposes of this study, the protection plan includes the entire 25,000 foot-long shoreline under attack, including Barrow, Browerville, and the sewage lagoon/landfill area. The construction of shore protection at the sites shown on figure 3 combined with the placement of nourishment and wave absorption beach fill shown at locations on the same figure should protect the City of Barrow, the sewage lagoon, and the landfill from erosion.

3. Real Estate Requirements for the Project:

Summary of Required Real Estate Interests for Storm Damage Reduction Revetment:

Project Feature	Areas Required	Owner	Estate Minimum
Revetment	14.62 acres	Municipal Public Private (5 lots)	Perpetual easement

A temporary construction staging area might be required but has not been identified at this time.

4. Within an existing Federal Project

There are no existing, authorized Corps of Engineers (Corps) or other Federal water projects within the proposed project area.

5. Federally/Government Owned Land included

There is no federally owned land included in the project area. There is local government land included in the project area.

6. LER below MHW/OHW – availability of Navigation Servitude

Navigation servitude is available however the MHW is 0.40 ft. Since it appears the project will lie entirely above MHW, navigation servitude may not need to be exercised.

7. Map of Project area is Attached as Exhibit A.

8. Potential flooding induced by construction, operation or maintenance of project

The intent of the project is to control flooding to low lying areas affected by storm surges.

9. Real Estate and Administrative Cost Estimate:

Table II
Federal project portions

Item	Federal	Local	Subtotal	Total
Administration	$50,000	$50,000	$000	$000
Real Estate Cost (Land)	-0-	$95,000	-0-	-0-

10. Relocation Assistance (PL 91-646)

There are no relocation assistant benefits anticipated for this project.

11. Mineral Activity

There is no known mineral activity occurring within the lands required for the project.

12. Non-Federal sponsor's acquisition experience: Assessment attached as Exhibit B.

13. Real Estate Acquisition Schedule:

Activity	COE	NFS
	Initiate – Complete	Initiate - Complete
Execution of PCA	1 day	
Formal transmittal of final ROW drawings to LS and instruction to acquire LER	1 week after PCA	
Mapping, legal descriptions, title evidence		3 months (minimum)
Conduct appraisals, negotiations & closing		6-9 months
Certify availability of LER for construction	1 week upon receipt of NFS certification	1 week upon completion of acquisition

14. Relocations (Facilities and Utilities)

There are no known facilities and/or utilities that will have to be relocated.

15. Environmental / HTW

There are no known hazardous and/or toxic waste on the land required for the project.

16. Known or Anticipated Support or Opposition of Landowners in project area

Based upon available information, landowner support appears to be good.

17. Other RE issues relevant to planning, design, or implementation of the project

Another alternative may be considered for relocation of the town.

U.S. Army Corps
of Engineers
Alaska District

Barrow, Alaska

Coastal Storm Damage Reduction Technical Report

Appendix C -- Cost Estimate

September 2008

APPENDIX C

COST ESTIMATE

Technical Report
for
Barrow, Alaska
Coastal Storm Damage Reduction

1.0 INTRODUCTION

This Cost Estimating Appendix describes the technical cost aspects of the Barrow Coastal Storm Damage Reduction study.

1.1 HISTORY

For the Preliminary Draft Interim Feasibility Report, the alternatives selected for further consideration consist of combinations of two initial alternatives, Coastal Dike and Bluff Revetment. The Coastal Dike portion was a 8,700-foot-long rock dike, with a crest of +20.5 ft (as shown in Figure 49 in Hydraulic Appendix), constructed of approximately 67,500 cubic yard (cy) of armor rock, 48,300 cy of B rock, 18,000 cy of core rock, and an estimated construction cost of $46.6 million. The Bluff Revetment portion was a 2,000-foot-long rock dike, with a top of rock of +15.0 ft (as shown in Figure 48 in Hydraulic Appendix), constructed of approximately 11,300 cy of armor rock, 10,000 cy of B rock, 3,400 cy of core rock and an estimated construction cost of $12.1 million. The two "action" alternatives considered were (1) Coastal Dike with full Bluff Revetment for 10,700-foot-long rock protection with an estimated construction cost of $53.3 million (full Coastal Dike cost but deleted MOB/DEMOB and 'Const. Temporary Dock' from Bluff Revetment costs), and (2) Coastal Dike with partial Bluff Revetment for 9,300-foot-long rock protection with an estimated construction cost of $48.8 million (full Coastal Dike cost but deleted MOB/DEMOB and 'Const. Temporary Dock' from Bluff Revetment costs and took 30% of remainder of Bluff Revetment costs). The quantities, cost and time calculations included gross cost estimates for providing public access to the shore, means of interior drainage through the dike, means of mitigating cultural concerns, and construction of maintenance material stockpile. They did not include provisions for possible changes in dike and/or bluff protection design (primarily rock size change) based on ice studies that were being performed at the time.

During the Independent Technical Review (ITR) phase, it was determined that: 1) the "modeling" method used to determine storm impacts overstated the impacts and benefits realized by the alternatives, and 2) understated the costs because low mobilization/demobilization, material, equipment, overtime, material placement, work duration, and escalation costs.

Post-ITR, the "modeling" method was revised, and 16 different alternatives were evaluated in an attempt to find a coastal flood and erosion protection method that had an acceptable cost-benefit ratio. They included protecting the coast to 4 different heights by either stone dike or beach nourishment, protecting the bluff along 3 different 'reaches' by stone dike, and 5 other options.

1.2 PROJECT COST SUMMARY

PRELIMINARY DRAFT INTERIM FEASIBILITY REPORT (PRE-ITR):

	Coastal Dike w/ full Bluff Revetment	Coastal Dike w/ partial Bluff Revetment
Construction Cost	$39.5 million	$36.3 million
Cultural Mitigation	$ 0.7 million	$ 0.7 million
Real Estate	$ 0.2 million	$ 0.2 million
Planning & Design	$ 4.0 million	$ 3.6 million
Construction Management	$ 3.2 million	$ 2.9 million
TOTAL	$47.6 million	$43.6 million
Stockpile Maint. Material	$ 7.0 million	$ 6.3 million

Specific Assumptions:

- Coastal Dike with full Bluff Revetment is 10,700 feet long constructed of approximately 78,800 cy of armor rock, 58,300 cy of B rock, and 21,400 cy of core rock. *{NOTE: Dike design change may affect quantities and project cost.}*
- Coastal Dike with partial Bluff Revetment is 9,300 feet long constructed of approximately 70,900 cy of armor rock, 51,300 cy of B rock, and 19,100 cy of core rock. *{NOTE: Dike design change may affect quantities and project cost.}*
- The gravel material will be obtained from local sources with a ten mile maximum haul distance.

TECHNICAL REPORT (POST-ITR):

Alternative No & Description	Const Costs	Total Initial Costs
#1 – Revetted Berm Sized for Waves (to 8’)	$ 19.506M	$ 24.591M
#2 – Revetted Berm Sized for Waves (to 10’)	$ 26.818M	$ 32.790M
#3 – Revetted Berm Sized for Waves (to 12’)	$ 45.845M	$ 53.876M
#4 – Revetted Berm Sized for Waves (to 14’)	$ 79.482M	$ 91.350M
#5 – Beach Nourishment to 8’ (Trns 27-31.5)	$ 23.166M	$ 28.488M
#6 – Beach Nourishment to 10’ (Trns 24.6-31.5)	$101.771M	$115.059M
#7 – Beach Nourishment to 12’ (Trns 22-33)	$219.535M	$244.387M
#8 – Beach Nourishment to 14’ (Trns 22-43)	$732.469M	$806.969M
#9- Revetted Berm for Ice (Transect 22-42)	$163.580M	$183.522M
#10- Revetment, Transect 17-22	$ 30.626M	$ 36.786M
#11- Revetment, Transect 22-24.625	$ 17.130M	$ 21.887M
#12- Revetment, Transect 22-27	$ 24.668M	$ 30.345M
#13- Revetted Berm for Ice (Transect 22-27)	$ 41.534M	$ 48.830M
#14- Beach Nourishment (Transect 22-27)	$124.560M	$139.867M
#15- Non-Structural (Elevate 10/Relocate 24)	$ 33.834M	$ 42.123M
#16- Fill Tasigrook Lagoon	$ 23.505M	$ 28.801M

Specific Assumptions:

- Alternates #1-9 would protect Transects ranging from 27-31.5 for 8’ contour up to 22-43 for 14’ contour, with varying quantities of materials and construction durations from 2 – 17 years.
- Alternates #10-14 would protect Transects ranging up to 17-27, with varying quantities of materials and construction durations of 2 years for each Alternatives #10-13 and 5 years for Alternative #14.
- Alternative #15 involves raising 10 buildings and relocating 24 buildings.
- Alternative #16 involves filling Tasigrook Lagoon to 8’ contour.
- The gravel material for Alternative #1-15 will be obtained from the quarry in Nome. The distance to transport these materials is estimated to be 600 sea miles one way from the jobsite. The gravel material for Alternative #16 will be obtained from a local quarry near Barrow.

1.3 COST ESTIMATE GENERAL ASSUMPTIONS

- The work is to be performed from the beach using earthmoving equipment.
- The rock materials will be provided from the quarry in Nome. The distance to transport these materials is estimated to be 600 sea miles one way from the jobsite.
- All equipment will be transported from Seattle to the job site, an assumed 3,287 sea miles.
- Crew will work 12 hours/day, 7 days/wk, for 4.5 months/yr for 2-17 years starting about 15 May each year.

****** TOTAL PROJECT COST SUMMARY ******

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study, DATED: JAN 2008

PROJECT: Barrow Erosion Control Feasibility Alternative #1 - Transect 27 - 31.5 Level of Protection = 8' Contour

LOCATION: Barrow, AK

DISTRICT: Alaska District

P.O.C.: Cost Estimator - John T. Dudgeon

	CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007						AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		4,536	907	20%	5,443		4,536	907	5,443			4,536	907	5,443
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC		106	21	20%	127		106	21	127			106	21	127
16 00 81	EXCAVATION		202	40	20%	242		202	40	242			202	40	242
16 00 81	CONSTRUCT GRAVEL FILL		1,313	263	20%	1,576		1,313	263	1,576			1,313	263	1,576
16 00 81	CONSTRUCT CORE ROCK		1,569	314	20%	1,883		1,569	314	1,883			1,569	314	1,883
16 00 81	CONSTRUCT B ROCK		3,917	783	20%	4,700		3,917	783	4,700			3,917	783	4,700
16 00 81	CONSTRUCT A ROCK		4,433	887	20%	5,320		4,433	887	5,320			4,433	887	5,320
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		179	36	20%	215		179	36	215			179	36	215
	TOTAL CONSTRUCTION COSTS ===>		16,255	3,251	20%	19,506		16,255	3,251	19,506			16,255	3,251	19,506
01---	LANDS AND DAMAGES	1.7%	322	64	20%	386		322	64	386			322	64	386
30---	PLANNING, ENGINEERING & DESIGN	10.3%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	1,720	344	20%	2,065		1,720	344	2,065			1,720	344	2,065
30---	CULTURAL MITIGATION	1.0%	195	39	20%	234		195	39	234			195	39	234
	TOTAL PROJECT COSTS ========>		20,492	4,098	20%	24,591		20,492	4,098	24,591			20,492	4,098	24,591
	STOCKPILE MATERIAL FOR MAINTENANCE		14,150	2,830	20%	16,980		14,150	2,830	16,980			14,150	2,830	16,980
	DIKE REPAIRS & RESTOCKPILING EVERY 5 YEARS		16,844	3,369	20%	20,213		16,844	3,369	20,213			16,844	3,369	20,213

****** TOTAL PROJECT COST SUMMARY ******

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study, DATED: JAN 2008

PROJECT: Barrow Erosion Control Feasibility Alternative #2 - Transect 24.625 - 31.5, Level of Protection = 10' Contour

LOCATION: Barrow, AK

DISTRICT: Alaska District

P.O.C.: Cost Estimator - John T. Dudgeon

			CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007				AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		4,536	907	20%	5,443		4,536	907	5,443			4,536	907	5,443
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC		163	33	20%	196		163	33	196			163	33	196
16 00 81	EXCAVATION		309	62	20%	371		309	62	371			309	62	371
16 00 81	CONSTRUCT GRAVEL FILL		1,989	398	20%	2,387		1,989	398	2,387			1,989	398	2,387
16 00 81	CONSTRUCT CORE ROCK		2,381	476	20%	2,857		2,381	476	2,857			2,381	476	2,857
16 00 81	CONSTRUCT B ROCK		5,962	1,192	20%	7,154		5,962	1,192	7,154			5,962	1,192	7,154
16 00 81	CONSTRUCT A ROCK		6,734	1,347	20%	8,081		6,734	1,347	8,081			6,734	1,347	8,081
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		274	55	20%	329		274	55	329			274	55	329
	TOTAL CONSTRUCTION COSTS ===>		22,348	4,470	20%	26,818		22,348	4,470	26,818			22,348	4,470	26,818
01---	LANDS AND DAMAGES	1.4%	372	74	20%	446		372	74	446			372	74	446
30---	PLANNING, ENGINEERING & DESIGN	7.5%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	2,305	461	20%	2,766		2,305	461	2,766			2,305	461	2,766
30---	CULTURAL MITIGATION	1.1%	300	60	20%	360		300	60	360			300	60	360
	TOTAL PROJECT COSTS ========>		27,325	5,465	20%	32,790		27,325	5,465	32,790			27,325	5,465	32,790
	STOCKPILE MATERIAL FOR MAINTENANCE		14,150	2,830	20%	16,980		14,150	2,830	16,980			14,150	2,830	16,980
	DIKE REPAIRS & RESTOCKPILING EVERY 5 YEARS		16,844	3,369	20%	20,213		16,844	3,369	20,213			16,844	3,369	20,213

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study, DATED: JAN 2008

PROJECT: Barrow Erosion Control Feasibility Alternative #3 - Transect 23 - 33, Level of Protection = 12' Contour
LOCATION: Barrow, AK

DISTRICT: Alaska District
P.O.C.: Cost Estimator - John T. Dudgeon

			CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007				AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		6,805	1,361	20%	8,166		6,805	1,361	8,166			6,805	1,361	8,166
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC		260	52	20%	312		260	52	312			260	52	312
16 00 81	EXCAVATION		537	107	20%	644		537	107	644			537	107	644
16 00 81	CONSTRUCT GRAVEL FILL		3,361	672	20%	4,033		3,361	672	4,033			3,361	672	4,033
16 00 81	CONSTRUCT CORE ROCK		4,035	807	20%	4,842		4,035	807	4,842			4,035	807	4,842
16 00 81	CONSTRUCT B ROCK		10,428	2,086	20%	12,514		10,428	2,086	12,514			10,428	2,086	12,514
16 00 81	CONSTRUCT A ROCK		12,311	2,462	20%	14,773		12,311	2,462	14,773			12,311	2,462	14,773
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		467	93	20%	560		467	93	560			467	93	560
	TOTAL CONSTRUCTION COSTS ===>		38,204	7,641	20%	45,845		38,204	7,641	45,845			38,204	7,641	45,845
01---	LANDS AND DAMAGES	0.8%	387	77	20%	464		387	77	464			387	77	464
30---	PLANNING, ENGINEERING & DESIGN	4.4%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	3,828	766	20%	4,593		3,828	766	4,593			3,828	766	4,593
30---	CULTURAL MITIGATION	1.0%	478	96	20%	574		478	96	574			478	96	574
	TOTAL PROJECT COSTS ========>		44,897	8,979	20%	53,876		44,897	8,979	53,876			44,897	8,979	53,876
	STOCKPILE MATERIAL FOR MAINTENANCE		14,150	2,830	20%	16,980		14,150	2,830	16,980			14,150	2,830	16,980
	DIKE REPAIRS & RESTOCKPILING EVERY 5 YEARS		16,844	3,369	20%	20,213		16,844	3,369	20,213			16,844	3,369	20,213

TPCS-Barrow Revetment Alt#3, 1-14-2008.xls

Printed: 5/23/2008

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study,

PROJECT: Barrow Erosion Control Feasibility Alternative #4 - Transect 22 - 43, Level of Protection = 14' Contour
LOCATION: Barrow, AK

DATED: JAN 2008
DISTRICT: Alaska District
P.O.C.: Cost Estimator - John T. Dudgeon

			CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007				AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		9,072	1,814	20%	10,886		9,072	1,814	10,886			9,072	1,814	10,886
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC		496	99	20%	595		496	99	595			496	99	595
16 00 81	EXCAVATION		985	197	20%	1,182		985	197	1,182			985	197	1,182
16 00 81	CONSTRUCT GRAVEL FILL		6,232	1,246	20%	7,478		6,232	1,246	7,478			6,232	1,246	7,478
16 00 81	CONSTRUCT CORE ROCK		7,477	1,495	20%	8,972		7,477	1,495	8,972			7,477	1,495	8,972
16 00 81	CONSTRUCT B ROCK		19,034	3,807	20%	22,841		19,034	3,807	22,841			19,034	3,807	22,841
16 00 81	CONSTRUCT A ROCK		22,054	4,411	20%	26,465		22,054	4,411	26,465			22,054	4,411	26,465
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		885	177	20%	1,062		885	177	1,062			885	177	1,062
	TOTAL CONSTRUCTION COSTS ===>		66,235	13,247	20%	79,482		66,235	13,247	79,482			66,235	13,247	79,482
01---	LANDS AND DAMAGES	0.6%	476	95	20%	571		476	95	571			476	95	571
30---	PLANNING, ENGINEERING & DESIGN	2.5%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	6,519	1,304	20%	7,822		6,519	1,304	7,822			6,519	1,304	7,822
30---	CULTURAL MITIGATION	1.1%	896	179	20%	1,075		896	179	1,075			896	179	1,075
	TOTAL PROJECT COSTS ========>		76,126	15,225	20%	91,351 (91,350)		76,126	15,225	91,351			76,126	15,225	91,351
	STOCKPILE MATERIAL FOR MAINTENANCE		14,150	2,830	20%	16,980		14,150	2,830	16,980			14,150	2,830	16,980
	DIKE REPAIRS & RESTOCKPILING EVERY 5 YEARS		16,844	3,369	20%	20,213		16,844	3,369	20,213			16,844	3,369	20,213

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study, DATED: JAN 2008
PROJECT: Barrow Erosion Control Feasibility Alternative #5 - Beach Nourish. Transect 27 - 31.5 Level of Protection = 8' Contour DISTRICT: Alaska District
LOCATION: Barrow, AK P.O.C.: Cost Estimator - John T. Dudgeon

			CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007				AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		4,369	874	20%	5,243		4,369	874	5,243			4,369	874	5,243
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC				20%										
16 00 81	EXCAVATION				20%										
16 00 81	CONSTRUCT GRAVEL FILL		14,878	2,976	20%	17,854		14,878	2,976	17,854			14,878	2,976	17,854
16 00 81	CONSTRUCT CORE ROCK				20%										
16 00 81	CONSTRUCT B ROCK				20%										
16 00 81	CONSTRUCT A ROCK				20%										
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		58	12	20%	70		58	12	70			58	12	70
	TOTAL CONSTRUCTION COSTS ===>		19,305	3,861	20%	23,166		19,305	3,861	23,166			19,305	3,861	23,166
01---	LANDS AND DAMAGES	1.4%	322	64	20%	386		322	64	386			322	64	386
30---	PLANNING, ENGINEERING & DESIGN	8.6%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	2,013	403	20%	2,416		2,013	403	2,416			2,013	403	2,416
30---	CULTURAL MITIGATION	0.4%	100	20	20%	120		100	20	120			100	20	120
	TOTAL PROJECT COSTS ========>		23,740	4,748	20%	28,488		23,740	4,748	28,488			23,740	4,748	28,488
	BEACH RENOURISHMENT		10,995	2,199	20%	13,194		10,995	2,199	13,194			10,995	2,199	13,194

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study, DATED: JAN 2008

PROJECT: Barrow Erosion Control Feasibility Alternative #6 - Beach Nourish. Transect 24.625 - 31.5 Level of Protection = 10' Contour
DISTRICT: Alaska District
LOCATION: Barrow, AK
P.O.C.: Cost Estimator - John T. Dudgeon

	CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007						AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		17,475	3,495	20%	20,970		17,475	3,495	20,970			17,475	3,495	20,970
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC				20%										
16 00 81	EXCAVATION				20%										
16 00 81	CONSTRUCT GRAVEL FILL		67,276	13,455	20%	80,731		67,276	13,455	80,731			67,276	13,455	80,731
16 00 81	CONSTRUCT CORE ROCK				20%										
16 00 81	CONSTRUCT B ROCK				20%										
16 00 81	CONSTRUCT A ROCK				20%										
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		58	12	20%	70		58	12	70			58	12	70
	TOTAL CONSTRUCTION COSTS ===>		84,809	16,962	20%	101,771		84,809	16,962	101,771			84,809	16,962	101,771
01---	LANDS AND DAMAGES	0.4%	372	74	20%	446		372	74	446			372	74	446
30---	PLANNING, ENGINEERING & DESIGN	2.0%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	8,302	1,660	20%	9,962		8,302	1,660	9,962			8,302	1,660	9,962
30---	CULTURAL MITIGATION	0.4%	400	80	20%	480		400	80	480			400	80	480
	TOTAL PROJECT COSTS ========>		95,883	19,177	20%	115,059		95,883	19,177	115,059			95,883	19,177	115,059
	BEACH RENOURISHMENT		77,837	15,567	20%	93,404		77,837	15,567	93,404			77,837	15,567	93,404

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study,
PROJECT: Barrow Erosion Control Feasibility Alternative #7 - Beach Nourish. Transect 22 - 33 Level of Protection = 12' Contour
LOCATION: Barrow, AK

DATED: JAN 2008
DISTRICT: Alaska District
P.O.C.: Cost Estimator - John T. Dudgeon

	CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007						AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		45,962	9,192	20%	55,154		45,962	9,192	55,154			45,962	9,192	55,154
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC				20%										
16 00 81	EXCAVATION				20%										
16 00 81	CONSTRUCT GRAVEL FILL		136,400	27,280	20%	163,680		136,400	27,280	163,680			136,400	27,280	163,680
16 00 81	CONSTRUCT CORE ROCK				20%										
16 00 81	CONSTRUCT B ROCK				20%										
16 00 81	CONSTRUCT A ROCK				20%										
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		584	117	20%	701		584	117	701			584	117	701
	TOTAL CONSTRUCTION COSTS ===>		182,946	36,589	20%	219,535		182,946	36,589	219,535			182,946	36,589	219,535
01---	LANDS AND DAMAGES	0.2%	387	77	20%	464		387	77	464			387	77	464
30---	PLANNING, ENGINEERING & DESIGN	0.9%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	17,723	3,545	20%	21,267		17,723	3,545	21,267			17,723	3,545	21,267
30---	CULTURAL MITIGATION	0.3%	600	120	20%	720		600	120	720			600	120	720
	TOTAL PROJECT COSTS ========>		203,656	40,731	20%	244,387		203,656	40,731	244,387			203,656	40,731	244,387
	BEACH RENOURISHMENT		223,753	44,751	20%	268,504		223,753	44,751	268,504			223,753	44,751	268,504

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study,

PROJECT: Barrow Erosion Control Feasibility Alternative #8 - Beach Nourish. Transect 22 - 43 Level of Protection = 14' Contour
LOCATION: Barrow, AK

DATED: JAN 2008
DISTRICT: Alaska District
P.O.C.: Cost Estimator - John T. Dudgeon

			CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007				AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		131,081	26,216	20%	157,297		131,081	26,216	157,297			131,081	26,216	157,297
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC				20%										
16 00 81	EXCAVATION				20%										
16 00 81	CONSTRUCT GRAVEL FILL		478,317	95,663	20%	573,980		478,317	95,663	573,980			478,317	95,663	573,980
16 00 81	CONSTRUCT CORE ROCK				20%										
16 00 81	CONSTRUCT B ROCK				20%										
16 00 81	CONSTRUCT A ROCK				20%										
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		993	199	20%	1,192		993	199	1,192			993	199	1,192
	TOTAL CONSTRUCTION COSTS ===>		610,391	122,078	20%	732,469		610,391	122,078	732,469			610,391	122,078	732,469
01---	LANDS AND DAMAGES	0.1%	476	95	20%	571		476	95	571			476	95	571
30---	PLANNING, ENGINEERING & DESIGN	0.3%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	58,758	11,752	20%	70,509		58,758	11,752	70,509			58,758	11,752	70,509
30---	CULTURAL MITIGATION	0.1%	850	170	20%	1,020		850	170	1,020			850	170	1,020
	TOTAL PROJECT COSTS ========>		672,475	134,495	20%	806,969		672,475	134,495	806,969			672,475	134,495	806,969
	BEACH RENOURISHMENT		604,901	120,980	20%	725,881		604,901	120,980	725,881			604,901	120,980	725,881

**** TOTAL PROJECT COST SUMMARY ****

PAGE 1 OF 1

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study,
PROJECT: Barrow Erosion Control Feasibility Alternative #9 - IVU Revetment Transect 22 - 43, Level of Protection = 14' Contour
LOCATION: Barrow, AK

DATED: JAN 2008
DISTRICT: Alaska District
P.O.C.: Cost Estimator - John T. Dudgeon

	CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007						AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		18,145	3,629	20%	21,774		18,145	3,629	21,774			18,145	3,629	21,774
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC		579	116	20%	695		579	116	695			579	116	695
16 00 81	EXCAVATION		1,341	268	20%	1,609		1,341	268	1,609			1,341	268	1,609
16 00 81	CONSTRUCT GRAVEL FILL		8,242	1,648	20%	9,890		8,242	1,648	9,890			8,242	1,648	9,890
16 00 81	CONSTRUCT CORE ROCK		10,110	2,022	20%	12,132		10,110	2,022	12,132			10,110	2,022	12,132
16 00 81	CONSTRUCT B ROCK		28,112	5,622	20%	33,734		28,112	5,622	33,734			28,112	5,622	33,734
16 00 81	CONSTRUCT A ROCK		67,867	13,573	20%	81,440		67,867	13,573	81,440			67,867	13,573	81,440
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		1,921	384	20%	2,305		1,921	384	2,305			1,921	384	2,305
	TOTAL CONSTRUCTION COSTS ===>		136,317	27,263	20%	163,580		136,317	27,263	163,580			136,317	27,263	163,580
01---	LANDS AND DAMAGES	0.3%	476	95	20%	571		476	95	571			476	95	571
30---	PLANNING, ENGINEERING & DESIGN	1.2%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	13,246	2,649	20%	15,896		13,246	2,649	15,896			13,246	2,649	15,896
30---	CULTURAL MITIGATION	0.5%	896	179	20%	1,075		896	179	1,075			896	179	1,075
	TOTAL PROJECT COSTS ========>		152,935	30,587	20%	183,523 (183,522)		152,935	30,587	183,523			152,935	30,587	183,523
	STOCKPILE MATERIAL FOR MAINTENANCE		14,889	2,978	20%	17,867		14,889	2,978	17,867			14,889	2,978	17,867
	DIKE REPAIRS & RESTOCKPILING EVERY 5 YEARS		19,173	3,835	20%	23,008		19,173	3,835	23,008			19,173	3,835	23,008

****** TOTAL PROJECT COST SUMMARY ******

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study,

PROJECT: Barrow Erosion Control Feasibility Alternative #10 - Bluff Revetment Transect 17 - 22
LOCATION: Barrow, AK

DATED: JAN 2008
DISTRICT: Alaska District
P.O.C.: Cost Estimator - John T. Dudgeon

	CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007						AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		4,536	907	20%	5,443		4,536	907	5,443			4,536	907	5,443
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC		150	30	20%	180		150	30	180			150	30	180
16 00 81	CONSTRUCT FILL		767	153	20%	920		767	153	920			767	153	920
16 00 81	CONSTRUCT GRAVEL FILL		1,932	386	20%	2,318		1,932	386	2,318			1,932	386	2,318
16 00 81	CONSTRUCT CORE ROCK		2,316	463	20%	2,779		2,316	463	2,779			2,316	463	2,779
16 00 81	CONSTRUCT B ROCK		6,714	1,343	20%	8,057		6,714	1,343	8,057			6,714	1,343	8,057
16 00 81	CONSTRUCT A ROCK		8,751	1,750	20%	10,501		8,751	1,750	10,501			8,751	1,750	10,501
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		356	71	20%	427		356	71	427			356	71	427
	TOTAL CONSTRUCTION COSTS ===>		25,522	5,104	20%	30,626		25,522	5,104	30,626			25,522	5,104	30,626
01---	LANDS AND DAMAGES	1.0%	307	61	20%	368		307	61	368			307	61	368
30---	PLANNING, ENGINEERING & DESIGN	6.5%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	2,610	522	20%	3,132		2,610	522	3,132			2,610	522	3,132
30---	CULTURAL MITIGATION	0.7%	217	43	20%	260		217	43	260			217	43	260
	TOTAL PROJECT COSTS ========>		30,656	6,131	20%	36,787 (36,786)		30,656	6,131	36,787			30,656	6,131	36,787
	STOCKPILE MATERIAL FOR MAINTENANCE		14,150	2,830	20%	16,980		14,150	2,830	16,980			14,150	2,830	16,980
	DIKE REPAIRS & RESTOCKPILING EVERY 5 YEARS		16,844	3,369	20%	20,213		16,844	3,369	20,213			16,844	3,369	20,213

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study, DATED: JAN 2008

PROJECT: Barrow Erosion Control Feasibility Alternative #11 - Bluff Revetment Transect 22 - 24.625

LOCATION: Barrow, AK

DISTRICT: Alaska District

P.O.C.: Cost Estimator - John T. Dudgeon

			CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007				AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		4,536	907	20%	5,443		4,536	907	5,443			4,536	907	5,443
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC		74	15	20%	89		74	15	89			74	15	89
16 00 81	CONSTRUCT FILL		249	50	20%	299		249	50	299			249	50	299
16 00 81	CONSTRUCT GRAVEL FILL		940	188	20%	1,128		940	188	1,128			940	188	1,128
16 00 81	CONSTRUCT CORE ROCK		1,134	227	20%	1,361		1,134	227	1,361			1,134	227	1,361
16 00 81	CONSTRUCT B ROCK		3,211	642	20%	3,853		3,211	642	3,853			3,211	642	3,853
16 00 81	CONSTRUCT A ROCK		3,971	794	20%	4,765		3,971	794	4,765			3,971	794	4,765
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		160	32	20%	192		160	32	192			160	32	192
	TOTAL CONSTRUCTION COSTS ===>		14,275	2,855	20%	17,130		14,275	2,855	17,130			14,275	2,855	17,130
01---	LANDS AND DAMAGES	1.9%	321	64	20%	385		321	64	385			321	64	385
30---	PLANNING, ENGINEERING & DESIGN	11.7%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	1,530	306	20%	1,836		1,530	306	1,836			1,530	306	1,836
30---	CULTURAL MITIGATION	0.7%	113	23	20%	136		113	23	136			113	23	136
	TOTAL PROJECT COSTS ========>		18,239	3,648	20%	21,887		18,239	3,648	21,887			18,239	3,648	21,887
	STOCKPILE MATERIAL FOR MAINTENANCE		14,150	2,830	20%	16,980		14,150	2,830	16,980			14,150	2,830	16,980
	DIKE REPAIRS & RESTOCKPILING EVERY 5 YEARS		16,844	3,369	20%	20,213		16,844	3,369	20,213			16,844	3,369	20,213

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study,
PROJECT: Barrow Erosion Control Feasibility Alternative #12 - Bluff Revetment Transect 22 - 27
LOCATION: Barrow, AK

DATED: JAN 2008
DISTRICT: Alaska District
P.O.C.: Cost Estimator - John T. Dudgeon

			CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007				AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		4,536	907	20%	5,443		4,536	907	5,443			4,536	907	5,443
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC		128	26	20%	154		128	26	154			128	26	154
16 00 81	CONSTRUCT FILL		249	50	20%	299		249	50	299			249	50	299
16 00 81	CONSTRUCT GRAVEL FILL		1,582	316	20%	1,898		1,582	316	1,898			1,582	316	1,898
16 00 81	CONSTRUCT CORE ROCK		2,209	442	20%	2,651		2,209	442	2,651			2,209	442	2,651
16 00 81	CONSTRUCT B ROCK		5,286	1,057	20%	6,343		5,286	1,057	6,343			5,286	1,057	6,343
16 00 81	CONSTRUCT A ROCK		6,321	1,264	20%	7,585		6,321	1,264	7,585			6,321	1,264	7,585
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		246	49	20%	295		246	49	295			246	49	295
	TOTAL CONSTRUCTION COSTS ===>		20,557	4,111	20%	24,668		20,557	4,111	24,668			20,557	4,111	24,668
01---	LANDS AND DAMAGES	1.5%	381	76	20%	457		381	76	457			381	76	457
30---	PLANNING, ENGINEERING & DESIGN	8.1%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	2,133	427	20%	2,560		2,133	427	2,560			2,133	427	2,560
30---	CULTURAL MITIGATION	0.9%	217	43	20%	260		217	43	260			217	43	260
	TOTAL PROJECT COSTS ========>		25,288	5,058	20%	30,346 (30,345)		25,288	5,058	30,346			25,288	5,058	30,346
	STOCKPILE MATERIAL FOR MAINTENANCE		14,150	2,830	20%	16,980		14,150	2,830	16,980			14,150	2,830	16,980
	DIKE REPAIRS & RESTOCKPILING EVERY 5 YEARS		16,844	3,369	20%	20,213		16,844	3,369	20,213			16,844	3,369	20,213

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study,

PROJECT: Barrow Erosion Control Feasibility Alternative #13 - Bluff Protection for IVU,Transects 22 - 27
LOCATION: Barrow, AK

DATED: JAN 2008
DISTRICT: Alaska District
P.O.C.: Cost Estimator - John T. Dudgeon

			CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007				AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		4,536	907	20%	5,443		4,536	907	5,443			4,536	907	5,443
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC		145	29	20%	174		145	29	174			145	29	174
16 00 81	CONSTRUCT FILL		264	53	20%	317		264	53	317			264	53	317
16 00 81	CONSTRUCT GRAVEL FILL		2,053	411	20%	2,464		2,053	411	2,464			2,053	411	2,464
16 00 81	CONSTRUCT CORE ROCK		2,520	504	20%	3,024		2,520	504	3,024			2,520	504	3,024
16 00 81	CONSTRUCT B ROCK		6,894	1,379	20%	8,273		6,894	1,379	8,273			6,894	1,379	8,273
16 00 81	CONSTRUCT A ROCK		16,832	3,366	20%	20,198		16,832	3,366	20,198			16,832	3,366	20,198
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		1,368	274	20%	1,642		1,368	274	1,642			1,368	274	1,642
	TOTAL CONSTRUCTION COSTS ===>		34,612	6,922	20%	41,534		34,612	6,922	41,534			34,612	6,922	41,534
01---	LANDS AND DAMAGES	0.9%	381	76	20%	457		381	76	457			381	76	457
30---	PLANNING, ENGINEERING & DESIGN	4.8%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	3,483	697	20%	4,179		3,483	697	4,179			3,483	697	4,179
30---	CULTURAL MITIGATION	0.5%	217	43	20%	260		217	43	260			217	43	260
	TOTAL PROJECT COSTS ========>		40,693	8,139	20%	48,831 (48,830)		40,693	8,139	48,831			40,693	8,139	48,831
	STOCKPILE MATERIAL FOR MAINTENANCE		14,889	2,978	20%	17,867		14,889	2,978	17,867			14,889	2,978	17,867
	DIKE REPAIRS & RESTOCKPILING EVERY 5 YEARS		19,173	3,835	20%	23,008		19,173	3,835	23,008			19,173	3,835	23,008

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study,

PROJECT: Barrow Erosion Control Feasibility Alternative #14 - Bluff Beach Nourish. Transect 22 - 27
LOCATION: Barrow, AK

DATED: JAN 2008
DISTRICT: Alaska District
P.O.C.: Cost Estimator - John T. Dudgeon

			CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007				AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		21,844	4,369	20%	26,213		21,844	4,369	26,213			21,844	4,369	26,213
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC				20%										
16 00 81	CONSTRUCT FILL				20%										
16 00 81	CONSTRUCT GRAVEL FILL		81,372	16,274	20%	97,646		81,372	16,274	97,646			81,372	16,274	97,646
16 00 81	CONSTRUCT CORE ROCK				20%										
16 00 81	CONSTRUCT B ROCK				20%										
16 00 81	CONSTRUCT A ROCK				20%										
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		584	117	20%	701		584	117	701			584	117	701
	TOTAL CONSTRUCTION COSTS ===>		103,800	20,760	20%	124,560		103,800	20,760	124,560			103,800	20,760	124,560
01---	LANDS AND DAMAGES	0.3%	381	76	20%	457		381	76	457			381	76	457
30---	PLANNING, ENGINEERING & DESIGN	1.6%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	10,125	2,025	20%	12,150		10,125	2,025	12,150			10,125	2,025	12,150
30---	CULTURAL MITIGATION	0.2%	250	50	20%	300		250	50	300			250	50	300
	TOTAL PROJECT COSTS ========>		116,556	23,311	20%	139,867		116,556	23,311	139,867			116,556	23,311	139,867
	BEACH RENOURISHMENT		69,225	13,845	20%	83,070		69,225	13,845	83,070			69,225	13,845	83,070

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study, DATED: JAN 2008

PROJECT: Barrow Erosion Control Feasibility Alternative #15 - Non-Structural Options (Raising & Relocating 32 Structures)

DISTRICT: Alaska District

LOCATION: Barrow, AK

P.O.C.: Cost Estimator - John T. Dudgeon

			CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007				AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
020301	MOB/DEMOB		4,966	993	20%	5,959		4,966	993	5,959			4,966	993	5,959
020347	STRUCTURE RAISING - 10		3,542	708	20%	4,250		3,542	708	4,250			3,542	708	4,250
020347	STRUCTURE RELOCATING - 24		19,687	3,937	20%	23,624		19,687	3,937	23,624			19,687	3,937	23,624
	TOTAL CONSTRUCTION COSTS ===>		28,195	5,639	20%	33,834		28,195	5,639	33,834			28,195	5,639	33,834
01---	LANDS AND DAMAGES	4.1%	1,396	279	20%	1,675		1,396	279	1,675			1,396	279	1,675
30---	PLANNING, ENGINEERING & DESIGN	7.4%	2,500	500	20%	3,000		2,500	500	3,000			2,500	500	3,000
31---	CONSTRUCTION MANAGEMENT	8.0%	2,907	581	20%	3,488		2,907	581	3,488			2,907	581	3,488
30---	CULTURAL MITIGATION	0.3%	105	21	20%	126		105	21	126			105	21	126
	TOTAL PROJECT COSTS ========>		35,103	7,021	20%	42,123		35,103	7,021	42,123			35,103	7,021	42,123

Summary of Cost for Barrow Structures Raise & Relocate

	#	Address	Type	Stories	SF/floor (field trip)	SF/floor (GIS)	Piles Needed	Pile Cost	Relocate Cost	RE, PED, CM, & Cultural Costs	Total
		Structures in Barrow Neighborhood									
Relocate 1	912	Stevenson St.	Res	1-1/2		816	20	59,019	$1,024,594	$243,795	$1,327,408
Relocate 2	914	Stevenson St.	Res	1	440	506	13	36,598	$1,024,594	$243,795	$1,304,987
Relocate 3	916	Stevenson St.	Res	1		1,070	27	77,390	$1,024,594	$243,795	$1,345,780
Relocate 4	920	Stevenson St.	Res	1		970	24	70,157	$1,024,594	$243,795	$1,338,547
Relocate 5	924	Stevenson St.	Res	2		460	12	33,271	$1,024,594	$243,795	$1,301,660
Relocate 6	926	Stevenson St.	Res	1	house 875	918	23	66,396	$1,024,594	$243,795	$1,334,786
Relocate 7	930	Stevenson St.	Res	1	940	832	21	60,176	$1,024,594	$243,795	$1,328,566
Relocate 8	936	Stevenson St.	**Com**	2	2,500	3,028	76	219,007	$1,130,674	$243,795	$1,593,477
Relocate 9	476	Egasak St.	**Res-apartm**	2	2,400	1,738	43	125,705	$1,130,674	$243,795	$1,500,174
Relocate 10	470	Egasak St.	Res	2		428	11	30,956	$1,024,594	$243,795	$1,299,345
Relocate 11	940	Stevenson St.	**Res-apartm**	2	750	908	23	65,673	$1,130,674	$243,795	$1,440,143
Relocate 12	950	Egasak St.	**Res-apartm**	2	1,000	1,232	31	89,107	$1,130,674	$243,795	$1,463,577
Relocate 13	489	Egasak St.	Res	1		1,379	34	99,739	$1,024,594	$243,795	$1,368,129
Relocate 14	491	Egasak St.	**Res**	2		2,017	50	145,884	$1,130,674	$243,795	$1,520,354
Relocate 15	493	Egasak St.	Res	1		872	22	63,069	$1,024,594	$243,795	$1,331,459
Relocate 16	730	Nachik St.	**Pub**	1		4,308	108	311,586	$1,130,674	$243,795	$1,686,055
Relocate 17	739	Nachik St.	Com	1		1,561	39	112,903	$1,024,594	$243,795	$1,381,292
Relocate 18	970	Stevenson St.	**Res-apartm**	3	2,025	1,637	41	118,400	$1,130,674	$243,795	$1,492,869
Relocate 19	744	Nachik St.	Res	1-mobile	825	1,094	27	79,126	$1,024,594	$243,795	$1,347,515
Relocate 20	978	Egasak St.	Res	1		885	22	64,010	$1,024,594	$243,795	$1,332,399
Relocate 21	976	Stevenson St.	**Res/Com**	2	1,650	1,722	43	124,548	$1,130,674	$243,795	$1,499,017
Relocate 22	980	Stevenson St.	**Com/Res**	2	1,700	1,938	48	140,170	$1,130,674	$243,795	$1,514,640
Raise 1	1209	Agvik St.	Res		769	989	25	71,532	$419,241	$243,795	$734,568
Raise 2	983	Stevenson St.	Res		925	833	21	60,249	$419,241	$243,795	$723,284
Relocate 23	989	Stevenson St.	Res	2	400	604	15	43,686	$1,024,594	$243,795	$1,312,075
Relocate 24	1092	Kiogak St.	Res	1-1/2	625	663	17	47,953	$1,024,594	$243,795	$1,316,342
Raise 3	1093	Kiogak St.	Res	1	875	1,008	25	72,906	$419,241	$243,795	$735,942
Raise 4	1089	Kiogak St.	Res	2	600	1,339	33	96,846	$419,241	$243,795	$759,882
Raise 5	1128	Hopson St.	Res	2		506	13	36,598	$419,241	$243,795	$699,633
Raise 6	1126	Hopson St.	Res	2	1,050	789	20	57,066	$419,241	$243,795	$720,102
Raise 7	3022	Simmonds St.	Res	2	700	869	22	62,852	$419,241	$243,795	$725,888
Raise 8	3026	Simmonds St.	Res	1	1,200	1,150	29	83,176	$419,241	$243,795	$746,212
Raise 9	3206	Simmonds St.	Res	1		623	16	45,060	$419,241	$243,795	$708,096
Raise 10	3419	Stevenson St.	Com	2		11,334	283	819,758	$824,274	$243,795	$1,887,827

**** TOTAL PROJECT COST SUMMARY ****

THIS ESTIMATE IS BASED ON THE SCOPE CONTAINED IN THE Feasibility Study, DATED: JAN 2008
PROJECT: Barrow Erosion Control Feasibility Alternative #16 - Fill Isatquaq Lagoon, Level of Protection = 8' Contour
DISTRICT: Alaska District
LOCATION: Barrow, AK
P.O.C.: Cost Estimator - John T. Dudgeon

	CURRENT MCACES ESTIMATE PREPARED: JAN 2008 EFFECTIVE PRICING LEVEL: OCT 2007						AUTHORIZ./BUDGET YEAR: 2007 EFFECT. PRICING LEVEL: 1 OCT 07				FULLY FUNDED ESTIMATE				
ACCOUNT NUMBER	FEATURE DESCRIPTION		COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
16 00 01	MOB/DEMOB		2,131	426	20%	2,557		2,131	426	2,557			2,131	426	2,557
16 00 99	PLACEMENT OF GEOTEXTILE FABRIC				20%										
16 00 81	EXCAVATION				20%										
16 00 81	CONSTRUCT GRAVEL FILL		17,420	3,484	20%	20,904		17,420	3,484	20,904			17,420	3,484	20,904
16 00 81	CONSTRUCT CORE ROCK				20%										
16 00 81	CONSTRUCT B ROCK				20%										
16 00 81	CONSTRUCT A ROCK				20%										
16 00 99	PROVIDE TOPOGRAPHIC SURVEYING		37	7	20%	44		37	7	44			37	7	44
	TOTAL CONSTRUCTION COSTS ===>		19,588	3,918	20%	23,506		19,588	3,918	23,506			19,588	3,918	23,506
01---	LANDS AND DAMAGES	1.4%	322	64	20%	386		322	64	386			322	64	386
30---	PLANNING, ENGINEERING & DESIGN	8.5%	2,000	400	20%	2,400		2,000	400	2,400			2,000	400	2,400
31---	CONSTRUCTION MANAGEMENT	8.0%	2,040	408	20%	2,449		2,040	408	2,449			2,040	408	2,449
30---	CULTURAL MITIGATION	0.2%	50	10	20%	60		50	10	60			50	10	60
	TOTAL PROJECT COSTS ========>		24,000	4,800	20%	28,801		24,000	4,800	28,801			24,000	4,800	28,801
	BEACH RENOURISHMENT				20%										

U.S. Army Corps
of Engineers
Alaska District

Barrow, Alaska

Coastal Storm Damage Reduction Interim Feasibility Report

Appendix D -- Economic Analysis

August 2008

BARROW, ALASKA
COASTAL STORM DAMAGE REDUCTION
FEASIBILITY STUDY

ECONOMIC APPENDIX

prepared for:

Alaska District
U.S. Army Corps of Engineers

prepared by:

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1.0 Introduction

Barrow, AK is the northern most community in the United States, lying north of 71 degrees north latitude (figure 1). Barrow is the economic, social, and cultural center for the North Slope Borough (NSB), which includes almost all of Alaska north of the 68th Parallel and has a population of about 6,900 persons[1] spread over 89,000 square miles, an area about the size of the state of Oregon. Barrow, incorporated in 1958, is a first-class City with about 4,200 residents[2], accounting for over half of the Borough's population.

Figure 1: State of Alaska Location Map

Barrow has been faced with storm damage and erosion problems for decades. A number of damage reduction measures have been tried by local entities in the past at Barrow with varying degrees of success. NSB studies in the 1980's culminated in the NSB's formal Beach Nourishment Program, authorized in 1991. That program was planned as an 8 year beach nourishment period, using a specially-built, barge-mounted dredge to remove materials from offshore of Barrow and place them on the beach. The NSB took delivery of the dredge, shore barge, and dredge tender in 1995. Numerous operational complications, including extensive damage to the dredge in the August 2000 storm, resulted in termination of the program without achievement of program objectives. It is estimated that approximately $27 million was spent over the decade on the NSB's Beach Nourishment Program.

Coastal flooding and erosion continue to threaten residential and commercial structures and community infrastructure in Barrow. The NSB is committed to continuing their current flood fighting practices, which include annual construction and repairs for push up gravel beach berms that provide limited protection to the beach frontage road (Stevenson Street) and development in its vicinity. Additionally, the NSB is participating with the Corps of Engineers in this feasibility study of alternative solutions to flooding and erosion problems in Barrow. This report documents economic analyses performed as part of the feasibility study.

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[1] 2005 State Demographer estimate.
[2] 2005 State Demographer estimate.

2.0 Economic Study Area

Barrow is located on the Chukchi Sea coast, 10 miles south of Point Barrow from which it takes its name. It lies 725 air miles from Anchorage and encompasses 18.4 sq. miles of land and 2.9 sq. miles of water. The climate of Barrow is arctic. Annual precipitation is light, averaging 5 inches, annual snowfall is 20 inches. Temperatures range from -56 to 78 degrees Fahrenheit, with an average temperature of 40 degrees Fahrenheit during summer. The sun does not set between May 10th and August 2nd each summer, and does not rise between Nov. 18th and January 24th each winter. The daily minimum temperature is below freezing 324 days of the year. Prevailing winds are easterly and average 12 mph. The Chukchi Sea is typically ice-free from mid-June through October.

The primary focus of the economic study of coastal flooding and erosion damages is in the neighborhoods of Barrow and Browerville, which are the two most developed areas in the City (figure 2). The developed portions of Barrow/Browerville contain both residential and nonresidential structures and most of the City's infrastructure. As a regional provider of services for communities throughout the North Slope Borough, economic effects of flooding and erosion damages in Barrow may also impact these outlying communities and these impacts are addressed in this report.

3.0 Socioeconomic Characteristics

Barrow has the largest population in the NSB and is the economic center of the region. Borough, state, and federal agencies are the largest employers in the City. Numerous businesses provide support services to oil field operations. Tourism and arts and crafts provide some cash income. Seven residents hold commercial fishing permits. Subsistence production is an important component of the local economy and social structure as many residents rely upon subsistence food sources. Whale, seal, polar bear, walrus, duck, caribou and grayling and whitefish are harvested from the coast or nearby rivers and lakes for local subsistence.

Barrow is located in the North Slope Census Area. The following paragraphs summarize population, housing, income, and employment statistics for Barrow. Most of the information is based upon data from the 2000 U.S. Census. More recent data from the State of Alaska is provided where available as noted in the following sections.

3.1 Population

Review of U.S. Census records shows that Barrow witnessed a steady increase in population over the period 1900-2000. The State of Alaska estimates the population of Barrow in 2005 at 4,199, down 8.3% from the 2000 census count of 4,581. Figure 3 shows the population change in Barrow over the period 1880-2005.

The most recent detailed demographic data for Barrow is from the 2000 census. At that time, 64% of the population was reported as Alaska Native alone (57%) or in combination with one or more races (7%). Of the remaining population, the largest racial groups were reported as white (21%) and Asian (9%). Table 1 provides a summary of the racial composition of the Barrow population in 2000.

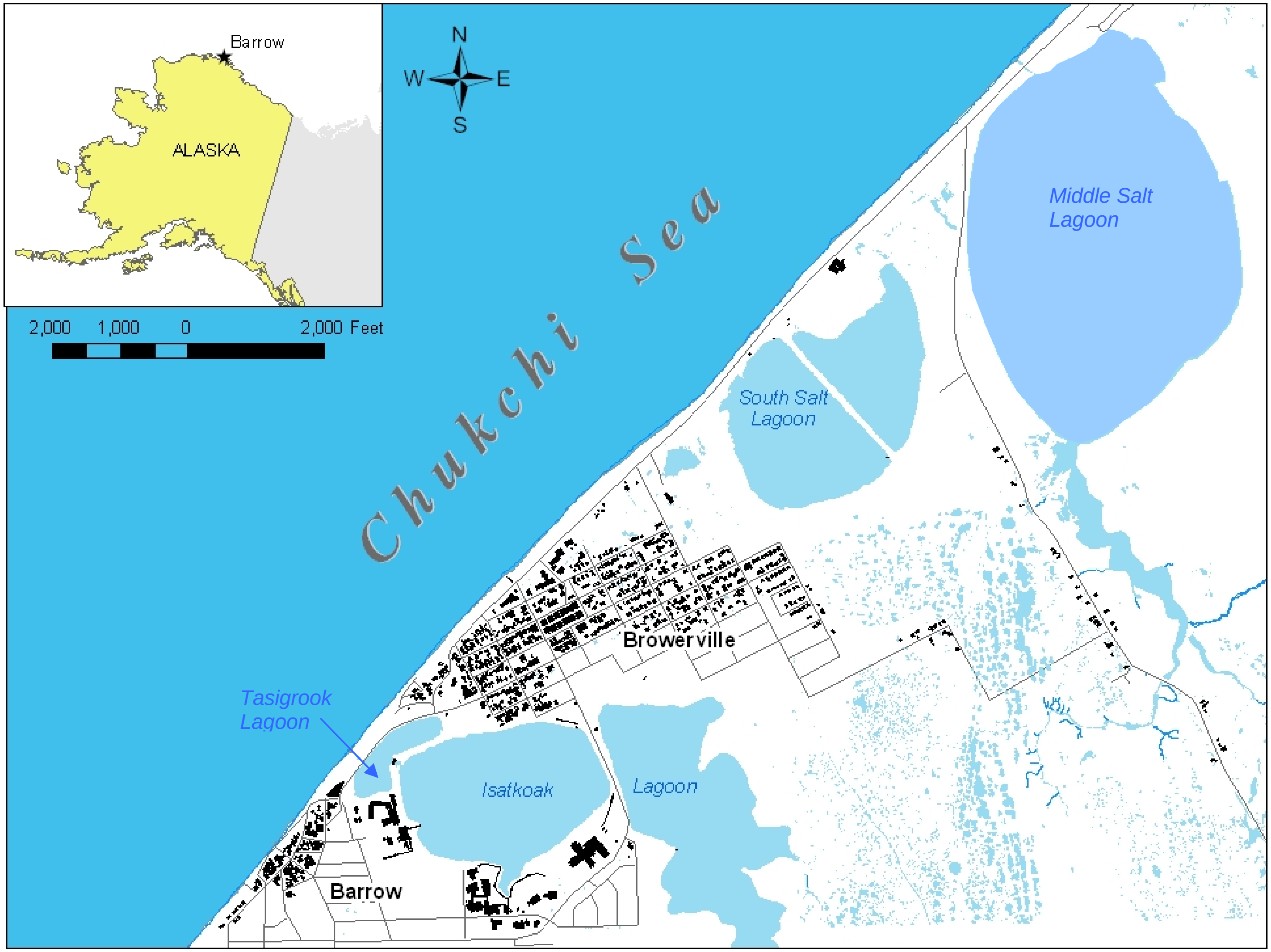

Figure 2: Economic Study Area

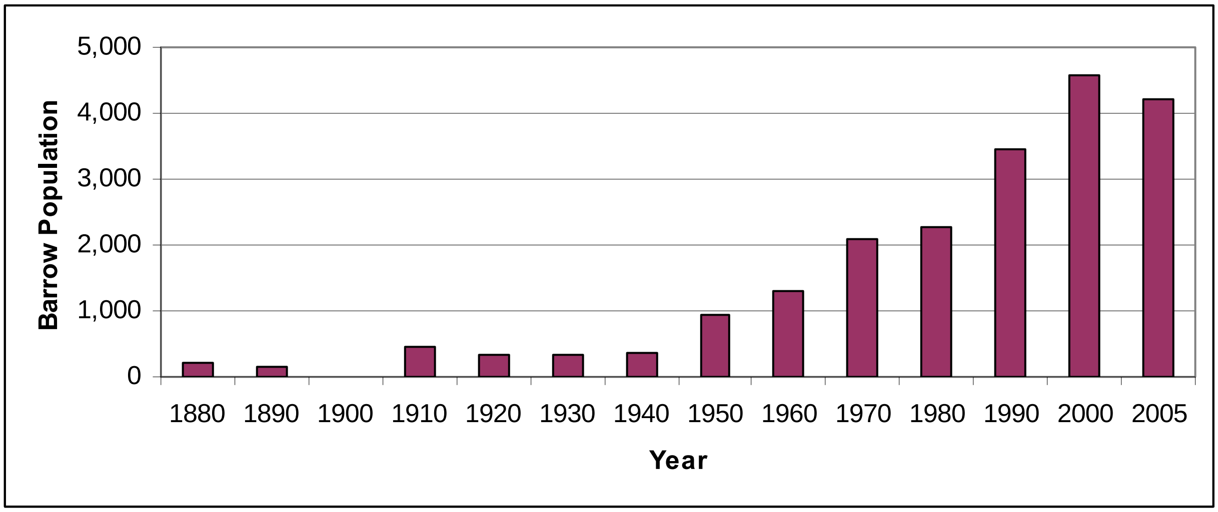

Figure 3: Population Change in Barrow 1880-2005

Table 1: Population by Race

Population in 2005: (Alaska State Demographer estimate)	4,199	
Population in 2000: (2000 U.S. Census)	4,581	
Racial Composition (2000 population):		
One Race Only:	4,191	91%
White:	1,000	22%
Alaska Native or Amer. Indian:	2,620	57%
Black:	46	1%
Asian:	431	9%
Hawaiian Native:	62	1%
Other Race:	32	1%
Two or More Races:	390	9%
All or Part Alaska Native/Indian:	2,933	70%
Hispanic Origin (Any Race):	153	3%
Not Hispanic (Any Race):	4,428	97%

The gender of Barrow’s population in 2000 was approximately 52% male and 48% female. Approximately 40% of Barrow’s population in 2000 was under the age of 20; with 51% between the ages of 20 and 54 and 9% over the age of 54. Barrow’s median age was reported as 28.8. Table 2 provides a summary of Barrow’s 2000 population statistics by gender and age.

Table 2: Population by Gender and Age

Male:	2,369	52%
Female:	2,212	48%
TOTAL POPULATION (2000):	4,581	100%
Age 4 and under:	450	9.8%
Age 5 - 9:	455	9.9%
Age 10 - 14:	508	11.1%
Age 15 - 19:	409	8.9%
Age 20 - 24:	262	5.7%
Age 25 - 34:	633	13.8%
Age 35 - 44:	816	17.8%
Age 45 - 54:	628	13.7%
Age 55 - 59:	168	3.7%
Age 60 - 64:	95	2.1%
Age 65 - 74:	97	2.1%
Age 75 - 84:	49	1.1%
Age 85 and over:	11	0.2%
Median Age:	28.8	
Pop. Age 18 and over:	2,901	63%
Pop. Age 21 and over:	2,720	59%
Pop. Age 62 and over:	212	5%

3.2 Housing

Barrow's 2000 population was grouped into 1,371 households and the City included 1,620 total housing units. The average household size was 3.27 persons. Table 3 summarizes the 2000 Census data related to housing and household characteristics in Barrow.

Table 3: Housing/Household Characteristics

Total Housing Units:	1,620	
Owner-Occupied Housing:	559	35%
Renter-Occupied Housing:	812	50%
Vacant Housing:	249	15%
Total Households:	1,371	
Average Household Size:	3.27	
Family Households:	942	69%
Average Family Household Size:	3.91	
Non-Family Households:	429	31%

During the 2000 Census, approximately 45% of the households in Barrow were sampled to collect additional data. Data from this sample characterizing Barrow's housing stock is presented in table 4.

Table 4: Housing Structure Types

Single Family (Detached):	954	59%
Single Family (Attached):	53	3%
Duplex:	171	11%
3 or 4 Units:	95	6%
5 to 9 Units:	50	3%
10 to 19 Units:	140	9%
20 plus Units:	123	8%
Trailers/Mobile Homes:	34	2%
TOTAL STRUCTURES:	1,620	100%

3.3 Employment and Income

Of the 4,581 people living in Barrow in 2000, approximately 67% were considered as being in the potential work force. Of the potential workforce, 65% were reported as employed. The remaining 35% were split with 9% reported as unemployed and 26% reported as not seeking work. The largest employer was government, accounting for 1,176 of the 1,986 jobs in 2000 (59%). Table 5 summarizes the employment statistics for Barrow from the 2000 Census. Figure 4 presents a breakdown of employment in Barrow by category.

Table 5: Employment

Total Potential Work Force (Age 16+):	3,069	
Unemployed (Seeking Work):	290	9%
Adults Not in Labor Force (Not Seeking Work):	793	26%
Total Employment:	1,986	65%
Breakdown of Employed Labor Force:		
Private Wage & Salary Workers:	765	39%
Self-Employed Workers (in own not incorporated business):	43	2%
Government Workers (City, Borough, State, Federal):	1,176	59%
Unpaid Family Workers:	2	0.10%

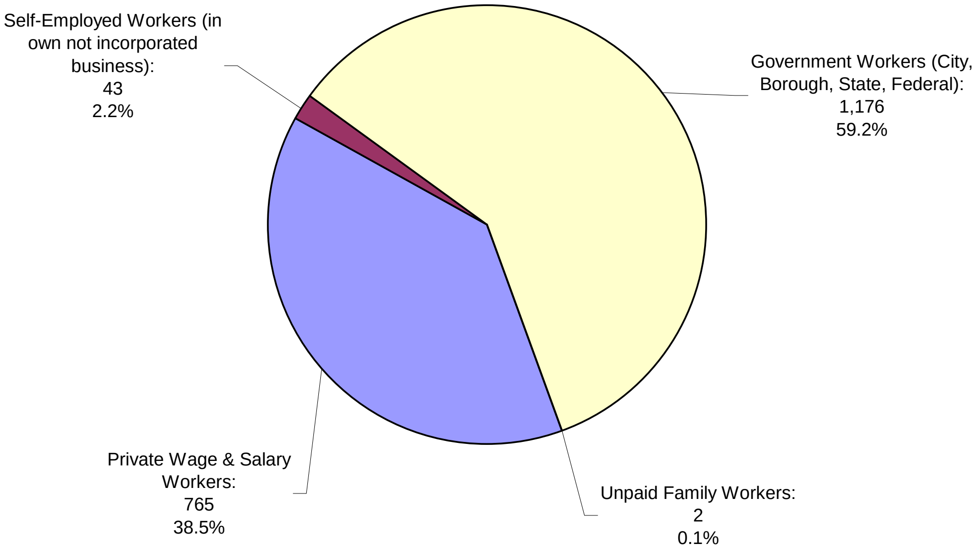

Figure 4: Employment by Employment Category

Table 6 presents the breakdown of the 2000 Barrow employed workforce by industry. The industry category of Education, Health, and Social Services accounts for the most jobs, followed by Public Administration. Combined, these two industry categories account for approximately 59% of the jobs in Barrow.

Table 6: Employment by Industry

Education, Health & Social Services:	718	36.2%
Public Administration:	447	22.5%
Transportation, Warehousing & Utilities:	167	8.4%
Other Services (Except Public Administration):	136	6.8%
Retail Trade:	123	6.2%
Construction:	103	5.2%
Professional, Scientific, Management, Administrative & Waste Mgmt:	85	4.3%
Finance, Insurance, Real Estate, Rental & Leasing:	62	3.1%
Arts, Entertainment, Recreation, Accommodation & Food Services:	57	2.9%
Agriculture, Forestry, Fishing & Hunting, Mining:	38	1.9%
Information:	38	1.9%
Manufacturing:	9	0.5%
Wholesale Trade:	3	0.2%
TOTAL EMPLOYMENT:	1,986	100.0%

Barrow's Per Capita Income was reported at $22,902 in the 2000 Census (1% higher than the state average of $22,660). Adjusted to 2007 prices using the USA Social Security Administration National Average Wage Index, the Per Capita Income is estimated at $27,024 (an 18% increase over the six year period). Table 7 presents summary income data for Barrow.

Table 7: Income

Per Capita Income: (Reported in 2000 Census)	$22,902
Median Household Income: (Reported in 2000 Census)	$67,097
Median Family Income: (Reported in 2000 Census)	$68,203
Per Capita Income: (Adjusted to 2007 Prices*)	$27,024
Median Household Income: (Adjusted to 2007 Prices*)	$79,174
Median Family Income: (Adjusted to 2007 Prices*)	$80,480
Persons in Poverty: (Reported in 2000 Census)	390
Percent Below Poverty: (Reported in 2000 Census)	8.60%
**Adjusted to 2007 prices using USA Social Security Administration National Average Wage Index.*	

3.4 Regional Emergency Services

As the political and economic hub of the NSB, Barrow provides important services to other communities in the Borough. In February 2006, the US Army Corps of Engineers (COE) and NSB hired ASCG, Incorporated to research and document the extent of dependence the various communities in the NSB have on services from Barrow and what would happen if Barrow were unable to provide these services due to a destructive storm event or other disaster.

The study area included the NSB communities of Barrow, Anaktuvuk Pass, Atqasuk, Kaktovik, Nuiqsut, Point Hope, Point Lay and Wainwright (figure 5). The study inventoried critical services currently provided to these other villages by Barrow and examined potential alternatives for obtaining services elsewhere should Barrow service providers be unable to deliver them. The study also compared the costs, availability and consequences of providing those critical services from other communities such as Nome, Kotzebue, Fairbanks or Anchorage as compared to Barrow. The emergency infrastructure systems in Barrow that were identified as currently supporting operations in the named villages include:

- Search and Rescue
- Law enforcement
- Fire Support
- Health Care
- Communication
- Cargo Delivery

Each NSB village was analyzed to determine its capacity to respond to emergencies on a short- or long-term basis. While the villages do have their own Search and Rescue building, police station, public works building, fire station and village health clinic, they are equipped to handle only limited emergency needs. Four alternate communities were identified and analyzed as alternatives for providing emergency support services to NSB communities should Barrow be unable to provide such support. The four communities (Anchorage, Fairbanks, Kotzebue and Nome) were chosen because of their capability to provide emergency services and their relative proximity to the North Slope.

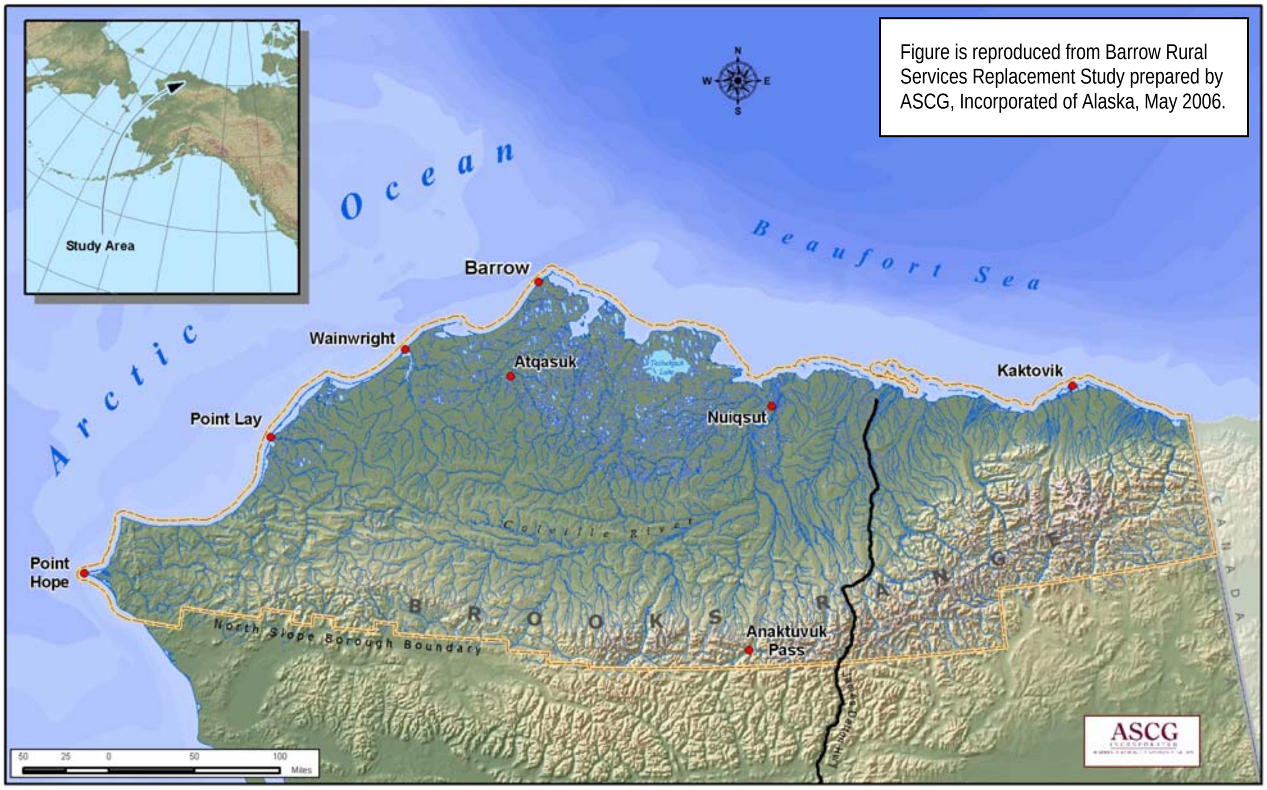

Figure is reproduced from Barrow Rural Services Replacement Study prepared by ASCG, Incorporated of Alaska, May 2006.

Figure 5: North Slope Borough Communities Served by Barrow

Distances between the alternate service centers and the NSB communities are presented in table 8. Distance between Barrow and each community is less than the distances between the villages and the other alternate service centers with the exception that Nome and Kotzebue are closer to Point Hope than is Barrow. Distance becomes critical when delivering emergency services, particularly in the arctic environment of the North Slope.

Table 8: Distances between NSB Communities and Alternate Service Centers

NSB Communities	Distance from Alternate Service Centers (miles)				
	Barrow	Anchorage	Fairbanks	Nome	Kotzebue
Anaktuvuk Pass	248	483	253	453	299
Atqasuk	58	674	463	462	279
Nuiqsut	154	624	381	547	371
Kaktovik	316	644	384	694	528
Point Hope	315	696	571	267	150
Point Lay	182	696	526	366	197
Wainwright	87	709	510	446	267

Source: Barrow Rural Services Replacement Study, ASCG, Inc., May 2006.

While each of the alternate service centers could provide all or most of the critical services, the practicality and response time to deliver these services were determined to be problematic due to a number of factors including:

- Distance to NSB communities and inability to respond in a timely manner
- The potential for response personnel and aircraft to be unavailable when needed in emergency situations because of needs in the areas that they regularly serve
- Inability of available aircraft to land at many of the NSB's small airstrips
- Unfamiliarity with the area, which would impede response in poor weather conditions

The findings of the study demonstrate that the villages are highly dependant on service providers in Barrow to deliver both critical and non-critical services. The study also concluded that alternate service centers such as Anchorage, Fairbanks, Nome, and Kotzebue would be unable to approximate this same level of service.

3.5 Recreation

Traditional recreation activities and opportunities in Barrow are limited due to the nature of life in the community. From November to June, the shoreline is iced in. The daily minimum temperature is also below freezing 324 days of the year. When the ice recedes, the community focuses on subsistence activities that support their daily lives. Whaling seasons occur in June and September, while fish camps focus on salmon and whitefish in Elson Lagoon. When the beach is free of ice, some recreational beach combing and walking occurs both by the local population and tourists.

There is a small salmon stream southwest of Barrow that supports a small run of chum salmon in August that is reported to be visited by a small number of locals. In the winter, people hunt inland for furbearers, caribou, ptarmigan, and under-ice fishing. Some hunting for seals and polar bear also take place. The cold and windy weather in December through February places some limits on the distance people can travel safely from Barrow, but residents will take advantage of nice weather to travel by snow machine. These months are popular times to socialize, hold gatherings, and travel.

3.6 Subsistence Production

Subsistence is extremely important to the community in Barrow. Seventy percent of the population is Alaskan Native (primarily Inupiat Eskimo) and practice a subsistence lifestyle. Traditional marine mammal hunts and other subsistence practices are an active part of the culture. Bowhead, gray, killer and beluga whales migrate near Barrow each summer. The harvesting of whales (primarily Bowhead) in Barrow is intrinsic to its way of life.

The community gathers for the kick-off of the whaling season with an annual festival that celebrates this lifestyle. There are two seasons for whaling in Barrow – spring and fall. For spring whaling people place camps out on the ice near leads where the whales are expected to appear. When a whale is spotted, they launch skin boats and paddle to pursue the whale. Then the whale is hauled onto the ice where it is butchered. The meat and *maktak* (skin and blubber) is brought back to Barrow using snow machines. Fall whalers use aluminum or fiberglass boats with motors on the open ocean. The crews come and go daily, rather than make camps. Struck whales are hauled back to Barrow and pulled onto the beach. Spring whaling is the most important. More crews participate in spring whaling and it is considered safer. It's also the more costly and involves more investment. Captains are expected to provide food and shelter for crews out on the ice. They must get women relatives or elders to sew seal skins to cover the boats and sew parka covers. All whaling captains – spring and fall – supply boats, fuel, motors, darting guns, ammunition, bombs, block and tackle, ropes and floats, CB/VHF/satellite radios, etc. Spring whaling captains also provide tents, snow machines and sleds, and host feasts at *Nalukataq* (whaling festival) and *Apugautituq* ("bringing up the boat" celebration where the successful crew's and captain's families serve a modest meal of fermented whale meat, soup, cake, and tea to visitors).

Seal, polar bear, walrus, duck, caribou, grayling and whitefish are also harvested from the coast and nearby rivers and lakes. Wild foods, furs, clothing, construction, arts, crafts, furs and other products are traditionally traded among households through extensive, non-commercial, kinship-based networks. Coastal resources such as whale meat, seal oil, herring and halibut commonly are shared inland, while inland resources such as moose and caribou are shared toward the coast.

Areas of the beach are used for subsistence access. Boats are launched using a portable mat on the beach and small boat trailers. There are approximately 50 boats ranging in size from 16-22-feet that use the mat for subsistence use. After whales are harvested, the boats haul them onto the beach using any available beach area. The whales are then cut up for distribution within the community. Subsistence activities have typically been extremely adaptable to changes on the beach since there is no preference to where the whales are brought up.

The Alaska Department of Fish and Game (ADFG) reports that the per capita annual harvest of wild foods within NSB is approximately 434 pounds per person. Subsistence activity is significantly higher in the smaller communities outside the regional hub community of Barrow. ADFG data show a range of subsistence production in NSB from a low of 289 pounds per person in Barrow to a high of 890 pounds per person in Point Lay. Table 9 summarizes ADFG harvest data for Barrow.

Table 9: Barrow Average Annual Subsistence Harvest

Estimated Per Capita Subsistence Harvest (pounds):	289
Fish Percentage of Subsistence:	13.6%
Land Mammals Percentage of Subsistence:	24.6%
Sea Mammals Percentage of Subsistence:	58.3%
Birds Percentage of Subsistence:	3.4%
Plants and Berries Percentage of Subsistence:	0.2%
Source: Alaska Department of Fish and Game Department of Subsistence, Community Subsistence Information System.	

Price data was collected in Barrow for a market basket of potential substitute food items for use in estimating the value of the subsistence harvest as a source of food. Items in the market basket included fresh, frozen, and processed beef, reindeer, pork, poultry, and fish. The average price for the items in the market basket in 2007 prices came to $7.36 per pound resulting in an estimated substitute value of approximately $8.9 million in 2007. Table 10 presents the data used in the estimation of the value of substitute food products.

Table 10: Value of Substitute Food Products

Estimated Current Barrow Population:	4,199
Estimated Per Capita Subsistence Harvest, Barrow (usable pounds):	289
Estimated Total Subsistence Production, 2007 Barrow (usable pounds):	1,213,500
Average Cost per Pound for 2007 Market Basket of Substitute Foods: [a]	$7.36
Estimated Annual Monetary Value of Substitute Food Products, Barrow: [b]	$8,931,400

[a] Based upon 2007 prices for a market basket of fresh, frozen, and processed beef, reindeer, pork, poultry, and fish available locally in Barrow.

[b] This estimate only serves as a proxy value for the economic value of subsistence production as a source of food. Subsistence lifestyles provide other cultural, social, and health benefits that are not captured in this estimate.

It is stressed that the estimate of Subsistence Value presented in Table 10 only serves as a proxy value for the economic value of subsistence production as a source of food. Subsistence lifestyles provide other significant non-monetary cultural, social, and health benefits that are not captured in this estimate.

The State of Alaska Department of Health and Social Services reports that subsistence consumption of fish and marine mammals provide valuable sources of protein, energy and other important nutritional components such as heart-healthy omega-3 long chain polyunsaturated fatty acids in addition to providing important cultural and economic benefits (AKH&SS, 2007). The Alaska Native Science Commission (ANSC) reports that studies have shown that eating subsistence foods is correlated to better health. In addition to its nutritional values, an important health aspect of subsistence foods is the energy people expend while harvesting them. The activities surrounding hunting, fishing, gathering and preserving subsistence foods contribute to an active lifestyle. Physical activity is important in preventing obesity. Obesity is associated with increased risk of heart disease, diabetes, and other medical conditions. For subsistence participants, the process of nourishing involves the body, the mind and the spirit. While the latter factors are not measured as easily as is physical health, they are just as important. The practice of obtaining subsistence foods gives a person healthy food, exercise, fresh air, a chance to be with family members and friends, and something to share. These contributions are tangible examples of important cultural and social values of subsistence activities. (ANCS, 2007)

3.7 Utqiagvik Village Archeological Site

The Utqiagvik Village Site is an historic/archeological site in northwestern Barrow. The Utqiagvik Village Site has been occupied for over 2,500 years and at one time covered a large portion of what is now Barrow. The remaining archeological site has been set aside by the City and is the last portion of the former Utqiagvik Village Site along the coast that has not been redeveloped. The site is eligible for the National Register of Historic Places. The site suffers occasional damage/loss from coastal erosion of the Barrow bluff.

3.8 Historic Flooding and Erosion Damages

Structures and community infrastructure in Barrow are vulnerable to impacts from coastal flooding. The shoreline is most susceptible to storm activity in the months of August through October, the typical open water period. From November through July, there is generally enough ice present to have a dampening effect on wave generation. The storms that impact the coast during the open water season are typically fast moving storms from the north and northwest that last between 24 to 48 hours, but can extend up to 96 hours. Photos of past floods and flood fighting activity are provided as figures 6-9.

In October of 1963 a strong cyclonic storm passed near Barrow and caused extensive damage; primarily from flooding. The 1963 storm blew gusts up to 73 knots over an ice-free ocean. Seawater is reported to have moved 400 feet inland in parts of Barrow. The reported damages totaled $25,090,000 in 2007 dollars, including:

- Extensive erosion
- Damages to 32 homes
- Flooded roads
- Loss of fuel oil
- Damage to a radio tower
- Contamination of the water supply for several months
- Discontinuation of utility service

With its effects intensified by the ice-free ocean, this was the most severe storm on record to hit Barrow. The maximum water elevation was 11 to 12 feet and, according to NARL researchers, the event generated the equivalent of 20 years of sediment transport and erosion. Fifteen homes were destroyed and 17 more were damaged. About 70 percent of the airstrip at the Naval Arctic Research Laboratory was destroyed along with 4 aircraft, 6 buildings and many supplies, stores and scientific equipment. The foundations of the Camp's buildings were also eroded causing structural damage. The city's power lines and the power plant were down, fuel was lost and the water supply was contaminated with salt water. Furthermore, roads were flooded and badly eroded and a timber bridge floated away.[3]

Historical data from storm surges and flooding events in Barrow are limited. Other notable storms before and after the 1963 storm are as follows[4][5][6]:

- <u>September 1954</u>: Water elevations reached between 9 and 10 feet, washing water over the beach and a helium tank from the community nearly to the Point.

- <u>October 1954</u>: Minor damage occurred with a maximum water elevation of 9.5 feet.

- <u>September 1968</u>: A maximum water elevation of 8.5 feet was reached and caused $50,000 in damages (not adjusted for inflation). The road between Barrow and the City dump was severely eroded and a bridge was damaged.

- <u>September 1970</u>: Minor damage occurred with an unknown water elevation.

- <u>December 1977</u>: Barrow's gas well runway partially flooded with 6 to 18 in. of water rising through a crack in the ice. Rising water also lifted the pack ice at Barrow and persistent winds drove it as much as 30 yards inland. A maximum water elevation of 3.5 feet was reached.

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[3] Becker, R. Jr., et. al. (August 1981). *Storm Surge Climatology and Forecasting in Alaska.* Environment and Natural Resources Institute: Alaska State Climate Center. University of Alaska, Anchorage. Fathauer, Theodore F. 1978. A forecast procedure for coastal floods in Alaska. NOAA Technical Memorandum NWS AR-23. 27 pp.; Brunner, R., et. al. (August 2001). *Big Storms*. Seminar – Integrated Assessment of the Impacts of Climate Variability on the Alaskan North Slope Coastal Region; Barrow. University of Colorado. Retrieved 06/19/2007 from: http://nome.colorado.edu/HARC_noframes/poster1/Barrow_poster_new_html.html

[4] Ibid.

[5] Brunner, R., et. al. *Presentation: Coastal Erosion, Flooding, and Hazards Near Barrow, Alaska.*

[6] Cassano, L., et. al. (August 2003). *Recent Strong Wind Events in Barrow: Forecast, Meteorology, and Responses.* Seminar – Integrated Assessment of the Impacts of Climate Variability on the Alaskan North Slope Coastal Region; Barrow.

- September 1978: A maximum water elevation of 5 feet occurred causing between $5,000 and $50,000 (not adjusted for inflation) in damages to the road between the Naval Arctic Research Laboratory and Barrow.

- September 1986: There is not much data available about this event, but there were apparently two different storms during this month. The Leavitt House had to be moved and large sections of land were lost to erosion along with archaeological remains.

- August 2000: This was the second most devastating storm in Barrow's recorded history, again with heightened effects from the lack of sea ice. The NSB Disaster Coordinator reported $7.7 million in damages (unadjusted for inflation) mainly to a barge that was dredging offshore for beach nourishment. The barge was damaged when it was grounded on the shoreline, damaging the bottom of the vessel beyond salvageable repair. The dredging operation was suspended after the storm, not only because of the damages sustained, but also because of the inability of the operation to produce gravel of sufficient quality for use on the beach. Most of this occurred to a beach nourishment dredge that was ripped from its anchors and washed ashore. There were also 36 private homes and 4 NSB housing units that sustained roof and siding damages.

- October 2002: This storm caused more widespread flooding than the storm in August 2000 due to the dynamics of the sustained winds and heavy surf. Waves reached a peak of about 14 feet. Heavy equipment had to be used to build up the existing sea walls and protect the fresh water lagoon. Some roads were damaged and a power outage occurred.

- July 2003: There were two storm events during this month, both with minor damages. Some road damage occurred, but was limited as sand and gravel berms were reinforced to reduce flooding and erosion.

Figure 6: Barrow Flood Damage Example

Figure 7: 1963 Flooding of Homes and Fish Racks

3.9 Annual Storm Protection and Road Repairs

3.9.1 Berm Building

Over the past 10 years berm building has been the first protection against storms for the community. These berms are gravel mounds with a top elevation of generally 13-15 feet in height and placed at the crest of the beach as a protection measure against rising water from storm surge and wave attack. The NSB normally uses lower grade material since they have a limited supply of gravel. The higher quality gravel is used to maintain the community's roads. Although the material is of a lower grade, the material still costs about the same per cubic yard as the higher quality gravel ($37/cubic yard) due to the cost to extract the material from the gravel pit. On average approximately 15,000 cubic yards of gravel are placed annually to protect the community at a materials cost of $548,000. Labor and fuel account for another $19,000, for a total of $567,000 annually in 2007 prices.

The storms that hit the community generally range in length from 3-5 days. When the storms are larger, the berms do not last very long, often gone after 8-10 large waves. When the berms are reinforced and/or rebuilt during storm conditions, D7/D8 dozers are operated in the salt water (figure 8). The NSB has stated that although the berms provide limited flooding and erosion protection during larger storms, they would continue doing what they could to keep the berms in place, even if that means continued operation of the dozers in the water. When the dozers are operated this way additional maintenance is required to keep this equipment in order. Due to the corrosive nature of the salt the electrical systems are the hardest to keep in working order. The dozers must routinely be steam cleaned to keep salt off, while the electrical connections are shrink-wrapped to prevent salt from entering the connections.

Figure 8: Dozers Rebuilding Beach Berm during Storm

Figure 9: Heavy Equipment Operations during Storm

3.9.2 Shoreline Road Maintenance

Stevenson Street is adjacent to the shoreline and is susceptible to direct storm attack. Figure 10 shows the location of Stevenson Street along the shoreline of Barrow. During the 2000 storm, water flooded overtop of Stevenson Street and four sections of the roadway were lost (approximately 200 yards in length) costing approximately $330,000 in 2007 prices to repair. It is estimated that the road needs to be repaired about every 3 years as a result of storm damages, or approximately $110,000 annually (in 2007 prices). Stevenson Street provides an important transportation connection to Pt. Barrow, where fish camps used for subsistence harvesting are located at Elson Lagoon. The subsistence-harvesting season for salmon, whitefish, and other types of fish all occur during open water periods, which also have the highest possibility of storm events.

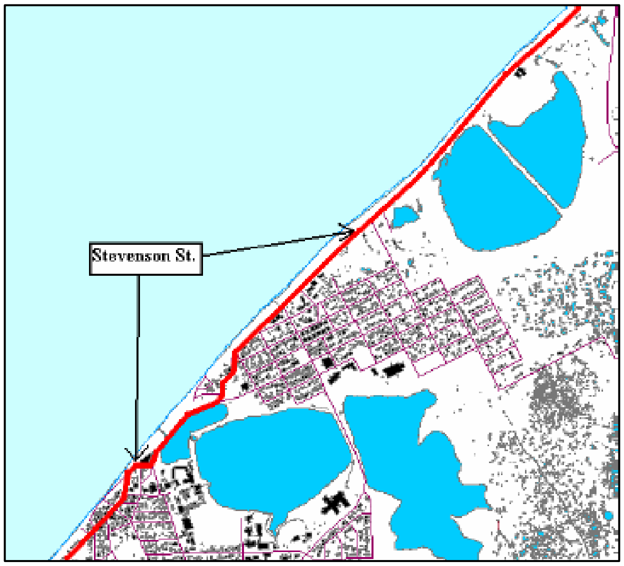

Figure 10: Location of Stevenson Street

3.9.3 Summary of Annual Berm Building and Road Repair Costs

The estimated annual cost for berm construction and maintenance and road repairs under existing conditions is approximately $677,000 in 2007 prices. In the without project condition this cost will continue until a project is put in place that controls wave activity and protects the roads from erosive forces during storm events.

4.0 System of Accounts for Project Evaluation

The U.S. Water Resources Council’s Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) identify a system of four accounts for evaluating and documenting the effects of proposed plans. These four accounts are the National Economic Development (NED), Regional Economic Development (RED), Other Social Effects (OSE), and Environmental Quality (EQ) accounts. Effects that fall within three of these accounts (NED, RED, and OSE) are addressed in the following sections of this economic appendix. Evaluation of NED effects is required by Corps planning regulations and all economic development projects require identification of the NED plan as the alternative plan that maximizes net benefits (the difference in project costs and benefits). For this analysis, a set of preliminary alternatives was identified and their NED effects were evaluated to support plan screening and identification of a set of final plans for further consideration. For the set of final plans, effects in all four accounts were evaluated and are documented in this report.

5.0 Period of Analysis, Discount Rate, and Price Level

The evaluation of economic conditions under with- and without-project conditions documented in this appendix was based upon a fifty-year period of analysis beginning in the base year of 2010. The base year is defined as the year that significant project benefits will begin to accrue. All costs and benefits are presented in October 2007 prices. Costs and benefits are converted to their equivalent values in the base year using the FY07/08 Federal discount rate for water resources implementation studies of $4^7/_8$% as published in Economic Guidance Memorandum 07-01 and 08-01. Similarly, costs/benefits presented as average annual costs are amortized over a fifty year period of analysis using the discount rate.

Economic analyses performed are consistent with pertinent Corps regulations and guidance including:

- Principles and Guidelines for Water and Related Land Resources Implementation Studies
- U.S Army Corps of Engineers Planning Guidance Notebook (Engineer Regulation ER1105-2-100)
- Planning - Risk Analysis for Flood Damage Reduction Studies (Engineer Regulation ER-1105-2-101)
- Risk-Based Analysis for Flood Damage Reduction Studies (Engineer Manual 1110-2-1619)

6.0 Future Without Project NED Evaluation

The P&G defines beneficial effects in the NED account as increases in the economic value of the National output of goods and services from a plan; the value of output resulting from external economies caused by a plan; and the value associated with the use of otherwise unemployed or underemployed labor resources. In the case of the Barrow Coastal Storm Damage Reduction study, potential beneficial NED effects are possible by reduction of damages from flooding and erosion that would be expected to occur without a project. The analytical framework identified in the P&G and further defined in Corps planning regulation (Engineer Regulation 1105-2-100) require that beneficial NED effects be determined by comparing expected future conditions without a project to the various alternative future conditions that would be expected to occur with implementation of an array of alternative projects.

6.1 Categories of Potential Damages

The primary categories of potential damages in Barrow are erosion damages to the bluff in the neighborhood of Barrow, erosion damages to the beach flood protection berm and shoreline roadways[7], and damages from coastal storms in the eastern portion of the neighborhood of Barrow and in the neighborhood of Browerville. Specific categories of potential damages evaluated include:

- Erosion Damages to
    - Land
    - Structures
    - Archeological Site (Utqiagvik Village Site)
    - Beach Berm and Shoreline Roadway

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[7] In this analysis, the expected annual costs associated with beach berm construction and maintenance and the roadway repairs associated with storm erosion damages as documented in Section 3.9 are accounted for as erosion damages as the maintenance and repair costs incurred are a result of upland erosion from coastal storms.

- Flooding Damages to
    - Structures and Contents
    - Water Supply
    - Spillway and Associated Utilities
    - Utilidor and Associated Utility Service

6.2 Future Without-Project Coastal Erosion Damages

Results of engineering studies and review of historic damages identified two primary sources of erosion damages in the study area. These damages include damages from wind and waves to the bluff in the Barrow area and costs associated with the ongoing construction and repair of the beach berms and beach frontage road (Stevenson Street) in the northeastern part of the neighborhood of Barrow and in Browerville.

6.2.1 Expected Bluff Erosion Damages

Historic erosion along the bluff in Barrow was studied as part of the feasibility study's engineering analysis and is documented in the Engineering Appendix. The erosion analysis identified two reaches of the study area that were each characterized by different historic erosion patterns, referred to in this report as Erosion Zones 1 and 2. Erosion Zone 1 extends southwestward from the beach in front of the western end of the lagoon to Okoksik Street. Erosion Zone 2 extends southwestward from Okoksik Street to the bluff in front of the northeastern end of the airport runway. Erosion Zone 1 was found to have an expected future erosion rate of 2.2 feet per year, resulting in inland movement of the bluffline by 110 feet over the 50-year period of analysis in Zone 1. Erosion Zone 2 was found to have a future without project expected annual landward erosion rate of 1.02 feet per year. At this annual rate, erosion is expected to move the bluff line inland by 51 feet over the 50-year period of analysis in Zone 2. The result of the erosion in both zones would be damages associated with the loss of land, structures, and cultural and historic resources. Figure 11 shows the expected zone of bluff retreat (erosion) over the 50-year period of analysis.[8]

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[8] The area shown in figure 11 is limited to the erosion prone areas in the western portion of the study area (southwest of the lagoon). Other areas to the east (Browerville) are not shown in this figure.

Figure 11: Expected 50-Year Erosion in the vicinity of Barrow

To estimate expected erosion losses, 5 polygons within each zone were developed in GIS that corresponded to the areas of expected erosion area in five 10-year increments: Years 1-10, 11-20, 21-30, 31-40, and 41-50 of the period of analysis. For each time increment, the area of land and number of houses lost or condemned were identified and assigned a damage value. Damages were totaled for each 10-year increment and converted to their present value in the base year from the midpoint in each increment. The results of the analysis of future without project erosion damages are presented in the following sections for each damage category.

Land Damages

As a result of continued bluff erosion, the total extent of lost land over the 50- year period of analysis is estimated at 7.43 acres. Valuation of lost land was based upon an average cost of $100,000 per acre; the average of the values of land per acre for parcels within the 50-year erosion zone. Estimated land damages from erosion over the 50-year period of analysis have a total present value of $283,000. The equivalent average annual damage is $15,000. Table 11 summarizes the expected land damages from erosion.

Table 11: Land Damages from Erosion

Item:	**Erosion Zone Increment**					
	Years 1-10	**Years 11-20**	**Years 21-30**	**Years 31-40**	**Years 41-50**	**Total (Years 1-50)**
Area of Land Lost (acres):	1.50	1.49	1.47	1.46	1.51	7.43
Value of Land Lost (2007 prices):	$151,000	$150,000	$148,000	$147,000	$152,000	$747,000
Present Value:	$119,000	$73,000	$45,000	$28,000	$18,000	$283,000
Average Annual Damages:						$15,000

Structural Damages

As a result of continued bluff erosion, it is estimated that 31 structures in the neighborhood of Barrow would be condemned. Condemnation was assumed to occur whenever any of two conditions occurred:

1) Once any part of a structure intersected with the eroded bluff line, or
2) Once over 50% of the area of the structure's parcel was lost[9]

Valuation of erosion damages to structures was based upon the estimated depreciated replacement cost of each structure. It was assumed that all contents of value would be removed and not damaged by erosion. It was also assumed that no future development would occur in the identified erosion zone over the period of analysis.

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[9] Parcel sizes containing structures within the erosion zone varied from a low of .04 acres to a high of .88 acres with an average size of .14 acres).

Continued erosion over the period of analysis is expected to result in loss or condemnation of 31 structures in the Barrow neighborhood of the study area. Estimated structure damages from erosion over the 50-year period of analysis have a total present value of $4,735,000. The equivalent average annual damage is $254,000. Table 12 summarizes the expected structure damages from erosion.

Table 12: Structure Damages from Erosion

Item:	**Erosion Zone Increment**					
	Years 1-10	**Years 11-20**	**Years 21-30**	**Years 31-40**	**Years 41-50**	**Total (Years 1-50)**
Number of Condemned Structures:	4	10	8	3	6	31
Value of Condemned Structures (2007 prices):	$864,000	$4,170,000	$3,619,0000	$1,182,000	$5,860,000	$15,695,000
Present Value:	$681,000	$2,042,000	$1,101,000	$223,000	$688,000	$4,735,000
Average Annual Damages:						$254,000

Archeological Site

The Utqiagvik Village Site falls in part within the 50-year erosion zone. The site is periodically impacted by bluff erosion that can result in artifacts, the remains of semi-subterranean houses, and occasional human remains being uncovered. More on the site is presented in Section 3.6. The non-monetary cultural value associated with the archeological site is not included in this NED analysis.

6.2.2 Expected Beach Berm and Roadway Costs

Sections 3.9.1 through 3.9.3 describe annual costs associated with damages and repairs to beach berms and the shoreline roadway. In the current without project condition these costs ($677,200 in 2007 prices) are expected to continue on an annual basis until a project is put in place that controls wave activity and protects the road during storm events. Over the 50-year period of analysis, this annual cost has a total present value of $12.6 million dollars.

6.2.3 Expected Utilidor Damages

The Barrow Utilidor is a heated underground utility corridor that provides utility service to parts of the study area. The system went into operation in 1984 and currently includes approximately 3.3 miles of utilidors in Barrow and Browerville, containing 11 miles of water, sewer, and force mains, as well as electrical conduit and communications cable. Erosion is expected to result in failure of the Utilidor at the west end of Agvik Street within 25 years. The resultant damage is estimated to have a present value of $1.4 million and an average annual value of $75,000.

6.2.4 Summary of Expected Coastal Erosion Damages

Total expected annual erosion damages in the study area are estimated at $1,021,000, including the above described damages to lands, structures, the beach berm, roadways, and the utilidor. Table 13 summarizes the present values of erosion damages for each category over the period of analysis and their average annual equivalent values.

Table 13: Summary of Expected Erosion Damages

Damage Category	Present Value	Average Annual Value
Land Loss	$283,000	$15,000
Structure Condemnation	$4,735,000	$254,000
Beach Berm Construction/Repairs and Roadway Repairs	$12,604,000	$677,000
Utilidor Damages	$1,399,000	$75,000
Total	$19,021,000	$1,021,000

6.3 Future Without-Project Coastal Storm Damages

Coastal flooding in Barrow’s neighborhoods of eastern Barrow and Browerville is expected to continue under without project conditions. Categories of expected flood damages include damages to structures and contents in the study area.

To evaluate without project flood damages, the Corps’ Beach-fx risk based economic model was applied. Beach-fx is a Monte Carlo-based, event-driven coastal storm damage assessment model developed by the Corps Institute for Water Resources (IWR) and Engineering Research and Development Center’s (ERDC) Hydraulic Laboratory. The model facilitates the planning and evaluation of coastal protection projects within a GIS framework. Application of the model allowed the study team to move away from the typical frequency-based, deterministic evaluation approach and towards an event-driven approach. The event approach uses a database of plausible storms in a Monte Carlo based model to evaluate the economic consequences of storm driven impacts on upland development. The methods and results of the analysis of future without project flooding damages are presented in the following sections for each damage category.

6.3.1 Expected Damages to Structures and Contents

Barrow Structural Inventory

A structural database was developed by ASCG, Inc. for NSB and the Alaska District that included 1,000 structures located either within or near the 20 foot contour line. The database included data from a land survey conducted by ASCG during 2004-2005 to record elevations of structures and facilities. The land survey portion focused on developing an accumulation of survey points to help assess flood risk for each dwelling, commercial building, and structure within the potential floodplain. Elevations of each structure were taken at three specific points: the ground elevation, first floor elevation, and the elevation where the building utilities connect to the service barrel (12 to 16 inches below the top of the utility box).

In 2006, a supplemental field inspection was performed on a sample of 112 of these structures to include both residential and nonresidential structures in both Barrow and Browerville. Characteristics such as building use, condition, type, construction material, and general description were recorded for use in structure valuation and to confirm data from the 2004-2005 survey.

Developable land within the coastal floodplain in the study area is largely built out. It was assumed that future development in the coastal floodplain would be limited and that any future development within the floodplain would be constructed above the damage-initiating elevation for that specific area.

Structure Categories

Based on field observations and database descriptions, structures were assigned to one of four categorical groups: Commercial, Public, Residential, and Outbuilding.

Structure Valuation

Structures were assigned values as a function of the estimated first floor square footage (taken from the GIS database) and estimated value per square foot by use, class and type from Marshall and Swift Valuation representing comparative costs for Anchorage, Alaska. The Marshall and Swift Valuation Database does not compile local multipliers for Barrow so these Anchorage-based values needed to be adjusted to represent the significant costs of getting construction materials to Barrow. Data from the 2006 Construction Cost Survey, prepared by the Alaska Department of Labor and Workforce Development for the Alaska Housing Finance Corporation (AHFC) was used to determine an adjustment factor. The AHFC survey data showed that home construction in Barrow cost 215% of that in Anchorage; an adjustment factor of 2.153. This factor was applied to the square footage values to determine values for the sample of 112 structures. For the remaining structures in the study area, the average value per square foot by category (see table 14) was assigned to each structure’s square footage. Field survey observations were used to apply applicable depreciation adjustments to estimated structure replacement values.

Table 14: Average Structure Depreciated Replacement Value per Square Foot (Sq Ft)

CATEGORY	SAMPLE	TOTAL SQ FT	TOTAL VALUE	VALUE PER SQ FT
Commercial	16	62,234	$12,303,212	$198
Public	19	61,621	$15,284,573	$248
Residential	72	135,061	$24,130,348	$179
Outbuilding	5	2,254	$57,922	$26

First Floor Elevations

Damages to both structures and contents are a function of depth of water relative to the first floor elevations. While a large number of structures lie within the 20 foot contour line, many are elevated above the ground level and would be at risk from only the rarest storm events as presented in table 15.

Table 15: Structures and Depreciated Replacement Value by First Floor Elevation

CATEGORY	FIRST FLOOR ELEVATION	NUMBER OF STRUCTURES	TOTAL DEPRECAITED STRUCTURE VALUE
Commercial	Under 15 Feet	13	$ 5,831,000
	Under 18 Feet	20	$ 6,367,000
	Under 20 Feet	25	$ 11,186,000
Public	Under 15 Feet	9	$ 7,327,000
	Under 18 Feet	22	$ 14,136,000
	Under 20 Feet	35	$ 65,399,000
Residential	Under 15 Feet	38	$ 6,945,000
	Under 18 Feet	146	$ 31,824,000
	Under 20 Feet	247	$ 55,539,000
Outbuilding	Under 15 Feet	60	$ 281,000
	Under 18 Feet	160	$ 723,000
	Under 20 Feet	213	$ 944,000
Total	Under 15 Feet	120	$ 20,383,000
	Under 18 Feet	348	$ 53,049,000
	Under 20 Feet	520	$ 133,068,000

Depth-Damage Functions

Estimated damages were determined based on flood depth relative to first floor elevation. For residential structures, depth-damage functions were taken from Economic Guidance Memorandum 04-01, which estimates both structure and content losses as a percentage of structure value. Non-residential depth damage functions were based on local surveys completed by ASCG and combine both structure and content losses as a percentage of total structure value. The depth damage functions applied in the study for estimation of flood damages to structures and contents are presented in table 16. The non-residential damage function can exceed 100% of the structure value for severe floods because of the content values of commercial inventories.

Table 16: Depth Damage Function

DEPTH ABOVE FIRST FLOOR (feet)	RESIDENTIAL (% of structure value)		NON-RESIDENTIAL (% of structure value)	OUTBUILDINGS	
	STRUCTURE	CONTENT	STRUCTURE + CONTENT	STRUCTURE	CONTENT
-3	0%	0%	0%	0%	0%
-2	2.5%	2.4%	2.5%	0%	0%
-1	8.0%	5.3%	8.0%	0%	0%
0	13.4%	8.1%	18.3%	7.0%	0.0%
1	23.3%	13.3%	37.0%	16.3%	17.2%
2	32.1%	17.9%	53.2%	24.7%	27.5%
3	40.1%	22.0%	68.0%	27.7%	33.3%
4	47.1%	25.7%	75.0%	29.6%	36.1%
5	53.2%	28.8%	81.1%	30.9%	38.8%
6	58.6%	31.5%	86.5%	39.8%	43.2%
7	63.2%	33.8%	91.1%	42.8%	47.7%
8	67.2%	35.7%	95.1%	43.3%	60.0%
9	70.5%	37.2%	98.4%	44.8%	60.0%
10	73.2%	38.4%	101.1%	45.8%	60.0%

Incorporation of Uncertainty in Economic Parameters

As noted above, the Corps' Beach-fx model was applied for estimating storm damage with uncertainty. The following economic parameters were incorporated into the model, including both the most likely values and their relative uncertainty statistics:

a) Residential Structure Depth Damage function- triangular distribution based on uncertainties found in Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures. No specific identification of uncertainty in depth-damage for non-residential structures was provided.
b) Residential Content Depth Damage function- triangular distribution based on uncertainties in EGM 04-01
c) First Floor Elevation- triangular distribution with a range of plus or minus 0.3 feet. Based on topographic and survey detail.
d) Structure Value- triangular distribution based on a function of potential error in square footage and range of M&S values per sq ft. On average, this uncertainty accounted for plus or minus 11% of the structure value.
e) Time to Rehabilitate/Rebuild- triangular distribution with a most likely value being one –year with a minimum of ½ year and a maximum of two-years.

Coastal Storm Damage Analysis

The Beach-fx model uses Monte Carlo simulation to generate probability distributed data that integrates both engineering and economic relationships to determine the impacts and damages of a storm passing a shoreline. Water surface elevations were modeled by the Corps' ERDC Coastal Hydraulics Laboratory using the SBEACH model and converted to Beach-fx Storm Response Database files for use in the damage assessment. Economic damage elements were spatially developed representing structure and content value, first floor elevations, and type categorizations with uncertainties for structural analysis. These were then linked to the storm elevation data with uncertainty in the model based by lot, reach and profile. Separate reaches were required to represent the unique profile and storm elevations for different events from reach to reach. Figure 12 shows the delineation of the study reaches for the coastal storm damage analysis.[10]

Damages were then estimated as a function of estimated water surface elevations for a series of storms relative to the first floor elevation for structures and contents or the identified damaging elevation for utility infrastructure. In the model, the damage functions determine the percent damage for individual storms relative to the value of structures and infrastructure at risk. As the series of storms are run in the Monte Carlo simulation, the damageable property is limited to the time of the last damaging storm and the time to rebuild parameter in the model. The present value of all these losses due to storms is evaluated over a 50-year period of analysis to determine average annual equivalent damages.

The Beach-fx model reports damages by reach in terms of mean, standard deviation, maximum and minimum values based on a summary of individual simulations for the number of iterations run in the model. For Barrow, 150 iterations were run to create a sample of storm damages over a 50-year period of analysis. For the without project damages, the present value of the estimated storm damages for both structures and contents combined over the 50-year period of analysis is shown in table 17, which also presents the estimated average annual equivalent coastal storm damages to structures and contents for all reaches. The total estimated annual damages to structures and contents have a mean expected value of $58,900.

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[10] The reach designations were defined for the study's hydraulic model (SBEACH). The hydraulic study reaches include additional reaches to the southwest and northeast of the reaches shown in Figure 9. These reaches were included in the hydraulic model to define boundary conditions and for the study of littoral beach erosion processes. A limited subset of the reaches (24-49) were included in the economic analysis because they comprised the area containing economic damages in the study area and were within the area considered for potential protective measures. Additionally some reaches were combined during iteration of the modeling, which results in non continuous numbering for the reaches (there are no reaches 27, 30, 33, 35, 37, 41, 44, 46, and 48).

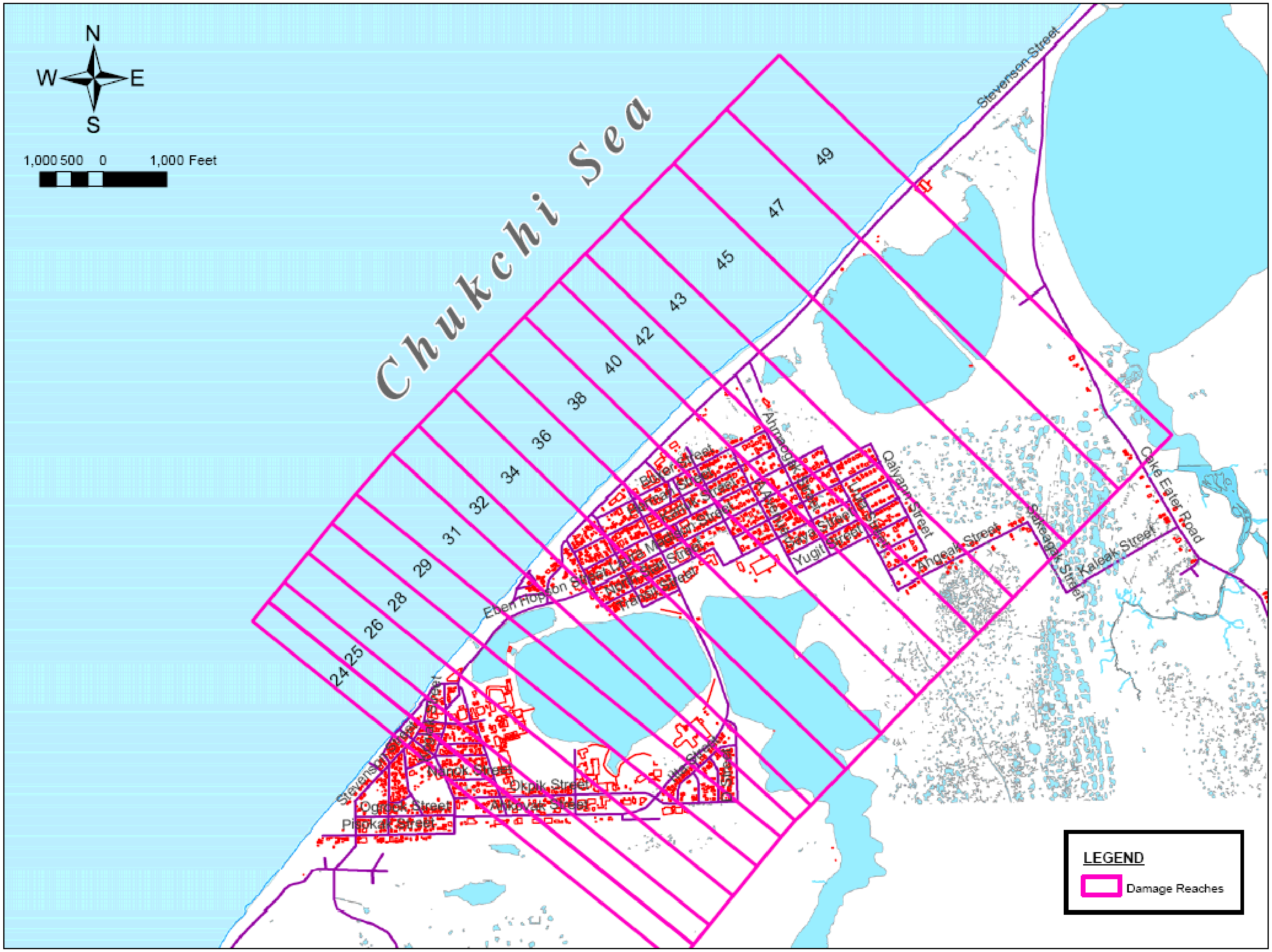

Figure 12: Coastal Flood Damage Economic Model Study Reaches

Table 17: Without Project Coastal Storm Damage to Structures and Contents

REACH	STORM DAMAGES PRESENT VALUE			
	MEAN	STANDARD DEVIATION	MAXIMUM	MINIMUM
24	$142,000	$167,600	$1,004,900	$0
25	$137,600	$96,200	$621,900	$0
26	$364,700	$226,600	$1,293,000	$0
31	$84,500	$76,800	$403,400	$0
32	$51,700	$51,800	$267,100	$0
34	$700	$1,900	$17,200	$0
36	$63,900	$107,400	$802,800	$0
38	$4,400	$12,900	$128,800	$0
40	$80,800	$171,100	$1,047,100	$0
42	$153,200	$241,000	$1,269,200	$0
43	$12,800	$7,900	$38,200	$0
TOTALS	$1,096,300	$1,161,200	$6,893,600	$0
REACH	**AVERAGE ANNUAL EQUIVALENT DAMAGES**			
	MEAN	**STANDARD DEVIATION**	**MAXIMUM**	**MINIMUM**
24	$7,630	$9,000	$53,990	$0
25	$7,390	$5,170	$33,410	$0
26	$19,590	$12,170	$69,460	$0
31	$4,540	$4,130	$21,670	$0
32	$2,780	$2,780	$14,350	$0
34	$40	$100	$920	$0
36	$3,430	$5,770	$43,130	$0
38	$240	$690	$6,920	$0
40	$4,340	$9,190	$56,250	$0
42	$8,230	$12,950	$68,180	$0
43	$690	$420	$2,050	$0
TOTALS	$58,900	$62,370	$370,330	$0

6.3.2 Expected Storm Damages to Utilities and Infrastructure

ASCG, Inc. prepared a report in September 2005 for the North Slope Borough and the Alaska District that documented their analysis of the monetary impacts resulting from loss or damage to utility infrastructure in the study area, including:

- Water Supply
- Tasigrook Dam Spillway and Utilities that Cross Lagoon at Spillway
- Utilidor/Buried Utilities

The Barrow Utilities and Electric Cooperative provides Barrow with water, sewer, and electric service. The City's water source is the upper portion of Isatkoak Lagoon. Water is taken from the lagoon, run through the treatment plant's nanomicrofiltration process and distributed to residents. Utility line and pipes are either direct-buried or contained in an underground utilidor system, which has portions adjacent to the beach. Most residents are hooked up to the system. However, some still rely on truck-based water delivery and sewage removal from home storage tanks. The NSB is responsible for solid waste disposal, road improvements, and emergency operations during storms, floods, and other disasters. South Salt Lagoon is divided in half, with the western half being used for the second year of sewage pond storage and the eastern half the old Barrow landfill, which is in the process of being closed. The new landfill will be located upland, about five miles southeast of Barrow.

Water Supply

The ASCG Study identified the damage initiating elevation for the water supply to be at 10’ msl at the outflow pipes form Isatkoak Reservoir at Ahkovak Street. The feasibility study’s engineering analyses found that the potential range of water surface elevations as simulated by the study’s SBEACH model are not expected to result in damages to the City’s water supply system.

Spillway and Associated Utilities

It is expected that the spillway would undergo damage when water surfaces in the area exceed 8 feet. The study’s hydraulic model (SBEACH) predicts that water surfaces can exceed 8’ in the reach with the spillway although only under low frequency storm events. The damage function applied for estimating damages was based upon 5% damage between 8 and 9 feet, 50% damage between 9 and 10 feet, and 100% damage with an 11’ or higher water surface elevation. The damage function and SBEACH data were integrated within the Beach-fx model to estimate expected damages to the spillway over the period of analysis. The total estimated annual damages to the spillway are estimated to have a mean expected value of $67,400.

Utilidor

It is expected that the utilidor would undergo damage when water surfaces in the area exceed 10 feet. The study’s hydraulic model (SBEACH) predicts that water surfaces can exceed 10’ although only under low frequency storm events. Maximum utilidor damages from any flood event were identified at approximately $4.5 million. The damage function applied for estimating damages was based upon 6% of the maximum damage at 12 feet water surface elevation, 40% damage at 14.5 feet, and 62% damage at 16’. The damage function and SBEACH data were integrated within the Beach-fx model to estimate expected damages to the spillway over the period of analysis. Damages never exceeded 49% of the maximum value in any iteration of the flood simulations in Beach-fx. The total estimated annual damages to the Utilidor over the period of analysis were estimated to have a mean expected value of $31,000. No flood damages were included for any periods after year 25 where the erosion analysis predicts damage to the utilidor to avoid double counting (see **Section 6.2.3**).

6.3.3 Summary of Coastal Storm Damages

Total expected annual coastal storm damages from flood inundation in the study area are estimated at $157,300, including the above described damages to structures and their contents, the spillway and associated utilities, and the utilidor. Table 18 summarizes the present values of coastal storm damages for each category over the period of analysis and their average annual equivalent values.

Table 18: Summary of Expected Coastal Storm Damages

Damage Category	Present Value	Average Annual Value
Structures and Contents	$1,096,300	$58,900
Spillway and associated Utilities	$1,254,000	$67,400
Utilidor	$577,900	$31,000
Total	$2,928,200	$157,300

6.4 Summary of Future Without-Project NED Damages/Costs

The evaluation of economic damages associated with coastal storm damages and erosion in the study area identified total expected annual damages of $1,178,300, including expected coastal storm/flooding damages to structures and their contents and erosion damages to the NSB's system of coastal storm protection beach berms, the beach frontage road, and lands and improvements located within the predicted erosion zone atop the bluff in Barrow. Table 19 provides a summary of the expected annual without project damages from coastal flooding and erosion in the study area.

Table 19: Summary of Expected Annual Damages

DAMAGE CATEGORY	ESTIMATED ANNUAL DAMAGE	% OF TOTAL
Average Annual Coastal Storm Damages	$157,300	13%
Average Annual Erosion Damages[11]	$1,021,000	87%
Total Expected Annual Damages	$1,178,300	100%

7.0 Future With-Project Conditions for Alternatives

In conducting the Barrow Coastal Storm Damage Reduction Study, several evolving iterations of plan formulation, evaluation, and comparison were conducted. In each iteration of this planning process, economic analysis was conducted to identify the potential economic benefits of alternative plans. The plan formulation process is documented in the main text of the feasibility report, and summarized in this appendix.

First, an array of five initial alternatives were developed by the study team for evaluating their effectiveness and efficiency at addressing identified coastal flooding and erosion damages in the study area. The alternatives considered included:

a) No Action[12]
b) Construction of a Revetted Berm to protect areas susceptible to coastal flooding

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[11] Erosion damages include expected annual costs associated with loss/repair of beach berms and erosion damage to Stevenson Street.

[12] The "No Action" alternative involves no federal action to address identified flooding and erosion problems in the study area. As documented in Sections 3.9.3 and 6.2.2, it is assumed that the NSB will continue with their annual flood fighting practices of beach berm building and repair of erosion damages to the beach frontage road in the absence of a federal project.

c) Construction of a Bluff Protection revetment to protect areas susceptible to bluff erosion
d) Combination of the Revetted Berm and Bluff Protection revetment to provide protection for the entire study area
e) Non-Structural Building Raise alternative to evaluate the effectiveness of elevating at-risk structures above expected coastal flood elevations

The economic methodologies applied for estimating without project conditions were reapplied to reflect the level of protection afforded by each of the alternatives to calculate damages reduced. Review of initial analyses identified the need to look at a wider range of configurations of these structural and non structural measures. The initial alternatives were refined and modified to allow for a more detailed analysis of the costs and benefits associated with different heights, lengths and configurations of the measures identified in the initial alternatives. Three additional alternatives were added to evaluate the costs and benefits of: a) constructing the Revetted Berm and Bluff Protection alternatives to better withstand ice (Ivu) forces, b) Beach Nourishment, and c) Filling the Lagoon.

The resultant final set of alternatives is presented in Table 20 and each alternative is described in the following paragraphs. Descriptions of the different configurations of the final alternatives include a reference to transects that each protects. A map of the transects is provided as Figure 13 for reference. A more detailed description of alternatives is presented in the main text of the feasibility report.

Table 20: Alternatives

ALTERNATIVES	CONFIGURATION	
	PROTECTION LENGT	**H**
No Action	not applicable	not applicable
Revetted Berm Sized for Waves	Protection to +8' Contour (Transects 27-31.5)	1,800 lf
	Protection to +10' Contour (Transects 24.6-31.5)	2,745 lf
	Protection to +12' Contour (Transects 22-33)	4,800 lf
	Protection to +14' Contour (Transects 22-43)	8,750 lf
Revetment	Protect Bluff Transects 17-22	2,000 lf
	Protect Bluff Transects 22-24.6	1,040 lf
	Protect Bluff Transects 22-27	2,000 lf
Revetted Berm Sized for Ice	Protection to +14' Contour (Transects 22-42)	8,750 lf
	Protect Bluff Transects 22-27	2,000 lf
Beach Nourishment	Protection to +8' Contour (Transects 27-31.5)	1,800 lf
	Protection to +10' Contour (Transects 24.6-31.5)	2,745 lf
	Protection to +12' Contour (Transects 22-33)	4,800 lf
	Protection to +14' Contour (Transects 22-43)	8,750 lf
	Protect Bluff Transects 22-27	2,000 lf
Non-Structural Plan	Protect 34 Structures (Raise 10 / Relocate 24)	not applicable
Lagoon Fill	Fill Tasigrook Lagoon (~ Transects 27-32)	not applicable

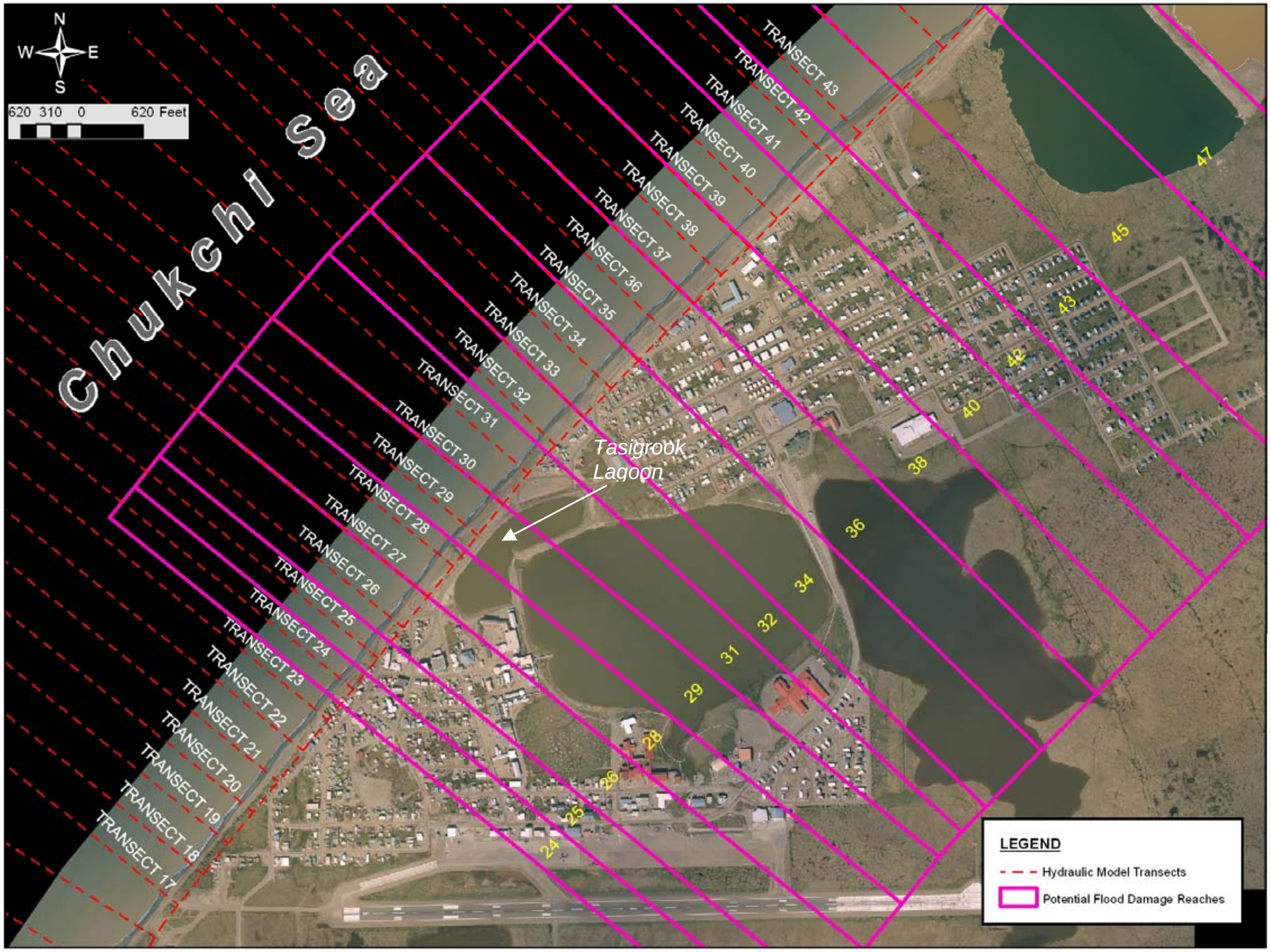

Figure 13: Shoreline Transects

7.1 No Action

The No-Action Alternative would not include any potential coastal storm protection or erosion protection measures in the study area other than those already proposed and accounted for in the determination of future without project conditions. Damages would be expected to continue as described in section 6 of this report and summarized in table 18.

7.2 Revetted Berm Sized for Waves

This alternative would construct a new revetted berm between the shore side roads and the beach above the high tide mark for the purpose of reducing flood and erosion damages in the study area east of the Barrow Bluff. The top elevation of the rock structure would be set at +14.0 feet (ft.) based on the hydraulics, tide, wind, and wave analyses for all lengths of the revetted berm. Different levels of damage reduction could be achieved by varying the length of shoreline protected. For protection to the contour elevation +8.0, +10.0, +12.0, and +14 ft, the revetted berm would be 1,800 ft., 2,745 ft., 4,800ft., or 8,750 ft. long, respectively.

The total initial project cost is estimated to have a present value ranging from $43 to $118 million depending on the alternative level of protection. Including annual O&M costs, the alternative Revetted Berm configurations had an average annual cost ranging from $10 to $14 million. Damages prevented (benefits) ranged from $.68 to $1.1 million (a reduction of 57 to 91%, respectively of total estimated damages in study area). None of the revetted berm configurations resulted in positive net benefits, the highest benefit to cost ratio was .09 to 1, and residual annual damages ranged from $108,900 to $501,300 as summarized in table 21.

Table 21: Alternative Configurations of Revetted Berm Sized for Waves Alternative

ALTERNATIVE CONFIGURATION	TOTAL COST (PV)	ANNUAL COST	ANNUAL BENEFITS	NET ANNUAL BENEFITS	BC RATIO	RESIDUAL ANNUAL DAMAGES
Protection to +8' Contour (Transects 27-31.5)	$43,186,000	$10,082,000	$677,000	-$9,405,000	0.07	$501,300
Protection to +10' Contour (Transects 24.6-31.5)	$51,787,000	$10,544,000	$805,900	-$9,738,100	0.08	$372,400
Protection to +12' Contour (Transects 22-33)	$75,296,000	$11,807,000	$1,025,800	-$10,781,200	0.09	$152,500
Protection to +14' Contour (Transects 22-43)	$118,006,000	$14,101,000	$1,069,400	-$13,031,600	0.08	$108,900

7.3 Revetment

This alternative is intended to provide bluff erosion protection to reaches along the Barrow neighborhood shoreline west of the west end of the revetted berm described in Section 7.2. Each of these revetment options could be combined with the revetted berm option whose west end coincides with the revetment otpion’s east end. The revetment top elevation of the rock would be set at +19.0 foot (ft.) or the existing elevation of the top of the bluff, whichever is lower. The sole purpose would be to prevent erosion of the bluff with resulting damages to the structures, roads, utilities, public facilities and the cultural historic site. Different levels of damage reduction could be achieved by varying the length of bluffline protected. The east end of the revetment varies by which, if any, of the revetted berm options is assumed to be implemented. This transition zone ranges from transect #27 westward to transect #22. The west end of the revetment could be located at either transect #22 or transect #17. The bluff protection lengths under consideration are either 2,000 ft. or 1,040 ft. long.

The total initial project cost is estimated to have a present value ranging from $40 to $56 million depending on the alternative level of protection. Including annual O&M costs, the alternative Revetment configurations had an average annual cost ranging from $9.9 to $10.8 million. Damages prevented (benefits) ranged from $.04 to $.31 million (a reduction of 3 to 26%, respectively of total estimated damages in study area). None of the Revetment configurations resulted in positive net benefits, the highest benefit to cost ratio was .03 to 1, and residual annual damages ranged from $873,100 to $1,138,700 as summarized in table 22.

Table 22: Alternative Configurations of Revetment Alternative

ALTERNATIVE CONFIGURATION	TOTAL COST (PV)	ANNUAL COST	ANNUAL BENEFITS	NET ANNUAL BENEFITS	BC RATIO	RESIDUAL ANNUAL DAMAGES
Protect Bluff Transects 17-22	$55,980,000	$10,769,000	$39,600	-$10,729,400	0.004	$1,138,700
Protect Bluff Transects 22-24.6	$40,349,000	$9,929,000	$200,700	-$9,728,300	0.02	$977,600
Protect Bluff Transects 22-27	$49,223,000	$10,406,000	$305,200	-$10,100,800	0.03	$873,100

7.4 Revetted Berm Sized for Ice

This alternative provides a more substantial alternative design than the Revetted Berm and Revetment designs to protect against future damage to the project from ice runup (ivu) events that periodically occur in the study area. The more substantial design uses larger rock than included in the Revetted Berm and Revetment alternatives that is expected to require less periodic rock replacement (maintenance) following an ivu event. The alternative alignments would be the same as described above for the Revetted Berm and Revetment configurations.

Initially, only two Revetted Berm Sized for Ice configurations were evaluated (protection to the +14 foot contour elevation and protection of transects 22-27 for cost comparison to the Revetted Berm and Revetment configurations that provided the same level of protection (and same level of benefits). Because the cost of the Revetted Berm Sized for Ice was higher than the cost of the Revetted Berm and the Revetment alternatives that provided the same level of benefit, no further configurations of the Ivu Revetment were analyzed. Costs and benefits of the two evaluated Revetted Berm Sized for Ice configurations are listed in table 23.

The configuration providing protection to the +14’ contour resulted in a $9 million reduction of annual net benefits and the configuration to protect bluff transects 22-27 resulted in a $2 million reduction of annual net benefits of when compared to the Revetted Berm and Revetment alternatives of the same alignments, respectively.

Table 23: Alternative Configurations of Revetted Berm Sized for Ice Alternative

ALTERNATIVE CONFIGURATION	TOTAL COST (PV)	ANNUAL COST	ANNUAL BENEFITS	NET ANNUAL BENEFITS	BC RATIO	RESIDUAL ANNUAL DAMAGES
Protection to +14' Contour (Transects 22-42)	$265,794,000	$23,114,000	$1,069,400	-$22,044,600	0.05	$108,900
Protect Bluff Transects 22-27	$69,523,000	$12,570,000	$305,200	-$12,264,800	0.02	$873,100

7.5 Beach Nourishment

The beach nourishment alternative provides another alternative means to obtain reduction in storm caused erosion and flood damages. Beach nourishment involves both an initial placement of gravel materials in selected reaches along the shoreline but also periodic nourishment of those materials. The reaches considered coincide with those considered for the all the Revetted Berm configurations and Bluff Protection for Transects 22-27 configuration for cost comparison. The Beach Nourishment configurations evaluated were found to provide the same level of benefits as the Revetted Berm and Bluff Protection alternatives of the same alignment.

The total initial project cost is estimated to have a present value ranging from $30 million to $1.2 billion depending on the alternative level of protection. Including annual O&M costs, the alternative Beach Nourishment configurations had an average annual cost ranging from $5.3 to $92.6 million. Damages prevented (benefits) ranged from $.68 to $1.1 million (a reduction of 57 to 91%, respectively of total estimated damages in study area). None of the beach nourishment configurations resulted in positive net benefits, the highest benefit to cost ratio was .13 to 1, and residual annual damages ranged from $108,900 to $501,300 as summarized in table 24.

The Beach Nourishment configuration providing protection to the +8’ contour resulted in a $4.7 million increase in annual net benefits over the Revetted Berm +8’ configuration, however the net annual benefits were still negative ($-4,712,000). All other configurations of the Beach Nourishment Alterative that were evaluated resulted in a further reduction in net benefits when compared to the Revetted Berm and Bluff Protection alternative configurations of the same alignment.

Table 24: Alternative Configurations of Beach Nourishment Alternative

ALTERNATIVE CONFIGURATION	TOTAL COST (PV)	ANNUAL COST	ANNUAL BENEFITS	NET ANNUAL BENEFITS	BC RATIO	RESIDUAL ANNUAL DAMAGES
Protection to +8' Contour (Transects 27-31.5)	$29,885,000	$5,389,000	$677,000	-$4,712,000	0.13	$501,300
Protection to +10' Contour (Transects 24.6-31.5)	$140,019,000	$12,307,000	$805,900	-$11,501,100	0.07	$372,400
Protection to +12' Contour (Transects 22-33)	$329,553,000	$31,458,000	$1,025,800	-$30,432,200	0.03	$152,500
Protection to +14' Contour (Transects 22-43)	$1,242,545,000	$92,619,000	$1,069,400	-$91,549,600	0.01	$108,900
Protect Bluff Transects 22-27	$157,899,000	$31,225,000	$305,200	-$30,919,800	0.01	$873,100

7.6 Non Structural

This measure identified 34 structures that would receive storm caused erosion and/or flood damages during the 50-year study period. To reduce/eliminate these damages, structures would either be relocated to flood/erosion free land (24) or would be raised (10) to place the first floor elevation above the damage elevation. This measure would eliminate 87% of the flood damages to structures and contents in the study area. Floods would continue to occur but damages to structures and contents would be reduced.

The buildings are currently supported on pile foundations. Raised buildings would have a new pile support system installed to bring the structure up to the required height. The utility services for each of the structures would be disconnected, the structure temporarily moved aside, a new pile foundation installed, the structure placed on the new foundation, and the utilities reconnected. No work would be performed along the beach.

Relocated buildings would be disconnected from utilities, moved on City streets using transporters to a new vacant site where a new pile foundation had been constructed, placed on the new pile foundation, and the utilities reconnected. To further reduce risk to human life and health, a flood evacuation plan would be developed during Preconstruction Engineering and Design for residents in the floodplain.

The total initial project cost is estimated to have a present value of $44 million. Including annual O&M costs, the non-structural alternative had an average annual cost of $2.4 million. Annual damages prevented (benefits) are estimated at $213,000[13] (a reduction of 18% of total estimated damages in study area). The non-structural alternative resulted in negative net benefits (-$2.2 million annually), the benefit to cost ratio was .09 to 1, and residual annual damages were estimated at $965,000 as summarized in table 25.

Table 25: Non-Structural Alternative

ALTERNATIVE CONFIGURATION	TOTAL COST (PV)	ANNUAL COST	ANNUAL BENEFITS	NET ANNUAL BENEFITS	BC RATIO	RESIDUAL ANNUAL DAMAGES
Protect 34 Structures	$44,189,000	$2,374,000	$212,950	-$2,161,050	0.09	$965,350

7.7 Lagoon Fill

The lagoon fill alternative provides another means to obtain reduction in storm caused erosion and flood damages to the Barrow water supply dam. This alternative was originally proposed by local residents during coordination meetings in Barrow. This alternative would provide storm damage reduction benefits by eliminating damages associated with the existing spillway and the recurring damages to the low point in the road fronting the lagoon; as well as addressing local environmental concerns associated with Tasigrook Lagoon, which has been used for sewage waste storage in the past.

This measure would provide storm damage reduction by filling Tasigrook Lagoon, the body of water between Eben Hopson Road and the water supply dam, with suitable material up to elevation +8.0 MSL. The Lagoon has an approximate length of 1,700 feet and a nominal width of 400 feet. The lagoon is estimated to have a surface area of about 665,734 square feet (15-16 acres) and have a bottom elevation near sea level. Thus the fill would be an average of eight-feet-deep. The required fill volume, including a

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[13] Breakdown in average annual benefits between relocating 24 structures and raising 10 structures is as follows:
Relocate ($191,000) + Raise ($22,000) = $213,000

25% contingency, would be about 260,000 cy. The measure would be constructed by obtaining suitable materials in available commercial sources in Barrow and transporting them by truck to the lagoon, where the materials would be spread to design elevations to drain seaward.

The total initial project cost is estimated to have a present value of $30 million. Including annual O&M costs, the alternative has an average annual cost of $1.6 million. Annual damages prevented (benefits) are estimated at $744,000 (a reduction of 63% of total estimated damages in study area). The non-structural alternative resulted in negative net benefits (-$878,600 annually), the benefit to cost ratio was .46 to 1, and residual annual damages were estimated at $433,900 as summarized in table 26.

Table 26: Fill Lagoon Alternative

ALTERNATIVE CONFIGURATION	TOTAL COST (PV)	ANNUAL COST	ANNUAL BENEFITS	NET ANNUAL BENEFITS	BC RATIO	RESIDUAL ANNUAL DAMAGES
Fill Lagoon (~ Transects 27-32)	$30,214,000	$1,623,000	$744,000	-$878,600	0.46	$433,900

8.0 Summary of NED Effects of Alternatives

Sections 6 and 7 of this report documented the results of economic modeling of future without- and with-project conditions. As reported in Section 7, none of the various configurations of alternatives evaluated were found to provide positive net benefits or a BC Ratio equal to or greater than unity. The Fill Lagoon alternative had the least negative annual net benefits (-$878,600) and the highest BC Ratio (.46) of the alternatives evaluated. Tables 27 – 29 provide consolidated summaries of all the alternatives' Benefits, Costs, and Benefit-Cost analysis, respectively.

Table 27: Summary of NED Coastal Storm Damage Reduction Benefits of Alternatives

ALTERNATIVE	WITHOUT PROJECT AVERAGE ANNUAL FLOOD DAMAGES	AVERAGE ANNUAL FLOOD DAMAGES REDUCED	AVERAGE ANNUAL RESIDUAL FLOOD DAMAGES	WITHOUT PROJECT AVERAGE ANNUAL EROSION DAMAGES	AVERAGE ANNUAL EROSION DAMAGES REDUCED	AVERAGE ANNUAL RESIDUAL EROSION DAMAGES	TOTAL ANNUAL DAMAGES	TOTAL ANNUAL DAMAGES REDUCED		RESIDUAL ANNUAL DAMAGES
REVETTED BERM (WAVES)	$157,300			$1,021,000			$1,178,300			
Protection to +8' Contour (Transects 27-31.5)		$0	$157,300		$677,000	$344,000		$677,000	57%	$501,300
Protection to +10' Contour (Transects 24.6-31.5)		$24,400	$132,900		$781,500	$239,500		$805,900	68%	$372,400
Protection to +12' Contour (Transects 22-33)		$43,600	$113,700		$982,200	$38,800		$1,025,800	87%	$152,500
Protection to +14' Contour (Transects 22-43)		$87,200	$70,100		$982,200	$38,800		$1,069,400	91%	$108,900
BEACH NOURISHMENT										
Protection to +8' Contour (Transects 27-31.5)		$0	$157,300		$677,000	$344,000		$677,000	57%	$501,300
Protection to +10' Contour (Transects 24.6-31.5)		$24,400	$132,900		$781,500	$239,500		$805,900	68%	$372,400
Protection to +12' Contour (Transects 22-33)		$43,600	$113,700		$982,200	$38,800		$1,025,800	87%	$152,500
Protection to +14' Contour (Transects 22-43)		$87,200	$70,100		$982,200	$38,800		$1,069,400	91%	$108,900
Protect Bluff Transects 22-27		$0	$157,300		$305,200	$715,800		$305,200	26%	$873,100
REVETTED BERM (ICE)										
Protection to +14' Contour (Transects 22-42)		$87,200	$70,100		$982,200	$38,800		$1,069,400	91%	$108,900
Protect Bluff Transects 22-27		$0	$157,300		$305,200	$715,800		$305,200	26%	$873,100
REVETMENT										
Protect Bluff Transects 17-22		$0	$157,300		$39,600	$981,400		$39,600	3%	$1,138,700
Protect Bluff Transects 22-24.6		$0	$157,300		$200,700	$820,300		$200,700	17%	$977,600
Protect Bluff Transects 22-27		$0	$157,300		$305,200	$715,800		$305,200	26%	$873,100
NON-STRUCTURAL										
Protect 34 Structures		$36,550	$120,750		$176,400	$844,600		$212,950	18%	$965,350
FILL LAGOON										
Fill Lagoon (~ Transects 27-31.5)		$67,400	$89,900		$677,000	$344,000		$744,400	63%	$433,900

Table 28: Summary of NED Costs of Alternatives

(All Values in October 2007 Prices, 4.875% Interest Rate, 50 Year Period of Analysis)

ALTERNATIVE	PROJECT COSTS	INTEREST DURING CONSTRUCTION	INVESTMENT COSTS	INTEREST & AMORTIZATION	OPERATION & MAINTENANCE	TOTAL ANNUAL COSTS
REVETTED BERM (WAVES)						
Protection to +8' Contour (Transects 27-31.5)	$41,571,000	$1,615,000	$43,186,000	$2,320,000	$7,761,000	$10,082,000
Protection to +10' Contour (Transects 24.6-31.5)	$49,770,000	$2,017,000	$51,787,000	$2,782,000	$7,761,000	$10,544,000
Protection to +12' Contour (Transects 22-33)	$70,856,000	$4,440,000	$75,296,000	$4,045,000	$7,761,000	$11,807,000
Protection to +14' Contour (Transects 22-43)	$108,331,000	$9,675,000	$118,006,000	$6,340,000	$7,761,000	$14,101,000
BEACH NOURISHMENT						
Protection to +8' Contour (Transects 27-31.5)	$28,488,000	$1,397,000	$29,885,000	$1,606,000	$3,783,000	$5,389,000
Protection to +10' Contour (Transects 24.6-31.5)	$115,059,000	$24,960,000	$140,019,000	$7,522,000	$4,785,000	$12,307,000
Protection to +12' Contour (Transects 22-33)	$244,369,000	$85,184,000	$329,553,000	$17,704,000	$13,754,000	$31,458,000
Protection to +14' Contour (Transects 22-43)	$806,969,000	$435,576,000	$1,242,545,000	$66,752,000	$25,867,000	$92,619,000
Protect Bluff Transects 22-27	$139,867,000	$18,032,000	$157,899,000	$8,483,000	$22,742,000	$31,225,000
REVETTED BERM (ICE)						
Protection to +14' Contour (Transects 22-42)	$201,390,000	$64,404,000	$265,794,000	$14,279,000	$8,835,000	$23,114,000
Protect Bluff Transects 22-27	$66,698,000	$2,825,000	$69,523,000	$3,735,000	$8,835,000	$12,570,000
REVETMENT						
Protect Bluff Transects 17-22	$53,767,000	$2,213,000	$55,980,000	$3,007,000	$7,761,000	$10,769,000
Protect Bluff Transects 22-24.6	$38,867,000	$1,482,000	$40,349,000	$2,168,000	$7,761,000	$9,929,000
Protect Bluff Transects 22-27	$47,326,000	$1,897,000	$49,223,000	$2,644,000	$7,761,000	$10,406,000
NON-STRUCTURAL						
Protect 34 Structures	$42,123,000	$2,066,000	$44,189,000	$2,374,000	$0	$2,374,000
FILL LAGOON						
Fill Lagoon (~ Transects 27-31.5)	$28,801,000	$1,413,000	$30,214,000	$1,623,000	$0	$1,623,000

Table 29: Benefit Cost Analysis

ALTERNATIVE	AVERAGE ANNUAL COSTS	AVERAGE ANNUAL BENEFITS	NET BENEFITS	BC RATIO
REVETTED BERM (WAVES)				
Protection to +8' Contour (Transects 27-31.5)	$10,082,000	$677,000	-$9,405,000	0.07
Protection to +10' Contour (Transects 24.6-31.5)	$10,544,000	$805,900	-$9,738,100	0.08
Protection to +12' Contour (Transects 22-33)	$11,807,000	$1,025,800	-$10,781,200	0.09
Protection to +14' Contour (Transects 22-43)	$14,101,000	$1,069,400	-$13,031,600	0.08
BEACH NOURISHMENT				
Protection to +8' Contour (Transects 27-31.5)	$5,389,000	$677,000	-$4,712,000	0.13
Protection to +10' Contour (Transects 24.6-31.5)	$12,307,000	$805,900	-$11,501,100	0.07
Protection to +12' Contour (Transects 22-33)	$31,458,000	$1,025,800	-$30,432,200	0.03
Protection to +14' Contour (Transects 22-43)	$92,619,000	$1,069,400	-$91,549,600	0.01
Protect Bluff Transects 22-27	$31,225,000	$305,200	-$30,919,800	0.01
REVETTED BERM (ICE)				
Protection to +14' Contour (Transects 22-42)	$23,114,000	$1,069,400	-$22,044,600	0.05
Protect Bluff Transects 22-27	$12,570,000	$305,200	-$12,264,800	0.02
REVETMENT				
Protect Bluff Transects 17-22	$10,769,000	$39,600	-$10,729,400	0.004
Protect Bluff Transects 22-24.6	$9,929,000	$200,700	-$9,728,300	0.02
Protect Bluff Transects 22-27	$10,406,000	$305,200	-$10,100,800	0.03
NON-STRUCTURAL				
Protect 34 Structures	$2,374,000	$212,950	-$2,161,050	0.09
FILL LAGOON				
Fill Lagoon (~ Transects 27-31.5)	$1,623,000	$744,000	-$878,600	0.46

9.0 Regional Economic Development Effects of Alternatives

The RED account displays changes in the distribution of regional economic activity as a result of each alternative plan. Regional income and employment are commonly applied measures of regional economic activity. The absolute level of effects is of less importance than the relative impact on the region.

The positive effects of a plan on a region's income are equal to the sum of the NED benefits that accrue to that region, plus transfers of income to the region from outside the region. The positive effects of a plan on regional employment are directly parallel to the positive effects on regional income. The primary types of positive regional impacts associated with the final alternatives involve short term employment and income gains associated with project construction. In the longer term, the final alternatives have the potential to positively affect income and employment stability in the community, economic growth, and tax revenues. The relative potential effects of each alternative on RED are summarized in the following paragraphs.

9.1 No Action Alternative

With the No Action alternative, expected coastal storm/flood damages would likely result in negative employment and income impacts in the study area. Based upon survey data collected by the North Slope Borough, businesses and government agencies with facilities at risk of coastal storm damage employ approximately 210 people in the study area. The 210 employees account for approximately 11% of Barrow's total of 1,986 jobs as reported in the 2000 U.S. Census. Approximately 75% of the 210 at-risk jobs are in the public sector and approximately 25% are in commercial establishments. At the average reported hourly wage of $22.06 and assuming an average workday of 6 hours per day, the value of income of employees in at-risk facilities is estimated at approximately $28,000 per day (assuming a five day work week: ~$557,000 per month; ~$6,688,000 per year). A large potential risk to employment and income in the study area is loss of the utility services provided by the underground utilidor. As noted previously in the NED analysis, the utilidor is subject to flooding in extreme events and is estimated to be impacted by erosion within 25 years. The risk of coastal storm damage serves as a disincentive for businesses to invest in the community, further reducing the potential for future employment and income growth in Barrow.

9.2 Revetted Berm Alternatives

In the short term, the study area is expected to experience positive income and employment effects from construction of this alternative. Construction is expected to occur from June to October for two to four annual construction seasons depending on the length of berm. The construction crew is expected to be made up of approximately 15 members, including Field Superintendent, Construction Quality Assurance Manager, equipment operators, and general laborers. Opportunities for direct local employment associated with project construction are possible but expected to be limited. Secondary positive employment and income impacts are expected to result from the crew's demand for lodging, groceries, food, entertainment, automobile rental/service/supply, health care, and payment of taxes.

Over the longer term, this alternative would reduce the risk of coastal flooding and erosion in Barrow and the associated negative employment and income effects described above for the No Action Alternative. The alternative would also reduce the existing disincentive for business investment in Barrow due to the current risk of potential storm damages. Out of pocket expenses of businesses and residents associated with coastal storm damage repairs and rehabilitation would be reduced, resulting in more disposable income, increased earnings, increased demand for local goods and services, and an increased tax base. Collectively, these positive income and employment effects are expected to result in a more stable, growing economy in Barrow than with the No-Action Alternative.

For the four alternative lengths of the revetted berm evaluated, positive employment and income effects would increase as the length and associated extent of protected economic infrastructure increases. This applies to both the short term and long term effects cited above. All configurations except the "Protect to 8' Contour" alignment protect against the expected future erosion damage to the utilidor and the associated potential interruptions to utility services that would have negative employment and income effects in the study area.

Additional configurations of the revetted berm alternatives designed to better withstand ice forces associated with an ivu event were developed as part of the study. Because these configurations of the berm were found to provide the same storm damage reduction benefits as other berm configurations of the same alignment, but at a higher cost, the configuration sized for ice was not considered further.

9.3 Revetment Alternative

In the short term, the revetment alternative is expected to provide positive local employment and income effects in the study area as a result of project construction. Construction is scheduled to occur from June to October for two annual construction seasons. The expected construction crew and opportunities for direct and secondary local employment would be similar to that described for the revetted berm alternative.

Over the longer term, the revetment alternative would reduce the risk of erosion damages in the neighborhood of Barrow, including the significant residential and commercial infrastructure at risk between Egasak and Stevenson Streets. The alternative would reduce the existing disincentive for long term business investment in the Barrow neighborhood due to the current risk of coastal erosion. Erosion-related expenses to businesses and residents associated with property losses, real estate devaluation, moving expenses and temporary residential shelter would be reduced, resulting in more disposable income, increased earnings, increased demand for local goods and services, and an increased tax base. As with the revetted berm alternative, these positive income and employment effects are expected to result in a more stable, growing economy in Barrow than with the No-Action Alternative.

For the three alternative lengths of the revetment structure evaluated, positive employment and income effects would increase as the length and associated extent of protected economic infrastructure increases. This applies to both the short term and long term effects cited above. Only the configuration that protects transects 22-27 would protect against the expected future erosion damage to the utilidor and the associated potential interruptions to utility services that would have negative employment and income effects in the study area.

9.4 Beach Nourishment Alternative

A beach nourishment alternative was developed to provide the same levels of protection as each configuration of the revetted berm for cost comparison purposes. Because the cost of the beach nourishment alternative was generally higher than that of the revetted berm alternative, the beach nourishment alternative was not considered further.

9.5 Non-Structural Alternative

The non structural alternative involves the relocation of 24 structures in the bluff erosion zone in the neighborhood of Barrow and elevation of ten other structures to the east of the Barrow bluff that were found to be the most significant source of flood damages over the period of analysis.

In the short term, the non-structural alternative is expected to provide positive local employment and income effects in the study area as a result of project construction. Construction is scheduled to occur for two annual construction seasons. Although the cost of this alternative is lower than for the revetted berm or bluff protection alternatives, there could be more opportunities for direct local employment as more local labor could be utilized for the types of construction required.

Over the longer term, the non-structural protection alternative would reduce the risk of erosion damages in the neighborhood of Barrow, including the significant residential and commercial infrastructure at risk between Egasak and Stevenson Streets by relocating structures to safe land although to a lesser extent than the bluff protection alternative as some at risk structures were determined to not be movable and would be lost to erosion. Similarly, erosion-related expenses to businesses and residents associated with property losses, real estate devaluation, moving expenses and temporary residential shelter would be reduced, resulting in more disposable income, increased earnings, increased demand for local goods and services, and an increased tax base. As with the revetted berm alternative, these positive income and employment effects are expected to result in a more stable, growing economy in Barrow than with the No-Action Alternative although to a lesser degree.

The non-structural alternative would not protect against the expected future erosion damage to the utilidor and the associated potential interruptions to utility services that would have negative employment and income effects in the study area. It also would not reduce the recurring damages to the roadway fronting the lagoon.

9.6 Fill Lagoon Alternative

The lagoon fill would provide storm damage reduction benefits by eliminating damages associated with the existing spillway and the recurring damages to the low point in the road fronting the lagoon; as well as addressing local environmental concerns associated with Tasigrook Lagoon, which has been used for sewage waste storage in the past.

In the short term, the Fill Lagoon alternative is expected to provide positive local employment and income effects in the study area as a result of project construction. Construction is scheduled to occur for two annual construction seasons. Like the Non-Structural alternative, the cost of this alternative is lower than for the revetted berm or bluff protection alternatives, however there could be more opportunities for direct local employment as more local labor could be utilized for the types of construction required.

Over the longer term, the non-structural protection alternative would reduce the risk of recurring erosion damages to the roadway fronting the lagoon by allowing it to be relocated back from the beach and reduce the flood damages associated with the spillway and its associated utilities. These positive income and employment effects are expected to result in a more stable, growing economy in Barrow than with the No-Action Alternative.

The non-structural alternative would not protect against the expected future erosion damage to the utilidor and the associated potential interruptions to utility services that would have negative employment and income effects in the study area.

10.0 Other Social Effects of Alternatives

10.1 Life, Health and Safety

The final alternatives have the potential to affect personal health and safety, including risk of injury and mortality. They also have the potential to affect the safety of property and the risk of property damage. Such damages have profound effects on quality of life for local residents. Additionally, the alternatives have the potential to affect life, health and safety of not only local residents, but also residents of outlying smaller communities throughout the North Slope Borough that depend on Barrow for emergency response. The relative effects expected with each final alternative are described below.

- **No Action Alternative:** The No Action Alternative poses risks to personal safety and mortality by not addressing the current risks of coastal storm damages and erosion in the study area. Frigid flood waters during storms in the study area result in unusually dangerous conditions. Additionally, the current practices of flood fighting during storms place equipment operators in extremely hazardous conditions to protect the community. As documented in this technical appendix, the community faces risk of damage to personal property, including residential and non-residential structures and their contents. The flooding and the risk of flooding negatively impact the quality of life of local residents. While local medical facilities and emergency response resources are not expected to be physically impacted by coastal flooding and erosion, localized coastal storms may fully occupy local emergency response personnel and limit their ability to serve regional outlying communities within the North Slope Borough. Expected erosion damage to the beach frontage roadway could result in hazardous road conditions during storms.

- **Revetted Berm Alternatives:** This alternative (either configuration sized for waves or for ice) would reduce the identified risks to personal safety and mortality associated with coastal flooding and flood fighting activities. The alternative would also reduce coastal storm damages to property. The magnitude of these positive effects increases as the length of the alignment increases. With the alignments that extend westward, risk to human health and safety associated with coastal erosion creating unstable bluffs in Barrow and risks to the safety of property along the Barrow Bluff erosion zone would improve relative to those conditions with the No Action Alternative. The improved safety of the local community in eastern Barrow and in Browerville resulting from the revetted berm alternative would result in an increased quality of life for residents. The alternative would reduce the safety risk associated with damage to the beach frontage roadway. The decreased risk of local coastal flood emergencies would reduce the likelihood that Barrow would not be able to provide emergency response services to other NSB communities during periods of coastal storms in Barrow.

- **Revetment Alternative:** This alternative would reduce the risk to human health and safety associated with coastal erosion creating unstable bluffs in Barrow. Safety risks to local residents along the Barrow Bluff erosion zone would improve relative to those conditions with the No Action Alternative. The magnitude of these positive effects would increase as the length of the alignment increases. The improved safety of the local community in eastern Barrow and in Browerville resulting from the bluff protection alternative would result in an increased quality of life for residents. Protection of the utilidor from erosion damage would reduce the potential losses human health and safety risks that would be associated with an interruption in utility service. The decreased risk of property and infrastructure losses would reduce the likelihood that Barrow would not be able to provide emergency response services to other NSB communities during periods of coastal storms in Barrow.

- **Beach Nourishment Alternative:** The effects on life, health and safety associated with this alternative are expected to be similar to those presented for the revetted berm alternative.

- **Non-Structural Alternative:** While this alternative would reduce coastal flooding damages to property, human health and safety risks would remain as residents in elevated homes could potentially be surrounded by dangerous low temperature floodwaters. The alternative would significantly reduce health and safety risks along the Barrow bluff by relocating movable structures to safer stable land. However some non-movable structures would remain in the erosion zone and the unstable bluff could present a human health and safety risk. The alternative would not protect the utilidor from projected erosion damage resulting in health and safety risks associated with an interruption in utility service. Required floodfighting and evacuation activities would be expected to present health and safety risks to emergency personnel and could reduce the likelihood that Barrow would not be able to provide emergency response services to other NSB communities during periods of coastal storms in Barrow.

- **Fill Lagoon Alternative:** This alternative would reduce the safety risk associated with recurring damage to the beach frontage roadway. The alternative would also provide health and safety benefits by capping the lagoon which was formerly used for sewage disposal. The decreased risk of property and infrastructure losses would reduce the likelihood that Barrow would not be able to provide emergency response services to other NSB communities during periods of coastal storms in Barrow.

10.2 Educational Opportunities

No flooding or erosion damages are expected to directly impact school facilities in Barrow. Interruption of utility service associated with flooding or erosion damage to the utilidor could impact ability to provide school services depending on the extent of damage to the utilidor and the resulting level and duration of service interruption.

The following alternatives do not provide protection to the utilidor and therefore have the potential to negatively impact educational opportunities:

- **No Action Alternative**
- **Non-Structural Alternative**
- **Fill Lagoon Alternative**

Alternative configurations of the following alternatives can provide protection to the utilidor:

- **Revetted Berm Alternatives**
- **Revetment Alternative**
- **Beach Nourishment Alternative**

10.3 Recreational Opportunities

As noted in **Section 3.5**, are primary traditional recreational opportunity affected by the final alternatives is recreational beach combing[14]. The relative effects expected with each alternative are described below.

- **No Action Alternative:** With the No-Action Alternative, future opportunities for recreational beach combing are expected to remain in the study area.
- **Revetted Berm Alternatives:** With this alternative, beach combing opportunities are expected to be similar to without project conditions except that the project could pose potential risks to human health and safety during beach combing where exit from the beach would be limited to the beach access locations or climbing over the coastal dike/revetment. Recreational participation would be expected to decline as a result of the potential hazard and the limited access. The diversity of the beach combing opportunities would not be impacted significantly as the beach would remain wide along the majority of the project alignment.
- **Revetment Alternative:** Beach combing opportunities along the western extension of the project footprint would be limited because of the narrow beach in this area that would be largely occupied by the bluff protection revetment.
- **Beach Nourishment Alternative:** The effects on recreational opportunities associated with this alternative are expected to be similar to those presented for the revetted beach alternative.
- **Non-Structural Alternative:** With the Non-Structural Alternative, future opportunities for recreational beach combing are expected to remain in the study area.

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[14] Additional recreational benefit is associated with subsistence activities. Subsistence is addressed in Sections 3.6 and 11.5.

- **Fill Lagoon Alternative:** With the Fill Lagoon Alternative, future opportunities for recreational beach combing are expected to remain in the study area. Additionally, there is potential for using the land created by the capped lagoon area for local recreational purposes.

10.4 Subsistence

As noted in **Section 3.6**, subsistence is extremely important to the community in Barrow. Sixty-four percent of the population is Alaskan Native (primarily Inupiat Eskimo) and practice a subsistence lifestyle. Traditional marine mammal hunts and other subsistence practices are an active part of the culture. The relative effects on subsistence activities expected with each final alternative are described below.

- **No Action Alternative:** With the No-Action alternative, future opportunities for subsistence participation are expected to remain in the study area. Although past storm erosion damages to Stevenson Street have impeded eastward connectivity to Pt. Barrow, where fish camps used for subsistence harvesting are located at Elson lagoon, a new alternative connector road is planned for construction that will address the issue.

Opportunities to participate in subsistence activities are not expected to be limited or improved from without project conditions by any of the action alternatives evaluated. Beach access for fishing boats would be maintained.

10.5 Cultural Opportunities

Cultural opportunities affected by the alternatives include loss of/damages to portions of the Utqiagvik Village Archeological Site in Barrow and fishing/whaling activities. The relative effects expected with each final alternative are described below.

- **No Action Alternative:** With the No-Action alternative, cultural resources and opportunities would be negatively impacted by the expected damages to the Utqiagvik Village archeological site in Barrow. Cultural activities associated with fishing/whaling are expected to continue as present.
- **Revetted Berm Alternatives:** This alternative would not result in protection of losses/damages to the Utqiagvik Village Site archeological site in Barrow and thus would exhibit the same expected losses of cultural opportunities associated with damage to the site as with the No Action alternative. While the ability of the local community to participate in customary fishing and whaling is not expected to be limited by the project, certain local customs and traditions associated with the Whaling festival would be impacted.
- **Revetment Alternative:** The alignment of the bluff protection revetment Protecting Transects 17-22 is the only configuration of any of the alternatives that would protect the Utqiagvik Village Site archeological site in Barrow and the associated cultural resources and cultural opportunities. It is assumed that the construction and any required maintenance of the project in the vicinity of the Utqiagvik Village Site would be from the water side of the site to ensure that no negative impacts to resources at the site occur.
- **Beach Nourishment Alternative:** The effects on cultural opportunities associated with this alternative are expected to be similar to those presented for the revetted beach alternative.
- **Non-Structural Alternative:** The effects on recreational opportunities associated with this alternative are expected to be similar to those presented for the revetted berm alternative.

- **Fill Lagoon Alternative:** The effects on recreational opportunities associated with this alternative are expected to be similar to those presented for the revetted beach alternative.

10.6 Population

The final alternatives have the potential for affecting the local population size in Barrow by influencing net migration. Additionally, conditions associated with the alternatives could result in the displacement of people and businesses. The relative effects expected with each final alternative are described below.

- **No Action Alternative:** Because the No Action Alternative would not reduce the risk or occurrence of coastal flooding and erosion in the study area, some local residents could be expected to migrate to safer communities following damaging and threatening coastal storms. Additionally, the local flood risk might preclude businesses from establishing in Barrow limiting employment opportunities that could attract new residents. Residences could be displaced by condemnation, especially in the Barrow bluff erosion zone.
- **Revetted Berm Alternatives:** This alternative would result in reduction of the flood risk in eastern Barrow and eastern Browerville and its effect as an incentive for outmigration from the community and a disincentive for establishment of business enterprises. Since a stable growing economy is more likely to provide an incentive for new residents to settle in Barrow, the population might be expected to increase with this alternative. The magnitude of these positive effects increases as the length of the alignment increases. While project construction is not expected to result in any displacement of homes and businesses, displacement by condemnation in the area of the Barrow bluff erosion zone would continue with this alternative for erosion prone areas not protected.
- **Revetment Alternative:** The bluff protection alternative would result in a reduction of the erosion damage risk in the Barrow neighborhood. The magnitude of these positive effects increases as the length of the alignment increases. Depending on the alignment, displacement by condemnation in the area would continue with this alternative for erosion prone areas not protected. The alternative would serve to reduce expected erosion damages and their effect as an incentive for outmigration from the community and a disincentive for establishment of business enterprises. The magnitude of these positive effects increases as the length of the alignment increases. Since a stable growing economy is more likely to provide an incentive for new residents to settle in Barrow, the population might be expected to increase with this alternative. While project construction is not expected to result in any displacement of homes and businesses, displacement by condemnation in the area of the Barrow bluff erosion zone would continue with this alternative for erosion prone areas not protected.
- **Beach Nourishment Alternative:** The effects on population associated with this alternative are expected to be similar to those presented for the revetted berm alternative.
- **Non-Structural Alternative:** This alternative would reduce coastal flooding damages to property by elevating frequently flooded structures. The alternative would also relocate movable structures from the bluff erosion zone in the neighborhood of Barrow to safer stable land. The alternative would serve to reduce expected flooding and erosion damages and their effect as an incentive for outmigration from the community and a disincentive for establishment of business enterprises although to a lesser extent that either bluff protection, revetted berm, or beach nourishment alternatives.
- **Fill Lagoon Alternative:** This alternative would not be expected have a direct effect on population in the study area relative to the condition described for the No-Action Alternative.

10.7 Aesthetics

The final alternatives have the potential to affect aesthetic resources in the study area. The relative effects expected with each final alternative are described below.

- **No Action Alternative:** Under the no action alternative the project area is already occupied by beach berms for coastal storm protection. These berms are gravel mounds generally anywhere from 6-8 feet in height and placed at the crest of the beach (top elevation of berm is approximately 12’ - 15’above msl) as a protection measure against rising water from storm surge and wave attack.
- **Revetted Berm Alternatives:** This alternative would result in a coastal dike with a top elevation of approximately 14’; a 5’- 8’ increase in elevation over the existing berm’s typical top height. The increased height of the protective structure would adversely affect the viewshed from low-lying areas in the study area; particularly those closest to the shoreline. The visual effect from the beach side of the dike/revetment would be more pronounced because the structure would result in more isolated perspective with no view of the transitional zone to upland areas.
- **Revetment Alternative:** The visual effect of the bluff protection alternative would be less pronounced than the revetted berm as the protection would not extend far beyond the existing top of bluff if at all.
- **Beach Nourishment Alternative:** The aesthetic effects associated with this alternative are expected to be similar to those presented for the revetted berm alternative. However, the smaller unit size of the nourishment materials relative to the revetment materials could result in a relatively more natural appearance than with the revetted berm.
- **Non-Structural Alternative:** The site of relocated structures from the bluff area would be expected to remain as open space which would be a positive aesthetic affect in the area. Elevating structures would not be expected to have a dramatic aesthetic impact as most structures in the study area are already elevated.
- **Fill Lagoon Alternative:** This alternative would result in a pronounced change to the existing landscape in the center portion of the study area. Filling the lagoon would modify the existing waterbody to upland. The newly created land would still be fronted by the sea the north and by the water supply lagoon to the south. Previous discussion of this alternative with local officials indicated the potential for the filled site to serve as a public recreation resource which could provide positive aesthetic and recreational benefits for the community.

11.0 Summar y of Effects

The NED, RED, and OSE effects documented in the previous sections are summarized in table 30.

Table 30: Summary of Economic/Social Evaluation of Final Alternatives

EVALUATION ACCOUNT:	EVALUATION CATEGORY:	ALTERNATIVES								
		NO ACTION	REVETTED BERM		REVETMENT		BEACH NOURISHMENT		NON STRUCTURAL	FILL LAGOON
NED	Average Annual Coastal Flooding Damages Reduced	$0	+8’ +10’ +12’ +14’ Ivu 14’	$0 $24,400 $43,600 $87,200 $87,200	17-22 22-24.6 22-27 Ivu 22-27	$0 $0 $0 $0	+8’ +10’ +12’ +14’ 22-27	$0 $24,400 $43,600 $87,200 $0	$36,550	$67,400
	Average Annual Erosion Damages Reduced	$0	+8’ +10’ +12’ +14’ Ivu 14’	$677,000 $781,500 $982,200 $982,200 $982,200	17-22 22-24.6 22-27 Ivu 22-27	$39,600 $200,700 $305,200 $305,200	+8’ +10’ +12’ +14’ 22-27	$677,000 $781,500 $982,200 $982,200 $305,200	$176,400	$677,000
	Total Average Annual Damages Reduced	$0	+8’ +10’ +12’ +14’ Ivu 14’	$677,000 $805,900 $1,025,800 $1,069,400 $1,069,400	17-22 22-24.6 22-27 Ivu 22-27	$39,600 $200,700 $305,200 $305,200	+8’ +10’ +12’ +14’ 22-27	$677,000 $805,900 $1,025,800 $1,069,400 $305,200	$212,950	$744,400
	Average Annual Residual Damages	$1,178,300	+8’ +10’ +12’ +14’ Ivu 14’	$501,300 $372,400 $152,500 $108,900	17-22 22-24.6 22-27 Ivu 22-27	$1,138,700 $977,600 $873,100 $873,100	+8’ +10’ +12’ +14’ 22-27	$501,300 $372,400 $152,500 $108,900 $873,100	$965,350	$433,900
	Average Annual Cost	$0	+8’ +10’ +12’ +14’ Ivu 14’	$10,082,000 $10,544,000 $11,807,000 $14,101,000 $23,114,000	17-22 22-24.6 22-27 Ivu 22-27	$10,769,000 $9,929,000 $10,406,000 $12,570,000	+8’ +10’ +12’ +14’ 22-27	$5,389,000 $12,307,000 $31,458,000 $92,619V $31,225,000	$2,374,000	$1,623,000
	Net Annual Benefits	$0	+8’ +10’ +12’ +14’ Ivu 14’	-$9,405,000 -$9,738,100 -$10,781,200 -$13,031,600 -$22,044,600	17-22 22-24.6 22-27 Ivu 22-27	-$10,729,400 -$9,728,300 -$10,100,800 -$12,264,800	+8: +10’ +12’ +14’ 22-27	-$4,712,000 -$11,501,100 -$30,432,200 -$91,549,600 -$30,919,800	-$2,161,050	-$878,600
	BC Ratio	not applicable	+8’ +10’ +12’ +14’ Ivu 14’	0.07 0.08 0.09 0.08 0.05	17-22 22-24.6 22-27 Ivu 22-27	0.004 0.02 0.03 0.02	+8’ +10’ +12’ +14’ 22-27	0.13 0.07 0.03 0.01 0.01	0.09	0.46

EVALUATION ACCOUNT:	EVALUATION CATEGORY:	ALTERNATIVES					
		NO ACTION	REVETTED BERM	REVETMENT	BEACH NOURISHMENT	NON STRUCTURAL	FILL LAGOON
RED	Employment and Income Effects	Lost jobs, income, and economic opportunity from storm damages and flood risk. Flood and erosion risk to utilidor is expected to result in future utility service interruption and associated employment and income impacts. Risk of coastal storm damage remains a disincentive for business investment in community.	Reduction of lost jobs and income that are associated with No Action Alternative. Improved Employment and Income stability and Economic Growth. Reduced out-of-pocket expenses for damage repairs. Short term positive employment and income effects of project construction (2 to 4 construction seasons depending on berm length).	Reduction of lost jobs and income that are associated with No Action Alternative. Reduced out-of-pocket expenses for damage repairs, relocations, and temporary/replacement housing. Improved Employment and Income stability and Economic Growth. Short term positive employment and income effects of project construction (2 construction seasons).	A beach nourishment alternative was developed to provide the same levels of protection as each configuration of the revetted berm for cost comparison purposes. Because the cost of the beach nourishment alternative was generally higher than that of the revetted berm alternative, the beach nourishment alternative was not considered further.	Structure relocations and elevations would present short term opportunities for local employment and income (2 seasons). Reduced out-of-pocket expenses for damage repairs, relocations, and temporary/replacement housing. Improved Employment and Income stability and Economic Growth. Residual flood and erosion risk to utilidor is expected to result in future utility service interruption and associated employment and income impacts.	Construction would present short term opportunities for local employment and income (2 seasons). Residual flood and erosion risk to utilidor is expected to result in future utility service interruption and associated employment and income impacts.

EVALUATION ACCOUNT:	**EVALUATION CATEGORY:**	**ALTERNATIVES**					
		NO ACTION	**REVETTED BERM**	**REVETMENT**	**BEACH NOURISHMENT**	**NON STRUCTURAL**	**FILL LAGOON**
OSE	Life, Health, and Safety	Risks of injury and mortality from coastal flooding and unstable bluffs. Dangerous flood fighting conditions.	Reduction in risks of injury and mortality from coastal storms and flood fighting. Longer alignments partially address safety concerns associated with eroding bluffs in Barrow. New safety concerns with limited exit points from beach with coastal dike.	Reduction in risk to human heath and safety associated with coastal erosion and the resultant unstable bluffs in Barrow. Protection of utilidor would protect against future utility interruption from erosion and that associated impacts on human health and safety.	A beach nourishment alternative was developed to provide the same levels of protection as each configuration of the revetted berm for cost comparison purposes. Because the cost of the beach nourishment alternative was generally higher than that of the revetted berm alternative, the beach nourishment alternative was not considered further.	Residual risk for emergency personnel and residents of elevated structures in situations of evacuation during high water. Reduction in health and safety risks along Barrow Bluff with relocations.	Potential health benefits of capping past sewage disposal site. Reduced frequency of emergency flood fight activities.
	Educational Opportunities	No direct effects.	No direct Effects.	No direct Effects.		No direct Effects.	No direct effects.
	Recreational Opportunities	Primary recreational activity associated with project area is beach walking/ combing.	Project conditions would encroach on beach (primarily in the narrow beach in the vicinity of Barrow bluff).	Project encroachment on narrow beach in the vicinity of Barrow bluff.		No direct effect expected.	No direct effect expected.
	Subsistence Opportunities	No expected change in opportuni-ties for subsistence participation.	No expected change in opportunities for subsistence participation.	No expected change in opportunities for subsistence participation.		No expected change in opportunities for subsistence participation.	No expected change in opportunities for subsistence participation.
	Cultural Opportunities	Expected damages to cultural resources at Utqiagvik Village Archeological Site as a result of beach erosion.	Same as with No Action.	Protection of cultural resources at Utqiagvik Village Archeological Site as a result of beach erosion with western alignment.		Same as with No Action.	Same as with No Action.

EVALUATION ACCOUNT:	**EVALUATION CATEGORY:**	**ALTERNATIVES**					
		NO ACTION	**REVETTED BERM**	**REVETMENT**	**BEACH NOURISHMENT**	**NON STRUCTURAL**	**FILL LAGOON**
OSE	Population	Population expected to remain at current levels or diminish over time due to expected limitations on employment and income opportunities	The cited constraints on population growth under no action would be reduced with this alternative. Population could be expected to grow over time due to increased employment and income opportunities	Similar effect as with Revetted Berm alternative.	A beach nourishment alternative was developed to provide the same levels of protection as each configuration of the revetted berm for cost comparison purposes. Because the cost of the beach nourishment alternative was generally higher than that of the revetted berm alternative, the beach nourishment alternative was not considered further.	Similar effect as with Revetted Berm alternative.	No direct effect expected.
	Aesthetics	Viewshed impaired by coastal storm protection berms on beach with approximate top elevation of 13-15 feet above sea level	Viewshed impairment increases with larger structure for coastal dike (design top elevation ~20'). Increased negative aesthetic impact on views and scenery from both Ocean side and land side viewpoints	The visual effect of the bluff protection alternative would be less pronounced than the revetted berm as the protection would not extend far beyond the existing top of bluff if at all.		The site of relocated structures from the bluff area would be expected to remain as open space which would be a positive aesthetic affect in the area. Elevating structures would not be expected to have a dramatic aesthetic impact as most structures in the study area are already elevated.	A change to the existing landscape in the center portion of the study area. Converting lagoon to open space could serve as a public recreation resource which could provide positive aesthetic and recreational benefits for community.

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U.S. Army Corps
of Engineers
Alaska District

Barrow, Alaska

Coastal Storm Damage Reduction Interim Feasibility Report

Appendix E – Draft Fish & Wildlife Coordination Act Report

September 2008

Interim Feasibility Report
Barrow, Alaska, Storm Damage Reduction

Appendix E – Draft Fish and Wildlife Coordination Act Report

NOTE:

This Appendix was originally created as the Draft Fish and Wildlife Coordination Act Report (CAR) to go with an early version of the Draft Integrated Interim Feasibility Report and Environmental Impact Statement for Coastal Storm Damage Reduction at Borrow, Alaska. It describes the preliminary alternatives and one tentatively selected for recommendation in the early draft report. That document underwent Independent Technical Review. As a result of that review, basic hydraulic and economic analyses were redone, with the result that no alternative yielded positive National Economic Development benefits greater than the costs. Therefore, the report was modified to reflect recommendation of the "No Action" alternative. Since there is no Federal action proposed in this report, there is no need for a Fish and Wildlife Coordination Act Report. However, since the draft CAR had compiled information on the natural, cultural, and social conditions of the Barrow area and the potential impacts of various alternatives, which may be useful for future planning, it is presented in this appendix.

BARROW COASTAL STORM DAMAGE REDUCTION STUDY, BARROW ALASKA

Draft Fish and Wildlife Coordination Act Report

Submitted to:
Alaska District
U.S. Army Corps of Engineers
Anchorage, Alaska

U.S. Fish and Wildlife Service
Fairbanks Fish and Wildlife Field Office
101 12th Ave, Rm. 110
Fairbanks, Alaska 99701

10 July 2007

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INTRODUCTION

The community of Barrow is located on the Chukchi Sea coast approximately 10 miles from Point Barrow, the northernmost point in Alaska. Barrow is situated on coastline that runs in a northeast and southwest direction and this orientation leaves the community susceptible to storms from the north and west. Storm events that occur during the open water period (August through October) have the greatest potential to cause erosion and flooding in Barrow. These storms are generated by fast moving weather systems and typically last between 24 and 48 hours, but can last up to 96 hours.

Since the 1960s, representatives of Barrow have expressed considerable concern about erosion of the coastline. As a result of this concern, the North Slope Borough has made multiple attempts to control erosion and flooding in the Barrow area. The largest of which was a beach nourishment program started in 1995 and terminated in 2001. Other attempts to curb erosion have included geotextile sack revetments, a filled utilidor seawall, placement of tar barrels, construction of sacrificial dikes, and placement of geotextile tubes. Most recently, seawall type structures using geotextile bags encased in wire baskets (HESCO Concertainer) were installed along a portion of the Barrow coastline known as the bluff and in front of the sewage lagoon. The Corps' evaluation is that the structures have been effective but have the potential to erode the fronting beach. This erosion would be mitigated by the placement of armor rock.

Due to concerns expressed by the North Slope Borough, the U.S. Army Corps of Engineers (Corps) began investigating methods to control erosion and flooding in the Barrow area. This investigation has resulted in development of several alternative approaches to the erosion and flooding problems in Barrow and these alternatives are collectively referred to as the Barrow Coastal Storm Damage Reduction Study, Barrow Alaska. This report constitutes the U.S. Fish and Wildlife Service draft Fish and Wildlife Coordination Act Report on the U.S. Army Corps of Engineers' proposed Barrow Coastal Storm Damage Reduction Project. The purpose of the report is to provide the Corps of Engineers with information regarding fish and wildlife resources and to identify the potentially significant impacts to these resources associated with this project.

This report is prepared in accordance with the Fish and Wildlife Coordination Act (48 Stat. 401, as amended: 16 U.S.C. 661 et seq.). This document constitutes the draft report of the Secretary of the Interior as required by Section 2(b) of the Fish and Wildlife Coordination Act.

The following report is based on information provided by the Corps of Engineers, a literature review, and an assessment of the potential impacts to fish and wildlife resources.

PROJECT AREA

The city of Barrow is located on a triangular landmass bound by the Chukchi Sea on the west and Elson Lagoon and the Beaufort Sea on the east. It is approximately 725 air miles north of Anchorage. Barrow is the economic center of the North Slope Borough and the northernmost community in the United States. The community has a population of 4,199, of which 64% are Alaska Natives. Many residents continue to rely on subsistence foods including whale, seal, walrus, duck, caribou, and fish. The state-owned Wiley Post-Will Rogers Memorial Airport provides year-round access to the community. Marine and land transportation also provide access on a seasonal basis.

The climate of Barrow is arctic, characterized by low annual precipitation (averaging 5 inches) and temperatures that range from -56 to 78 degrees Fahrenheit. The daily minimum temperature is below freezing 324 days of the year. Barrow is in an area of semi-diurnal tides, with two high-tides and low-tides each lunar day. Tidal range is only 0.4 feet from Mean Higher High Water to Mean Lower Low Water. The Barrow landscape is characterized by low relief, ice-wedge polygons, oriented lakes, and drained lake basins (Bunnell et al. 1975). The southwestern end of the community is fronted by coastal bluffs. These bluffs taper off and the northeastern section of the community is fronted by low-lying beach. Located to the northeast of the community is a large gravel spit that forms Point Barrow. Point Barrow is a major barrier to ice movement and as a result, the coastline near Barrow is subject to the forces of ice more than most regions.

BIOLOGICAL RESOURCES

Information on the biological resources is derived from Bunnell et al. 1975 (vegetation/habitat), Bee and Hall 1956 (wildlife species), Alaska Department of Fish and Game 1986 (wildlife species) and National Oceanic and Atmospheric Administration 1987 (wildlife species) unless otherwise noted.

Vegetation/Habitat

The landscape of the Barrow area is characterized by low relief and is dominated by ice-wedge polygons, shallow lakes, and drained lake basins. Vegetation type varies along a moisture gradient ranging from drier upland meadow communities through wet meadows and marshes to emergent vegetation. Drier communities are dominated by northern woodrush, arctic cinquefoil, willow, wideleaf polargrass, arctic bluegrass, and witch's hair lichen. Wet meadows and marches are dominated by water sedge, cotton grass, Fisher's tundragrass, chickweek, felt lichen, and mosses. Species such as pendantgrass, buttercups, and mosses are found in the wettest areas.

Mammals

Small mammals in the project area include shrews, brown lemmings, collard lemmings, red-backed vole, ermine, and least weasel. Other terrestrial mammals likely to be encountered in the area include caribou, arctic fox, red fox, brown bear, musk ox, and wolf.

The presence of marine mammals along the Chukchi and Beaufort coastlines is often dependent on the movement of sea ice. Animals such as bowhead whale, grey whale, beluga whale, pacific walrus, ribbon seal, bearded seal, and spotted seal follow the seasonal movement of the sea ice. As ice retreats northward in spring, belugas move to summering areas in the Chukchi and Beaufort Sea. Bowhead whales move past Barrow while traveling to summer feeding areas in the Amundsen Gulf and the Canadian Beaufort Sea. Most walruses in the arctic are found on the southern edge of the pack ice west of Barrow. Polar bears may be found in the project vicinity year round. Polar bears are associated with shore-fast and drifting pack ice along the Chukchi, Beaufort, and northern Bering Sea coasts. In summer, polar bears typically concentrate along the southern edge of the drifting pack ice. Like polar bears, ringed seals are highly ice-adapted mammals and regularly inhabit fast ice.

Birds

The tundra surrounding Barrow provides breeding and post-breeding habitat for a large variety of birds. Twenty-two species of birds are regular breeders and 13 species are occasional breeders in the Barrow area (Pitelka 1974). By in large, breeding birds arrive in the Barrow area in May and early June. Many species including phalaropes, jaegers, and terns migrate over land while other species such as eiders, long-tailed duck, and glaucous gulls follow leads northward (reviewed by Divoky 1984).

A significant portion of the breeding birds in Barrow are shorebirds (Pitelka 1974). Species of shorebirds breeding regularly in the area include Golden plover, ruddy turnstone, pectoral sandpiper, white-rumped sandpiper, and dunlin (Pitelka 1974). During the nesting period in June and July, shorebird activity is centered in tundra habitats, however, by August littoral habitats (gravel beaches, mudflats, and slough edges) becomes a major foraging area for many shorebirds (Connors et al. 1979). Use of littoral habitats through the course of summer varies among species. Some species, such as Golden Plovers continue to use tundra habitats whereas ruddy turnstones become heavily dependant on littoral habitats (Connors et al. 1979).

Common species of tundra-nesting ducks found in the Barrow area include, king eider, Steller's eider, spectacled eider, long-tailed duck, and pintail (Pitelka 1974). Ducks migrate into the area in late May and early June. Female ducks and their broods may remain on the tundra into September before moving into marine waters. In years with high numbers of brown lemming, pomarine jaegers, snowy owls, and short-eared owls may also nest on tundra in the Barrow area (Pitelka et al. 1955)

Fish

Fish species occupying the marine and fresh waters near Barrow include pink salmon, chum salmon, capelin, rainbow smelt, saffron cod, starry flounder, Arctic cod, Pacific sand lance, Arctic sculpin, Arctic grayling, least cisco, and broad whitefish. Seine hauls conducted in 2004 and 2005 captured a high percentage of juvenile capelin and Arctic cod in the nearshore waters near Barrow (Johnson and Thedinga 2004, Thedinga and Johnson 2006), suggesting that this in an important rearing area.

Marine invertebrates

Marine invertebrate species found in the vicinity of Barrow include arthropods (e.g., opossum shrimp, large crangonid shrimp, amphipods, and copepods) and mollusks (e.g., chalky macoma, Greenland cockle, and Iceland cockle).

Subsistence use

Information in the following section is derived from Alaska Department of Fish and Game (2001), and Braund et al. (1993).

The ADF&G Community Profile Database (2001) Harvest Survey for Barrow for 1989 shows the greatest volume of subsistence resource use was marine mammals, followed by land mammals, fish, and birds and eggs.

The availability of marine mammals is generally associated with the edge of pack ice. Hunting for the majority of marine mammals begins in March or April as leads open in the Chukchi Sea and continues through October. Between 1987 and 1990, marine mammals represented 55% (by weight) of the total subsistence harvest. Of that, bowhead whale accounted for 69% and walrus accounted for 16% of the total marine mammal harvest. Nearly half (46% by weight) of the marine mammal harvest takes place in either May or October.

Terrestrial mammals, primarily caribou and moose, make up roughly 30% of the subsistence harvest. Caribou are an important subsistence resource and account for 88% of the total harvest of terrestrial mammals. Fish rank third in total pounds harvested (11%). Whitefish (including, but not limited to broad whitefish, humpback whitefish, round whitefish, and least cisco) account for approximately 77% of the total fish harvest. Birds make up about 4% of the total subsistence harvest. Geese (white-fronted, brant, and snow goose) and eiders (common and king) represent a significant portion of the total bird harvest (59% and 37%, respectively).

Threatened and Endangered Species

Marine Mammals

Bowhead whales, listed as endangered under the Endangered Species Act of 1973, could be sighted in the project area. This species is not under the jurisdiction of the Fish and Wildlife Service.

Plants

There are no plants listed as threatened or endangered in the project area.

Birds

The proposed project is within the breeding range of two threatened eider species: Steller’s eider (*Polysticta stelleri*) and spectacled eider (*Somateria fischeri*).

Steller’s eider

The Steller’s eider is the smallest of the four eider species. The Alaska-breeding population of Steller’s eider was listed as threatened on June 11, 1997 due to a decrease in the species nesting range (within Alaska) and reduced numbers of Steller’s eiders nesting in Alaska.

Steller’s eiders breed along the coast of the Arctic Ocean in Russia and, to a lesser extent, Alaska (reviewed by Fredrickson 2001, Jones 1965). In Alaska, Steller’s eiders breed in two areas: western Alaska on the Yukon-Kuskokwim delta (Y-K delta), and in northern Alaska. Historically, Steller’s eider was considered a common breeding bird on the Y-K delta (Kertell 1991). In the years from 1975-1994, no Steller’s eider nests were detected in western Alaska, and it was theorized that a breeding population of Steller’s eiders had abandoned the Y-K delta (Kertell 1991). More recent data suggests that this species continues to breed on the Y-K delta, but at low densities (Flint and Herzog 1999). In northern Alaska, Steller’s eiders historically occurred from Wainwright east across the Arctic Coastal Plain to Demarcation Point, near the United States-Canada Border (Brooks 1915, Quakenbush et al. 2002). In recent decades, most sightings of Steller's eiders have occurred east of Point Lay and west of the Colville River, with the highest densities near Barrow (Quakenbush et al. 2002).

Steller's eiders still regularly occur near Barrow, although abundance and nesting effort varies among years. For example, ground-based surveys conducted in the vicinity of Barrow have calculated pair densities (males/km^2) ranging from 0 to 0.98 (Rojek 2006). Steller's eiders do not nest annually. In seven years (1999-2005), only 1999, 2000, and 2005 were considered 'nesting' years (Rojek 2006). This periodic non-breeding may be related to number and species of avian predators present on the breeding grounds (Quakenbush and Suydam 1999).

In years that eiders nest, hens may choose nest sites that are within a few square kilometers of other Steller's eiders (Rojek 2006). Initiation dates are typically in the first half of June (Quakenbush et al. 1995). In the vicinity of Barrow, low-centered polygons, low (indistinct flat-centered) polygons, or in drained lake basins are important habitats for nesting (Quakenbush et al. 1998). Ponds with emergent grasses (*Carex* spp. and *Arctophila fulva*) are used for brood rearing (Rojek 2006 and Quakenbush et al. 1998).

After the breeding season, Steller's eiders migrate to molting areas along on the Russian Chukchi and Bering seacoast, near St. Lawrence Island, and in lagoons, principally Nelson Lagoon and Izembek Bay, along the Alaska Peninsula (Kistchinski 1973, Fay 1961, Jones 1965, and Petersen 1981).

Spectacled eider

The spectacled eider is a medium-sized sea duck. The entire population was listed as threatened on May 10, 1993, due to population declines on the Y-K delta.

Spectacled eiders breed in Alaska and in arctic Russia (reviewed by Petersen et al. 2000). In Alaska, there are two breeding populations: a population that nests in western Alaska on the Y-K delta, and a population nesting across the North Slope. From the early 1970's to the early 1990's, the breeding population of spectacled eiders in western Alaska declined by 96% (Stehn et al. 1993). The northern population is thought to have declined, although survey data are not conclusive (Petersen et al. 2000).

Spectacled eiders occur in low density across the North Slope (Larned et al. 2003) and regularly occur in the vicinity of Barrow. Nest sites tend to be located near water on small islands and peninsulas, pond shorelines, and dry areas in wet meadows (Anderson et al. 1999). Ponds with emergent vegetation may be important brood rearing habitat (Warnock and Troy 1992). Males spend little time on the breeding grounds and depart near the start of incubation (Petersen et al. 1999). Those males present on breeding grounds east of Barrow apparently make little use of marine habitats in the Beaufort Sea and move directly to the Chukchi Sea (TERA 2003). Departure of females from the breeding grounds is dependant on the success or failure of the breeding attempt. Females with broods may remain on the breeding grounds into September (Petersen et al. 1999).

After leaving the breeding grounds, spectacled eiders migrate to molting and staging areas off the coast of Alaska (Ledyard Bay and eastern Norton Bay) or off the coast of Russia (Petersen et al. 1999). The winter range of the spectacled eider is restricted to polynyas (areas of open water surrounded by sea ice) and open leads south of St. Lawrence Island in the Bering Sea (Petersen et al. 1999).

TECHNIQUES FOR REDUCING EROSION AND FLOODING

The Corps investigation was initiated to address potential methods of reducing coastal erosion and flooding in the Barrow area. The following shore protection techniques have been outlined by the Corps and are placed in two categories: techniques that limit bluff erosion and options reducing the threat of flooding. Although some options may serve both purposes, they are considered separately. Background information regarding the various techniques was derived from Corps documents and Burcharth and Hughes (2002).

Bluff (coastline) protection

The bluffs near Barrow are comprised of fine sand, silt, and organic materials bound by ice. Wave action on the face and at the base of the bluffs cause localized melting of the permafrost and niching at the toe. The bluffs have little inherent strength, thus melting of the permafrost leaves the bluff susceptible to slumping and block failure. Slumping occurs when permafrost melts and the thawed material flows down the face of the bluff. This material is then washed away during high water events. Block failure occurs when the base of the bluff erodes to the point where the frozen material is no longer capable of supporting the weight of the bluff and a section collapses.

Revetment

A revetment is a structure designed to protect a segment of coastline from waves and strong currents. Revetments are often constructed by placing erosion resistant materials, such as rock, concrete or asphalt, directly on an existing slope, embankment or dike. Construction of revetments in Barrow would protect the bluffs from the major erosion sources of slumping and block failure. Materials considered for revetment included rock, super sacks, and articulated concrete mats. Factors that might prevent the construction of a revetment along the bluffs include the cost of the construction materials, susceptibility of the revetment to ice forces, and the difficulties of construction and maintenance.

Beach nourishment

Beach nourishment involves placing loose material (e.g. sand and gravel) on an eroded section of beach to compensate for the lack of natural beach material. Successful beach nourishment requires placement of material that is as coarse as or coarser than the existing beach material. Because the materials (loose sand and gravel) used for beach nourishment are easily eroded this option may require frequent maintenance. Beach nourishment would protect the toe of the bluffs, but would not address the slumping issues associated with melting permafrost.

Seawalls

Seawalls are structures typically constructed to prevent or alleviate overtopping and flooding due to storm surges and waves. These structures can also stop or reduce erosion landward of the seawall. Materials used in the construction of a sea wall could include sheetpile, timber, pipe, concrete or a wire basket/geotextile system. A seawall in Barrow would provide protection for the bluff face. However, it is possible that waves breaking on the seawall face could erode the beach fronting the seawall eventually resulting in failure of the structure.

Offshore breakwaters

Offshore breakwaters are structures built parallel to the shore, just seaward of the shoreline, in shallow water. The breakwaters reflect and dissipate incoming wave energy, thus reducing wave heights and reducing shore erosion. Materials that could be used in the construction of the breakwater include rock or concrete. Breakwaters placed seaward of the bluffs would lessen the wave energy impacting the beach and the base of the bluff, but would not address the melting permafrost. Any breakwater structures placed along the Barrow coastline would have to be designed to withstand the forces of sea ice.

Groins

Groins are narrow structures, usually constructed perpendicular to the shoreline, that reduce the amount of material lost from a beach due to longshore transport. Materials commonly used in the construction of groins include sheetpile, armor stone, or gabions (i.e., cylinders filled with stone). Installation of a groin system would limit the movement of longshore sediment and build up a beach. However, due to the limited longshore transport of beach material, the groins would be only marginally effective.

Flood protection

The area of Tasigarook Lagoon and the northeast low-lying beach along the coast are susceptible to flooding. Community infrastructure along this section of coastline includes roads, utilidor, sewage lagoon, and an existing landfill. Flooding occurs during storms that generate surges greater than eight feet.

Dike

Dikes are onshore structures usually built as a mound of fine materials, such as sand, clay, or gravel. Construction of a dike on the seaward side of the coastal road or incorporated as a base for the road would protect the low lying areas of Barrow and Browerville from flooding. The raised road/dike system would need to be designed to withstand both waves and sea ice. Primary disadvantages of the raised road/dike include the need for post storm maintenance and large project footprint.

Beach nourishment

The use of beach nourishment as a flood protection measure has not been used in Alaska.
The intent of beach nourishment is to increase beach elevation and reduce run up potential of the waves. Because the materials (loose sand and gravel) used for beach nourishment are easily eroded this option may require frequent maintenance.

Seawalls

Construction of a seawall in Barrow would be used for flood protection in a manner similar to a dike. A seawall would require less land for construction because it is a vertical structure. The primary concern with seawalls is erosion of the seabed in front of the structure due to increased wave reflection that leads to failure of the structure.

ALTERNATIVES

The Corps evaluated the advantages and disadvantages of each shoreline protection structure listed in the previous section and determined that not all options would be appropriate for the Barrow Coastal Storm Damage Reduction Project. Specifically seawalls, beach nourishment, breakwaters, and groins were dropped from further analysis. Construction of a seawall would protect the bluff and raise the inland coast elevation to withstand flooding. Seawalls were dismissed because of the potential for increased beach erosion at the base of the structure. Beach nourishment was initially considered by the Corps because it would return the beach to its original width before it was used as a material source, protect the toe of the bluffs, and raise the beach elevation. The Corps concluded that the beach is reaching equilibrium since beach sand mining ended therefore beach nourishment is no longer needed. Breakwaters would reduce the waves impacting the base of the bluff, but are susceptible to ice damage and have the potential to limit sediment transported outside the project area thus increasing the potential for erosion. Groins would help build the beach by retaining sediments being transported along the coastline, but given the limited amount of longshore sediment transport, groins are not likely to be effective.

The alternatives listed below were retained for further consideration by the Corps:

Alternative 1 – No action

This alternative could result in continued erosion, flooding, and damage to community infrastructure and residential housing units.

Alternative 2 – Non-structural alternative

The Corps will consider non-structural alternatives including moving buildings away from the coastline and areas prone to flooding. Hardened protection in selected areas of the utilidor will also be considered as an element of this alternative.

Alternative 3 – Proposed alternative: Construction of a revetment and dike

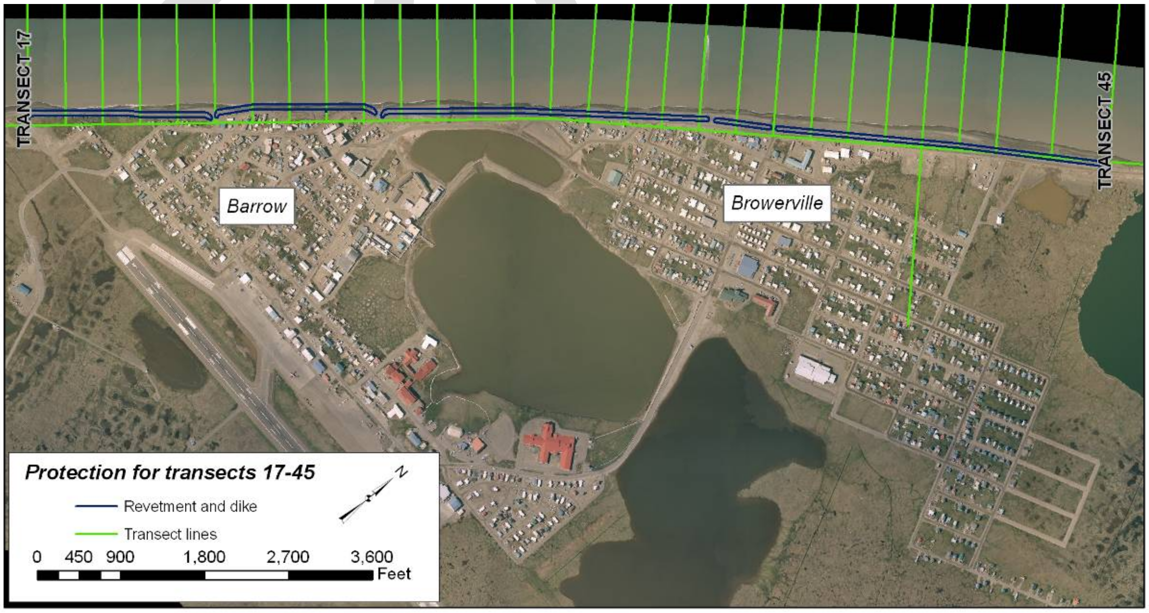
The Corps has narrowed the structural alternatives to a rock revetment and dike design to protect the beach bluffs and to provide flood protection for low lying areas. This alternative will protect the coastal bluffs south of Barrow and would also protect the low lying areas adjacent to Browerville. The revetment would be composed of gabion-like (i.e., wire mesh lined with geotextile) blocks filled with sand, gravel fill, core rock, medium sized rock, and armor rock. Sand filled geotextile bags will be place against the bluff face on top of the rock revetment. The revetment will be designed to allow beach access. Flood protection for the lowland beach area will consist of a dike. The height of the dike has yet to be determined, but it is possible it will be designed to protect against storm surge and wave run-up to the 16 foot elevation. Sand and gravel fill will most likely be obtained from the UIC gravel pit. Core sized rock and larger rock will likely be imported from the Cape Nome quarry. Barges would be beached and unloaded by a front-end loader. The current construction scenario calls for 28 barge loads of material to be delivered across two open-water seasons.

The Corps has preliminary designs for a revetment and dike, however, the length of shoreline that would be protected has yet to be finalized. Currently, the Corps is considering three possible construction alternatives. In the description of these three construction alternatives, the Barrow coastline has been divided into transects:

- Transect 17 is the area of coastline directly west of the Wiley Post-Will Rogers Memorial Airport runway.
- Transect 26.25 is a section of coastline near the junctions of Eben Hopson St. and Stevenson St. near the southwest edge of Tasigarook Lagoon.
- Transect 31 is a section of coast near Brower St.
- Transect 45 is a section of coast southwest of the sewage lagoon and northeast of Ahmaogak St.

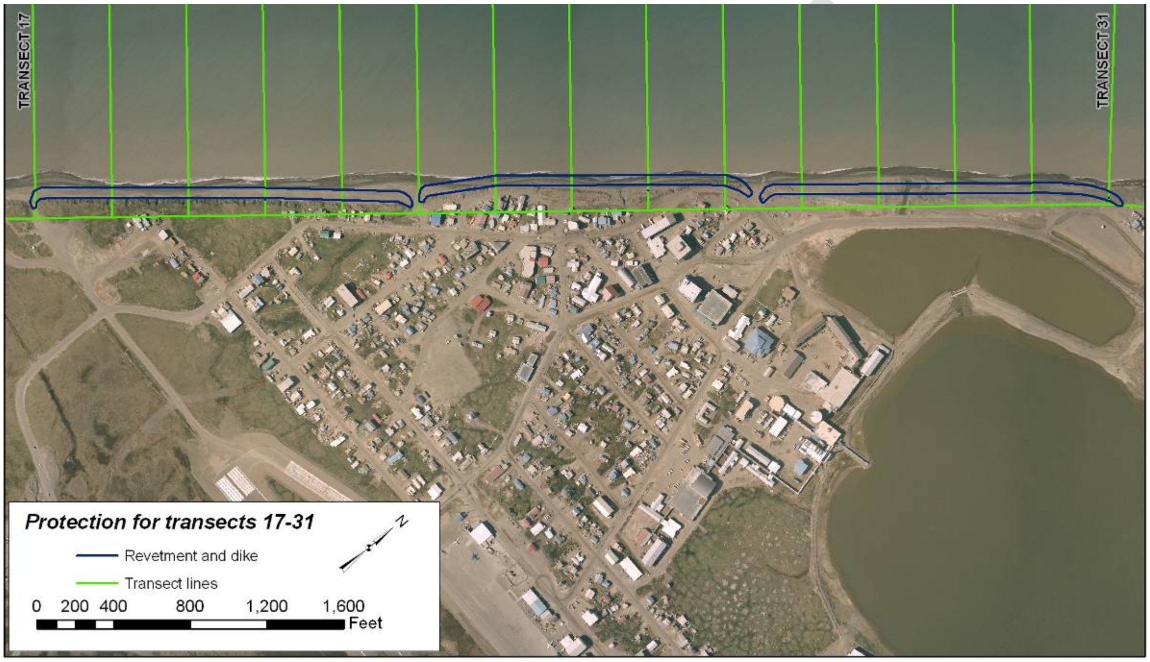
<u>Alternative 3a – Protection for transects 17-45</u>

This alternative would protect the bluffs fronting Barrow by constructing a revetment between transect 17 and 26.25 and provide flood protection for Browerville by constructing a dike between transect 26.25 and 45. Construction of this alternative would require approximately 107,900 cubic yards (cy) of rock from Cape Nome quarry and 241,400 cy of sand and gravel from Barrow area material sites.



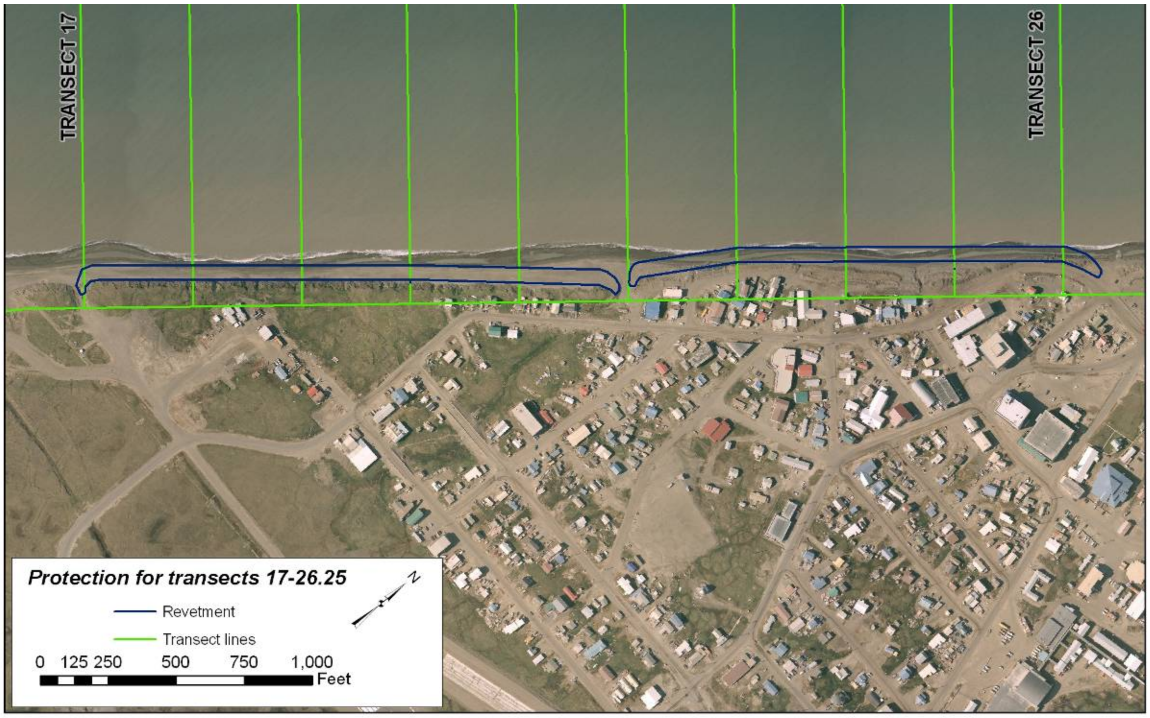
Alternative 3b – Protection for transects 17-31

Protect the bluffs by constructing a revetment between transect 17 and 26.25 and protect Tasigarook Lagoon from flooding by constructing a dike between transect 26.25 and 31. Construction of this alternative would require approximately 62,700 cy of rock from Cape Nome quarry and 157,600 cy of sand and gravel from Barrow area material sites.



Alternative 3c – Protection for transects 17-26.25

Protect the bluff by constructing a revetment between transect 17 and 26.25. No dike would be constructed. Construction of this alternative would require approximately 44,300 cy of rock from Cape Nome quarry and 129,400 cy of sand and gravel from Barrow area material sites.



PROJECT IMPACTS

Alternative 1 - No action

Under this alternative erosion of the coastline and flooding associated with storm events would be allowed to continue. Although these natural processes would not be expected to significantly impact biological resources, that are presumably adapted to a dynamic coastal environment, the potential impacts on community infrastructure could have negative consequences for the surrounding biological resources. For example, if erosion and flooding events compromised the utilidor, various contaminants could enter adjacent waters, and could affect fish, birds, benthic organisms, and marine mammals.

Alternative 2 - Non-structural alternative

This alternative would involve relocation of threatened structures and hardening vulnerable sections of the utilidor. Relocation of structures is unlikely to have significant impacts to fish and wildlife resources provided that structures are moved to existing gravel pads or previously disturbed areas. Similarly, hardening of the utilidor is not expected to have significant impacts on fish and wildlife resources provided that the hardening does not increase the footprint of the utilidor. Alternatively, relocation of structures and hardening of the utilidor may require placement of gravel in previously undisturbed areas, resulting in direct loss of valuable migratory bird habitat and potential nesting and brood-rearing habitat for threatened Steller's and spectacled eiders. Furthermore, placement of fill and relocation of structures may decrease habitat value of surrounding wetlands due to increased levels of disturbance.

Alternative 3 - Construction of revetment and dike

Under this alternative, sections of the bluff would be protected from erosion by placement of a revetment between 17 and 26.25. This structure would include geotextile sand bags placed against the bluff face on top of the rock revetment. Construction of the revetment to protect the bluffs might decrease the habitat value for some shoreline invertebrate species and could diminish feeding opportunities for some shorebirds. Impacts to fish and wildlife may also result from the use of geotextile bags as a component of the revetment. Geotextile bags are susceptible to damage from ice or other forces. Once the material is torn, the sand can escape and geotextile material can be transported out to sea or deposited on beaches elsewhere. The loose geotextile material becomes a hazard for seabirds, marine mammals, and other wildlife due to risk of entanglement. Although construction of the revetment may reduce the habitat value along a portion of the coastline, it would not be expected to have a significant effect on fish or wildlife.

The Corps may also construct a dike to protect low lying areas from flooding. The dike would start at transect 26.25 and end at or before transect 45. This structure might decrease the habitat value for some shoreline invertebrate species and could reduce feeding opportunities for some shorebirds. Construction of a dike is not expected to have significant impacts on fish and wildlife provided that the project footprint is limited to the beach and previously disturbed areas.

Activities associated with project construction

Underwater Noise

Increased underwater noise would result from barge traffic transporting materials to the project site. Underwater noise can cause pronounced short-term behavioral reactions and temporary local displacement in cetaceans (Richardson and Würsig 1997). Exposure to underwater noise can also alter behavior in diving birds. For example, Ross et al. (2001) demonstrated that underwater recordings of boat engines could reduce predation by common eiders at mussel farms by 50% to 80%. As with birds, the effects of anthropogenic underwater noise on fish are not well understood. Underwater noise, such as that associated with seismic surveys, can affect fish distribution, local abundance, and catch rates (Engås et al. 1996). Smith et al. (2004) concluded that noise exposure could produce a significant reduction in hearing sensitivity in goldfish. This suggests that loud sounds, such as boat traffic, can have a detrimental effect on hearing in fish. Additionally, exposure to ship noise can elicit a stress response (e.g. increased levels of cortisol) in fishes regardless of their hearing sensitivity (Wysocki et al. 2006). While there may be some temporary behavioral changes in marine mammals, birds, and fish in response to the noise from barge traffic associated with this project, the long-term impacts to fitness are probably not measurable.

Seawater turbidity

Beaching of material barges and construction of a barge ramp/road may result in a temporary increase in seawater turbidity. Schamel et al. (1979) suggest that increased turbidity could obscure food items for loons, seaducks, phalaropes, and gulls. Additionally, increased turbidity could directly affect prey species of birds. Marine invertebrates can be negatively impacted by increased turbidity and sedimentation. Additionally, some fish species could be impacted by increases in turbidity. Arctic cod, and important forage fish, are tolerant of widely ranging turbidities during the open water season (Craig et al. 1982), thus the species is not likely to be impacted by increased turbidity. Presumably other fish species found in the nearshore environment would also be tolerant of widely varying turbidity. Given that it is likely that seawater condition would return to pre-construction conditions at the end of the construction season, therefore the Service does not expect long-term impacts to fish and wildlife.

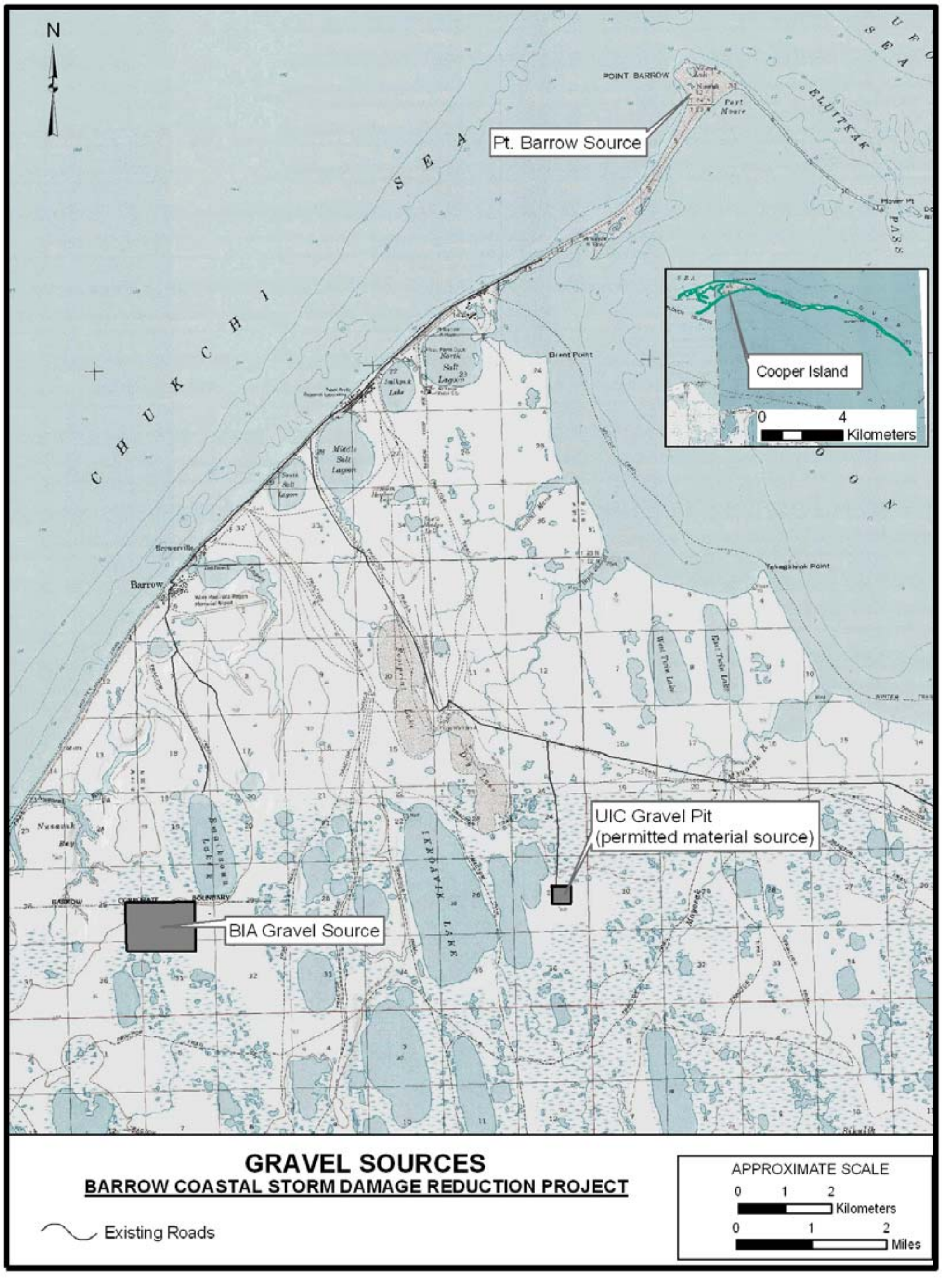
DEVELOPMENT OF NEW MATERIAL SOURCES

If large amounts of gravel are required for the project, particularly beyond existing sources, the most significant environmental effects of the project may be a result of mine site development. For this reason, we have examined potential mine sites, the process for recovering material, and the resources potentially impacted at each site.

Point Barrow

The Point Barrow source is within a gravel accretion zone. Extraction of material would not require removal of overburden. Material mined at the site would be trucked down the beach to the construction site. Of the three potential material sources, it would be the least costly to develop.

In general, shorebird densities are usually lower on gravel beaches than in other types of littoral habitats (Connors 1984). However, some shorebird species such as ruddy turnstones, sanderlings, and red phalarope often use gravel beaches in late summer (Connors 1984). Water bird species shown to favor gravel beach areas in Barrow include king eider, long-tailed duck, arctic tern, glaucous gull, and Sabine’s gull (Smith and Connors 1993). The potential material source was surveyed in August 2005 to determine use by post-breeding shorebirds and waterfowl (Hoffman 2005). Hoffman observed approximately 65 sea ducks (common eider, king eider, and long tail ducks) foraging in waters southwest of the proposed gravel excavation site. Shorebirds were not encountered during the survey; however use of this area by post-breeding shorebirds has been documented by other researchers. Development of this material site would result in a loss of shorebird habitat and, depending on the time of year material is excavated, could result in increased seawater turbidity.



GRAVEL SOURCES

BARROW COASTAL STORM DAMAGE REDUCTION PROJECT

Bureau of Indian Affairs (BIA) site

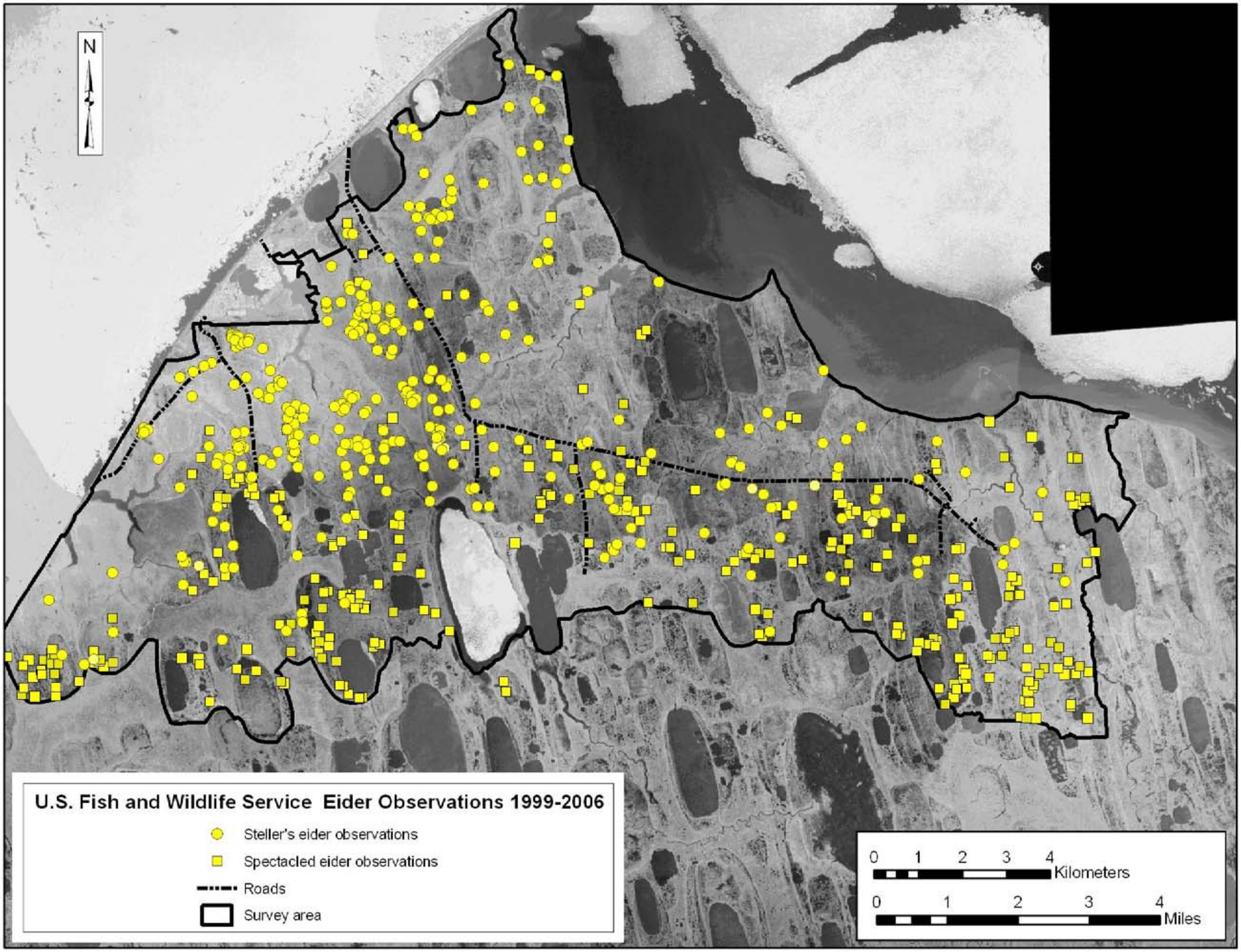
The BIA Prospect site is an onshore tundra site that is a southern extension of a deposit currently used for construction projects in the Barrow area. The general conclusion from exploration activity conducted in 2004 is that the prospect contains about two million cy of usable sand and gravel (U.S. Army Corps of Engineers 2005). Extraction of this material will require the removal of overburden in volumes approximately equal to the volume of material extracted. Material would be extracted during winter and an ice road would be constructed to transport material from the quarry to the beach.

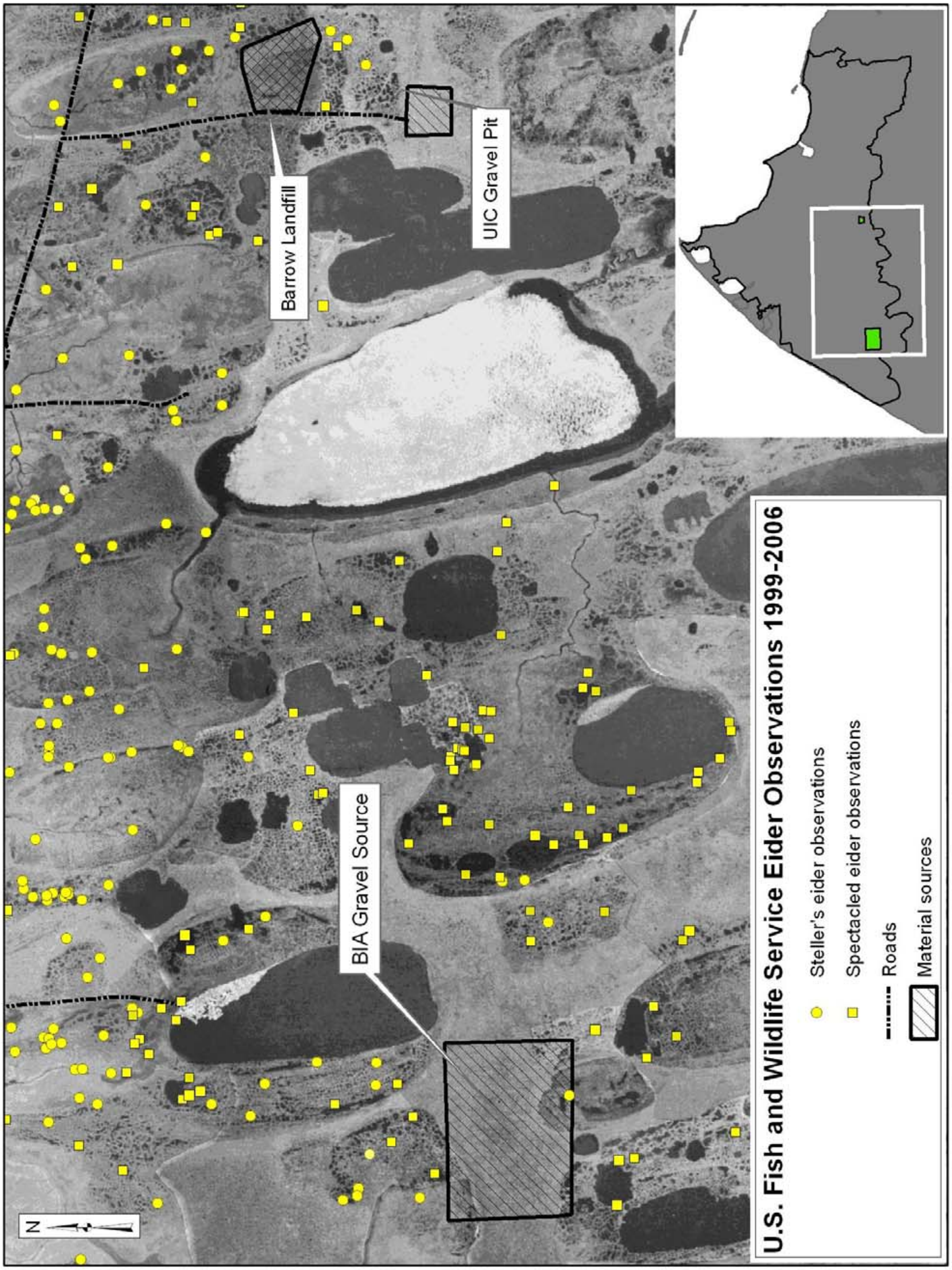
This site was surveyed in June 2005 to assess habitat use by breeding birds (Hoffman 2005). In this survey, Lapland longspurs were the most common birds, followed by pectoral sandpipers. Other birds sighted included dunlin, red phalarope, and white-fronted goose. In addition, both Steller's eiders and spectacled eiders, listed as threatened under the Endangered Species Act, are known to nest in the vicinity of this proposed gravel site. Development of this material site would result in a direct loss of valuable migratory bird habitat and potential nesting and brood-rearing habitat for threatened Steller's and spectacled eiders. The Service is concerned with the cumulative loss of wetland habitats in the Barrow area due to the potential impact of this loss on the recovery of Steller's eiders.

Cooper Island site

Cooper Island is a barrier island 30 miles from Barrow, in the Plover Island group north of Elson Lagoon. Gravels are accreting and eroding on a yearly basis. The Cooper Island site contains more than two million cy of useable clean sand and gravel (U.S. Army Corps of Engineers 2005). Granular soils extend from the island surface to the elevation of the surrounding ocean surface. The removal of overburden will not be required for the extraction of sand and gravel. Material would be barged to the construction site.

The island is known to support traditional uses including hunting, camping, trapping, and is used as a stopover for vessels. Cooper Island is also the site of a long term black guillemot and horned puffin nesting study. The waters along the Plover Island chain may be important feeding areas for post breeding birds moving westward (Divoky 1984) and an area important for molting long-tailed duck (ADFG 1986). Development of this material site would result in a direct loss of bird nesting and staging habitat. Furthermore, the barge traffic associated with transporting sand and gravel off the island may disturb feeding and molting birds. In addition to potentially impacting birds, increased barge traffic may disrupt migrating bowhead whales.


N
U.S. Fish and Wildlife Service Eider Observations 1999-2006
● Steller's eider observations
■ Spectacled eider observations
Roads
Survey area
0 1 2 3 4 Kilometers
0 1 2 3 4 Miles


U.S. Fish and Wildlife Service Eider Observations 1999-2006
● Steller's eider observations
■ Spectacled eider observations
Roads
▨ Material sources
Barrow Landfill
UIC Gravel Pit
BIA Gravel Source
N

RECOMMENDATIONS

The Service provides the following recommendation for minimizing the potential impacts of the Barrow Coastal Storm Damage Reduction Project on fish and wildlife:

1. If possible, sand and gravel should be taken from existing permitted material sites. If gravel is needed beyond what currently exists within permitted sites, additional consultation with the Service, including Section 7 consultation, will be needed. We recommend the Corps avoid developing the BIA material site due to its potential value as Steller's eider nesting habitat. We also recommend the Corps avoid use of Cooper Island as a material site due to potential impacts to post-breeding and staging shorebirds and seaducks. Of the three potential material sites considered, we believe the Point Barrow site to have the fewest impacts to fish and wildlife. However, the Service recognizes that Point Barrow is considered part of an archeological site and that development of this material site may not be possible due to its cultural significance. If any of these three material sites are deemed necessary for the project, operation and reclamation plans should be developed in collaboration with the Service and other resource agencies.

2. Should relocation of structures be needed, we recommend that those structures be placed on existing gravel pads or in previously disturbed areas.

3. Staging areas for construction materials should be designated prior to construction. The Service recommends that staging areas be located on existing gravel pads or in previously disturbed areas.

As this project proceeds through its final design phase, the Service may have further recommendations for minimizing impacts to fish and wildlife.

SUMMARY

The Service believes the Barrow Storm Coastal Damage Reduction Study, as currently proposed, will have minimal impacts on fish and wildlife, and will not likely affect threatened Steller's and spectacled eiders provided that:

1) Construction of the dike and revetment can be accomplished using existing, permitted material sites, and,

2) Relocation of threatened structures does not result in the construction of gravel pads in previously undisturbed areas.

Development of new gravel sources could potentially have the most significant impact to trust resources. If construction of the revetment and dike require either 1) a permit modification to expand an existing material site or 2) development of a new material site, it is possible that formal endangered species consultation will be necessary. Similarly, if relocation of threatened structures or construction of the dike requires placement of gravel in previously undisturbed areas, formal consultation may be necessary. The Corps is advised to contact the Fairbanks Fish and Wildlife Field Office (Larry Bright 907-456-0324 or Ted Swem 907-456-0441) when construction plans have been formalized to determine if further review and/or consultation will be needed.

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U.S. Army Corps
of Engineers
Alaska District

Barrow, Alaska

Coastal Storm Damage Reduction Interim Feasibility Report

Appendix F – August 2006 Public Meeting

August 2008

BARROW COASTAL STORM DAMAGE REDUCTION FEASIBILITY STUDY BARROW PUBLIC MEETING—August 23, 2006

A public meeting was held in Barrow, Alaska on August 23, 2006 to discuss the status of the Barrow Coastal Storm Damage Reduction Feasibility Study being conducted jointly by the Corps of Engineers (COE) and the North Slope Borough (NSB). This is a summary of the public meeting made from a video taken by the NSB during the meeting. The sound quality was not always sufficient to allow a precise record of what was said. This document is not a verbatim transcript of the entire meeting, but is intended to reflect the discussions held during the meeting. The usual meeting procedure was for discussion to occur in English in about 20-to-40-second-long segments, followed by translation into Inupiat. Questions/concerns by attendees were provided in either English or Inupiat and translated into the other language, before a response was made in both languages. For ease of reading, this entire document is presented in English and has been edited where useful to clarify meaning. Locations in the text where Inupiat translation took place are shown by ##. Explanatory notes are shown in *italics*. A powerpoint presentation was shown during the meeting. [Slide 1] identifies what slide is on the screen at that point in the meeting. The power point presentation is available at the following web site: http://www.poa.usace.army.mil/en/cw/barrow/barrow_index.html.

The study team members present during the meeting were:

Michael D. Stotts (Mike), North Slope Borough, Project Study Coordinator
Forest Brooks, (Forest) Corps of Engineers, Planner
Dennis Blackwell, (Dennis), Corps of Engineers Cost Engineer
Dee Ginter, (Dee), Corps of Engineers, Hydraulic Engineer
Ridge Robinson (Ridge), Tetra Tech (Corps contractor), Economist
Kurt Keilman (Kurt), Tetra Tech, (Corps contractor), Economist

(Mike): [Slide 1] I am Michael Stotts, NSB Department of CIPM. Tonight we have with us the Army COE visiting Barrow regarding the Barrow Coastal Storm Damage Reduction Study. Feel tree to ask any questions of the speaker. We will have an interpreter tonight, James Patkopak. We want to pass on as much information as possible. The radio talk show this afternoon was fun. This project is ongoing, in its third year. Feel free to interrupt the speaker this evening with questions, suggestions, and comments. We will take it slow tonight. It's not like there are hundreds of people here. We want to do our job. The Army Corps wants to do their job. The main point is to get as much information across as possible. There's some food and some pop. If I can ask the kids not to run around and to stay out of the Museum areas. Before we start, I would like to ask Genelle Okpeaha to open us up with a prayer.

(Genelle): Let us all stand. Thank you, Lord. ##. For this time, Lord, you are providing our guide. Give us wisdom, understanding, and knowledge. Lord, we thank You. You say ask in Your Name. We are asking in Your Name, Guide us. Lead us in Jesus, we beg You. We ask You right now this evening to guide us. Lead us in Jesus' Name. We beg you, Lord. Thank you for this time. Bless all the people here, Lord Jesus. We thank you for everything you do, everything you will do. In Jesus Name, we ask you. Amen. ##.

(Mike): Thank you, Genelle. James, I want you to welcome everyone tonight. ##.

Thank you, James. At this time, I want to introduce Forest Brooks, the Planner from the Corps study team, who can introduce the rest of the team present. ##.

(Forest): Thank everyone for coming out tonight. It's a beautiful day in Barrow, a beautiful day in Paradise. I know it's hard to be inside on an evening like this. We appreciate your coming out. We want to be able to talk with you to find out your concerns. I will now introduce the members of our study team present. Up front we have Dennis Blackwell, the cost engineer on the team. He will be writing your comments down on the board, so we can be sure we understand your concerns accurately when we get back to Anchorage. In the back is Dee Ginter, the hydraulic engineer on the team. She will be operating the computer and projector tonight. Over to my right are two from Tetra Tech, an economic consultant, Ridge Robinson and Kurt Keilman. We started out with an in-house economist, but he was a cheesehead and took a job is Wisconsin. Tetra Tech will be finishing up the economic analysis, which he started. ##.

Our purpose tonight [Slide 2] is to discuss our studies, where we are now, and update you on our progress since the last public meeting. We've been coming every summer to update you. Right now, many of the technical studies have been completed. We are looking at possible measures which will get combined into alternatives. Those will be compared to identify those that will go into a final report and environmental impact statement. We want community input: Are we looking at the right place? Is the project high enough? Long enough? Is it the right design? ##.

We have the results of technical studies to date [Slide 3]. We have completed an analysis of the possible beach erosion. We had originally thought that there was a big beach erosion problem. The analysis indicates the beach is relatively stable but we feel there is bluff erosion and flooding problem during severe storms at the lagoons and toward Browerville. We will be talking about two areas. The bluff area from the Top of the World to near airport runway is likely to experience erosion during severe storm events. Flooding will occur from the Top of the World going northeast during severe storm events. ##.

The general result of our studies is that the beach is stable. During last 50 years, the beach has eroded some, with most in the 60's to 70's, when material was used for upland purposes. So, large beach nourishment has been dropped from active consideration. The beach nourishment we talked about 1 or 2 years ago won't happen. Portions of the community are susceptible to bluff erosion and flooding. Our focus will be to provide erosion protection for the bluff and flood protection to the northeast.

Bluff lines in 1948 and 2003 are shown on this slide [Slide 4]. The University of Colorado determined that there's 1 foot/year average erosion in this time frame. They also looked at the shoreline from 1948 to 2003 and determined that loss of beach is shown [Slide 5]. There has been loss of approximately 50' of beach since 1948. Evaluation of the loss indicates that most of the loss occurred when material was removed from the beach to support construction of the airport runways. This occurred between 1954 and 1974. Since that time, the beach has returned to a stable condition. ##.

Photos of the beach during these time frames are posted in the room on the table to my right. The photos comparing 1948 and 1954 show a relatively stable beach. The photos comparing 1954 and 1974 show general beach retreat, primarily we think due to excavation and removal of beach material for a number of upland purposes, such as the airport. The photos comparing 1974 and 2003 again show a relatively stable beach, which we expect to continue into the future. Dee's computer modeling analyses confirm the expectations for a relatively stable beach in the future. ##.

There is still potential for floods and flood damage during severe storms in the Barrow area. I want to explain some terms that we are going to use to determine how high flood waters are [Slide 6]. Still water level is the level of ocean without tides. Then we factor in tides. *Barrow tides are very small*. This gives the ocean level. We also use computer models to find storm surge on top of the tide. In Mississippi, they had a storm surge of 28 feet during Hurricane Katrina. Oceans have waves. Near shore, the wave breaks. After the wave breaks, you have wave setup, which forms a relatively constant water level. Then you have wave run up, which is the rush of the water up the beach after it reaches the shoreline. We use this elevation to describe the highest elevation of flood, but, at that elevation, there would be intermittent water, not solid water. ##.

If we look at work that's been done and talk about the 50-yr storm event [Slide 7] of tide plus surge plus set up, the elevation is 8 ft above mean sea level and run-up would add an additional 5 feet. The maximum height of the 50-yr flood would be 13 feet above mean sea level. The level and duration of the flooding at the individual houses would depend on their location. So, you wouldn't have complete flooding all the time. As you move inland, the flooding would be less severe. For the 100-yr [Slide 8], the corresponding levels are 10 ft and 15 feet. ##.

Dennis has asked me to point out that the flood of 1963 is roughly approximate to a 50 yr flood. Last year, University of Colorado had a photo with a green line that approximates where contours of this flood were.

(***Audience***):
Which direction is the gravel migrating? It appears to be migrating toward Pt. Barrow. Is that the right direction, that most of the sand is heading toward? ##.

(***Forest***):
About 10,000 CY of material per year moves along the beach in front of the town toward Point Barrow. ##.

(***Audience***):
How do you determine what's a 50 year event or a 100 year event? ##.

(***Dee***):
A 20 year wind and wave hindcast was conducted at the Waterways Experiment Station in Mississippi. They supplemented with specific storms back to 1954. Then they determined return intervals using statistical analysis. ##.

(***Audience***):
How does movement of 10,000 CY of gravel affect the storm forecast? ##.

(***Forest***):
The 10,000 CY is not really a big quantity in beach movement, so doesn't have much effect on the erosion or flooding. It is a relatively small number. ##.

(***Audience***):
How did you determine yellow and red lines and how does it compare to the 1963 flood? For some of us who lived here during the flood, how did you determine where those lines are?

(***Forest***):
The lines on the map are contour lines and represent specific elevations. Through studies we have determined that we expect the ocean level is going to be about 10 feet and the run up will be about 5 feet above that for a total of 15 feet. Lines reflect elevation 10 foot and 15 foot contour lines for current conditions. Land has changed since 1963, so flooding would be different too. ##.

(Audience):
##.

(Forest):
Now that the problems have been identified, bluff erosion and flood damages, we will talk about solutions [Slide 9]. There's two prime ideas, first, provide protection to bluff by providing a revetment. For flooding, we want to replace the temporary dike built by the Borough that is currently refurbished on a regular bas that with a more permanent structure. ##.

The west part of town has an erosion problem [Slide 10]; the eastern part of town a flooding problem. In between these areas is a transitional zone that starts as an erosion area and gradually drops in elevation and becomes a flooding area. This slide shows the type of structure that would be used to protect the western part of Barrow [Slide 11]. The particular slide reflects a location somewhere west of the Top of the World Hotel. The design provides a core using a Concertainer system with rocks placed where the waves will be hitting the bluff. Rocks will be placed over the core to provide protection from the waves. Backfill will be placed along the face of the bluff to reshape the bluff. The height of the bluff will vary depending on the location. The surface of the bluff will be covered with supersacks to take ocean spray and rainfall and runoff. ##.

(***Audience***):
The last boat ramp we had some years that were concrete almost got swallowed by the sand. How will the rocks on top work with all the sand moving around? This is pretty heavy weight stuff. ##. *There was concern from the questioner that the rocks would not be stable. The concrete ramps got covered by sand and there was concern that this was because of the weight of the concrete or it could be from the storm. There was concern that the current design would suffer a similar problem and the rocks would sink into the sand.*

(*Dee)*:
To take care of placing larger material on finer sand, we build it up with varying sizes of material. On top of the beach material there is a very fine layer. We'd put little bigger material on top of the sand and a little bit bigger material on top of that layer. The intent is not to put large material on top of fine material and then have the fine material wash out. That's why it is built in different size layers. The HESCO Concertainers *(that are at the center)* have geotextile fabric inside with a very tight weave to hold in the finer material.

(*Audience*):
How long should the geotextile fabric last?

(*Dee*):
It should last a long time, it is very protected by rock on outside and only serves the purpose of providing core material. Rock out in front will protect it from ice and people, anything that could damage it. The supersack area will need maintenance because people will walk on them, and they'll suffer from ice gouging. But the supersacks only protect from overland runoff. It's up above where wave run-up will be. We're trying to insulate the slope so permafrost isn't melting. We are also going to protect the slope from damage due to runoff and people walking over it.

(*Audience*):
So the top is the beach? *This question concerns what the top of the section represents.*

(*Dee*):
The top represents the top of the bluffs. This transect is at the airport where there are high bluffs.

(*Audience*):
How about the beach? Can we walk the beach anymore? Is this going to cover the whole beach? *(This question expresses concern about the potential loss of beach in front of the structure. The beach serves as a recreational area and provides access along the entire waterfront. The diagram looks like it will cover the entire beach.)*

(*Dee*):
It will go down to waterline in some areas. This will mostly occur along the bluff. In Browerville, where they have a very wide beach you will have beach left to drive on. Only in bluff area where we're trying not to cut into bluff because they are archaeologically sensitive. We would normally cut into the bluff to get a stable slope and add the armor protection on the front. We are trying to stay away from it because it is archaeological sensitive. We're building core with HESCO Concertainers, putting rocks out in front and then backfilling with gravel to insulate the bank and keep it from melting. ##.

(*Audience*):
As far as the archeology, I was looking at this and looking back at how they built the seawall. How are you going to build this? Where is the construction equipment going to be?   On top?

(*Dee*):
From the beach.

(*Audience*):
Are you going to be able to reach that because that was what they told us at Point Hope and when they went to build it, they had to work from the top? If you build it from the top, you will have to put heavy equipment on an archeological site.   This puts the archaeological site at risk. When the supersacks go, you will probably have to replace them from the top especially if there is a storm. This leaves the site exposed to a lot of danger. So you may want to think about doing a proper mitigation and putting rock up there. Otherwise, I think you are putting it at continuing risk every time you repair it. How are you going to place supersacks? Maybe you should put rock on top to protect the archaeological site. You wouldn't need to do as much maintenance. ##.

(*Forest*):
We will take that concern into account when we decide how this will be done and how things would have to be maintained over time. One of the things we were trying to avoid was cutting into the bluff and taking out part of the archeological site. Our concern discussed at our team meetings was whether we can we build this structure from the waterside. We feel the work can be done from the waterside, but we will continue to work on the details. If this remains our design, we need to take care of operational maintenance without impacting the archaeological site. ##.

(*Dennis*):
We looked at it. We can get cranes with a long enough reach that once we put the baskets in. We can fill in behind them and set the sacks. It gets back to the reach of a crane. You will have to work the rock from the beach side and get a crane with a long enough reach. ##.

(*Audience*):
Where has this been tested? Where you put the fine gravel so it will not get washed out?

(*Dee*):
This is the way we build our breakwaters. Nome and Homer are built like this. We always build revetments coarser as we go up.

(*Audience*):
Is this the first for an arctic site?

(*Dee*):
No, we had a project in Shishmaref last year.

(*Audience*):
That is not the arctic. So it has never been done up here?

(*Dee*):
No

(*Audience*):
The sand is always sheared from underneath. You talk about the wave going up. Ice, what we call ivu, along the beach will shear from bottom and lift up the rock. Your presentation is based on waves going over. You are trying to prevent the waves from going over and bringing the erosion (*fine material*) out. You think this is going to hold it? It hasn't been proven up here. Let's say this is an ivu. The ocean going above will not bring it out. That's true. (*The ocean going over the rocks will not bring out the fine material.*) The ocean (*ice*) will shear under and lift and bring it up.

(*Dee*):
So ice will gouge underneath and bulldoze it up?

(*Audience*):
Yes! ##.

(*Dee*):
How deep do they usually bulldoze down into there under the toe of the revetment?

(*Audience*):
This season the ivu was brought up. That sand you see built up between here and Scare Cliff, which was done by shearing and lifting up of the huge evue that came ashore by the ocean.

(*Dee*):
I wonder if they (*rocks at the toe of the revetment*) just couldn't be buried?

(***Audience***):
Have you done studies of icebergs? Ice build up? (*There was concern that the design would not withstand the forces of ice.*

(***Dee***):
Once we come up with the final design, we'll construct a little model and have the Cold Regions Lab (*the Corps of Engineers, Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire)* run ice up on it and see how it performs. ##.

(Glen Sheehan, Director of the Barrow Arctic Science Consortium):
Mayor, isn't it correct that one of the things you are pointing out is that the ice might be just lying on beach. When it is on the beach, the water goes under the ice. It's not a question of how deep the ice gouges when it comes in but it's what the open water does to that ice afterwards?

(Audience):
Yes.

(***Audience***):
When you say zero, is that the sea level?

(***Forest***):
That would be a calm sea level. Yes, that would be an average sea level.

(***Audience***):
When you have a storm, is that zero where the riptide is? The riptide will undercut your material and tear it apart. Anybody ever heard of riptide?

(***Forest***):
Yes

(***Audience***):
Undercut?

(***Dee***):
We have the toe out there. The main protection is slope you see there. If toe erodes, it will start launching itself, and slide down until it stabilizes. *(Using the slide, Dee pointed to the toe and showed how the rock would react as the fine material was washed out)*

(***Audience***):
You said you had membrane under that slope. The riptide is going to wash out the gravel from underneath.

(***Dee***):
There's no membrane (under the toe), just a core material. If it erodes it will fill in itself.

(***Audience***):
Where are you going to get rock material around here?

(***Dee***):
Nowhere. This material will have to be imported. Right now we are looking at our source of import being Nome. We are looking at a stockpile of material being here so repairs could be made. We would always have stock pile here so we can be ready to make repairs.

(***Audience***):
How about from the mountain, from Atigun Pass area? ##. *(Atigun Pass is located about 170 miles south of Prudhoe Bay on the Dalton Highway that runs from Prudhoe Bay to Fairbanks. There is no road connection to Barrow.)*

(***Forest***):
The cost estimate is based on using existing commercial sources for Corps projects. Contractors have flexibility on where they'll be getting the material. So if it's cost effective to get material from a closer source, then the contractor would have that opportunity. We don't think it'd be cost effective to get material from the pass vs. bringing the material from Nome by barge.

(***Audience***):
Have you heard of jetties? Like they use in California? They put those jetties on a beach with them and when a storm comes around, the jetty just builds up the beach.

(***Forest***):
We are familiar with jetties. You have identified the good aspects of a jetty. It traps sand on one side, but on other side of a jetty you get an increase of erosion because you've stopped the littoral drift. Beach grows on one side, but erodes on other side. If you put a row of jetties you often will get a beach that looks like a set of saw blades. Good in certain incidences, but has down sides.

(***Audience***):
Difficult to understand the entire comment but the individual pointed out that one year there was something along the beach that acted like a jetty. The jetty was only 200 to 300 feet long. When the storm came, it built up sand on both sides of the jetty.

(***Forest***):
Sometimes, the effect depends on topography, currents, but generally when you interrupt the beach, it grows on one side, and erodes on other side.

(***Audience***):
Do you use those barges, the 400-foot barges and bring them in, fill them up, and sink them? The beach would build up around the barges. When it comes time to move them you could just pump the water or gravel out and move them. ##.

(Audience):
##.

(***Audience***):
How big are the rocks going to be 2' in diameter or larger?

(***Dee***):
They are going to be about 3 ft.

(***James***):
They say that the rocks will be too small for up here. They have to be bigger. Everybody take a note on that. (*This was a serious concern among the audience.*)

(Forest):
Dennis, Bigger Rock!

(***Audience***):
The conditions in Shishmaref and Nome are different than up here. The pressure ridges are smaller and the currents are not as strong as up here. You don't see ice coming up against the land like here. The smaller boats have harsher conditions here with the ice regarding the build-up on the beach. Bigger boats are better than smaller boats. ##.

(***Dee***):
That's why we want to go to the CRREL when we have a final design to run the model into ice so that rock is sized adequately. Rock will be expensive portion of this.

(***Audience***):
Difficult to understand the question because of interfering sounds in the room but the question concerned how to model the ice conditions.

(***Dee***):
They'll model a sheet of ice.

(***Audience***):
Will it be a full size model?

(***Dee***):
No. We will have a reduced size model. ##.

(Audience):
##.

(***James***):
Translator interpreted the question: Sheldon is suggesting that if COE built a barrier island all along the coast out far away from the shoreline, it would probably work.

(***Dee***):
We would have difficulty getting enough material to build up a barrier island. Bringing enough material from Nome would be quite the undertaking. When we were looking at beach nourishment, one biggest stumbling block is getting material we could use. A barrier island would need an enormous amount of material to construct. ##.

(***Audience***):
After the project is complete, will you have a monitoring system? Will you let the residents know if it is moving? Will you come up here to check on this periodically?

(***Forest***):
In general, for a COE dike-like project, the COE and local sponsor (*North Slope Borough*) cost share to build the project. The local sponsor (*North Slope Borough*) will operate and maintain the dike. As part of the project, the COE will develop an Operations and Maintenance Manual for the specific project. We will give the Manual to the local sponsor and it will tell them what they should do, how often they should do it, what to look for, what may show project distress. Plus we do periodic inspections on project we are involved with. The local sponsor does an inspection every year. We review their inspection and if things didn't look right, we would come our and do our own inspection. There is a process to monitor the project and it is tailored to the specific location and design of the project. ##.

This slide [Slide 12] shows the Homer spit project showing rock on the beach, similar to wide portion of the beach after the project would be completed.

Next photo [Slide 13] shows Nome, which shows a narrow beach. Some of the beach might look like this in the narrow areas after the project is completed. ##.

(***Audience***):
Is the rock in the picture the same size rock that will be used in Barrow?

(***Dee***):
I will look it up in my notes and tell you after the meeting. *Dee talked with him after the meeting. The rock used at Nome is much larger than the rock currently in the design for Barrow.*

(***Forest***):
Moving on beyond the bluff, this slide [slide 14]shows the general design of the dike towards the eastern part of Barrow towards Browerville. Because the land behind is a lower elevation you do not have the gravel fill or supersacks. We will consider comments you've made about the bluff part to be applicable to this part of the project.

We don’t have to go back through those again. This includes the issue of the ivu and the size of the rock being too small. If you have new concerns or ideas about this particular project, please ask.

(*Audience*):
How much land is there going to be on the beach side? Is there enough room to drive ATVs on the beach?

(*Forest*):
From lagoon to the east there will be room. The beach is wider there. The design will cover the area where the sand is piled up now. You will be able to drive up and down and walk on the beach. We have a slide that shows an aerial view with a footprint coming up in a few minutes. ##.

This slide [Slide 15] shows the entire area that we are looking at, the revetment on the beach, bluff and dike to east of there. There are four locations *(shown by yellow arrows) that* will have breaks in the levee for boat launch ramps, vehicle access, etc. The first cross section was for the beginning of the bluff, the 2nd was for the end of the bluff. From lagoons east, driving along will be quite possible. Near the beginning of the bluff to the 1st access point you probably will not be able to drive. At the west end of the project, you may or may not be able to drive on the beach. ##.

This slide [Slide 16] shows potential impacts. Assuming successful design, minimal environmental impacts to beach habitat and wildlife along beach are expected. The biggest impacts would be if we put in a borrow pit. This is confirmed by the draft Coordination Act Report by the US Fish and Wildlife Service. It would potentially have adverse impact stellar eiders. But since we feel the project could be built using commercial sources, that particular concern goes away. The things that might get damaged by flooding in town include the dam protecting the water supply, parts of the utilidors, structures, archeological sites and parts of utility system. This could include water, sewer and electrical. If the project were constructed and we could stop some of the bad flooding damages from happening, we feel that it will result in positive social and economic effects because money spent now because of flooding can be spent elsewhere. The biggest impacts we have seen include: narrowing beaches, limiting beach access, and a permanent visual block to the sea. Right now, the project we are considering has the same height as the temporary structure constructed by the borough. They build them up, the waves drive them down and they get built up again. If we build the project, this becomes a permanent situation. Hydraulic studies we have done so far, indicate there would not be a be beach problem as a result of building the project. ##.

(*Audience*):
Have you factored in global warming issues? With global warming, things are melting more, that part of our land could be under water because of global warming issues. Have you taken that factor into account? Sometimes when people come up here to have meetings, they say Barrow will be all under water. *##. (The individual was concerned about the potential increase in water level resulting from global warming and wanted to make sure this issue had been considered as part of the project.)*

(*Forest*):
Up to this point we have not directly considered that. However in the study plan put together with the North Slope Borough, it is one of the things we want to look at. Right now we’re working to develop a design that will work under the current conditions. Once we do that and identify the costs and the potential benefits if that design given the current weather conditions, then we’ll perform a sensitivity analysis or a more elaborate analysis as to possible potential future conditions. Lots of people have different ideas of what global warming will do. These ideas range from much warmer, stay the same or even another ice age. ##.

(*Audience*):
I know in the past there were a lot of issues about gravel. It looks like there is still a certain amount of gravel needed. Are we getting it all from one UIC pit?

(*Forest*):
Two years ago we thought we would need 2 million CY, for beach nourishment. Now we’re talking about ¼ to 1/2 million CY. Last month Dennis came up with one of our geotechnical engineers. They visited the existing pits around here and have spoken with the UIC people. In the future, there should be enough gravel material available in existing commercial pits. Rock is not available in this area and will still have to come some distance away. ##.

This slide [Slide 17] shows the estimated costs. Each piece, bluff protection and flood protection, looks like it will cost about 30 million dollars. The total project ranges from 50-70 million dollars. The price range depends on how high we build the rock. Cost sharing between the Federal government and the non-Federal sponsor uses a complicated formula. I discuss this with you individually if want more info. But it looks like the federal share is about 60%, and local share will be about 40% of the construction cost. ##.

So far we have talked about structural measures. This means building something that would prevent stuff happening. We will also look at what we call non structural measures [Slide 18].   These might include items such as relocating structures, raising roads, modify the utilidors to prevent flooding, participate in the federal flood insurance program and develop flood hazard mitigation plan. Know that a lot of you participated in survey. People were asked about their houses and what contents they had in them that might get damaged. We surveyed the commercial property so we could determine where the damages were going to come from during certain levels of flooding. You may be able to eliminate those centers of damage by doing something other than building a dike all the way along the beach. May be able to reduce damage by moving those things and see what non structural measures can be done. See if better bang for buck from this or combination of structural and nonstructural. We will be working with the North Slope Borough on these options. As you see, the cost of structural project is very big, going to be very difficult to justify economically under COE policy. We will develop a lot of info and do our best to alleviate flooding and erosion problems that you do have. ##.

(*Audience*):
They now have gravel berms along the beach areas. At times the water builds up behind them. Will the dike project be trapping water that needs to be pumped out? *The concern was that flood water would get over the dike and not be able to get back to the ocean. The individual wanted to know if we were going to pump the water out.*

(*Forest*):
That's a minor design detail that would be incorporated into the design once we have the major design done. Once the major items are worked out, we then go back and take care of drainage problems that dike might cause. We would find most cost effective way on a site by site basis. We would try to avoid pumping, because it is a costly way to solve the problem. ##.

(*Audience*):
We have a lot of hunters around here. Right now we have all these gravel berms. Are you going to make ways for some areas to be low for the hunters to go to and from the ice during winter whaling and seal hunting?

(*Forest*):
Right now just four gaps in the levee for access to the beach [Slide 15], but are interested in needs that exist, how many other places would you need to have access across the rock. We would be interested in any additional access you might need. You could provide us the information or talk with Mike at the NSB so that we can get the info. We could put access in, if there is a need, almost anywhere but we want to put them in the most beneficial places, not just all over the place.

(*Audience*):
Why don't you ask the whaling captains association for guidance on where they are taking the whaling vessels in and out of the water, if that's where they feel they need to get to the beach.

(*Forest*):
We have met with some of whaling captains. The design here is in response to what they said. Obviously, we didn't talk to all of the whaling captains, but those that came to meetings gave us these four locations. We have no good way of knowing ourselves. So if anyone has any additional input, we encourage you to get with Mike and let him know what the needs are so he can forward them to us for incorporation into any design that we might build. ##.

(*Audience*):
What about that drainage outfall by the lagoon? Will it be left open?

(*Forest*):
The drainage thru the lagoon area will be taken care of after the big design is done. We will see what makes works best given the conditions at that location. We will deal with those types of things based on what the big design is. You look at what makes most sense to accommodate drainage, access across or along. We have not looked at those details to date but will take them into account as we proceed with design

(*Audience*):
Will the access areas shown be weak points in the dike? We don't want to worry about that. If we ask for more is it going to be bad?

(*Forest*):
The best idea would be to have none. Right now with the current design, the NSB will have to go out and dump sand in the holes. It's less work than what they do now. If you would like to spend more money, we could have formal flood gates like New Orleans but those are expensive and we are trying to keep the costs down and balance things. Yes. You can add more but you don't want too many. That's why we were asking if these are the best locations. Vehicle access is different than people access. People can access by go over the rocks with metal or wooden stairs over the rocks. Vehicles can not do that. You don't have space for road ramps. ##.

(*Audience*):
There was a discussion on the location of the current access points. It was pointed out that the current locations are based on where the whaling captains live. This makes it easy for them to access the beach.

(*Forest*):
It would be ideal to have no slots. We realize the need for access to the beach for whaling and hunting. There is a need for some access to the beach so you can move boats and vehicles and such so you need to come to a compromise between the two extremes.

(*Audience*):
You said the dike would be 6' high?

(*Forest*):
The height of the dike depends on where you are [Slide 14]. Right now we have shown that the dike would go up to 16 ft if we say sea level is zero. That is not to say the dike would be 16 ft above ground level. In some areas is would 5', in some areas it would be less and some areas it would be more. In front of Brower's Café, it will be about 3 ft above land. The height varies.

(*Audience*):
You will create a lot of snow drifts on the land. Do you have any drainage for the water to go when the snow starts melting? ##.

(*Forest*):
The study team has not specifically talked about drainage from snow drifts. That is a good point. We will consider it during design. ##.

(*Audience*):
Mentioning snow and snow fences, you may have noticed that the snow drifts that are persisted by snow fences are causing thermocarsting and permafrost melting do that needs to go into considerations as well.

(*Forest*):
Thank you. That's why we come to the community and have public meetings so you can point out factors that we not have thought of. We don't live in the same area or climate as you. This is the type of information we were hoping we would get by coming and talking with you.

(*Audience*):
I see the beach material is contiguous under the whole structure. *The audience was looking at the cross section of the dike.*

(***Forest***):
It would be whatever material the existing ground would be. The material would vary depending on the location along the dike. This is the existing ground. We will build on top of that. The drawing is an oversimplification, and the material will be whatever is there now.

(Audience):
The road end that's close to the bingo hall, with a little bit of drainage, about a foot wide flow in a very short time will cut a trench about 3 ft deep. This material is like sugar. It doesn't stand up to anything. So when I see this, the wave action and the retreating of the beach, when you get to this material it goes away. I'm not very optimistic about this. Sorry. ##.

(***Forest***):
We're interested in your comments to poke holes in what we have done so far so we can try to do a good job and hopefully come up with something that works [Slide 15]. That is why we come to town and ask questions. In tying in this specific site here, a potential alternative might be to either abandon the road completely or move somewhere else or move the dike and have the dike and the road be one. Those are other possibilities that we may get into depending on where the damages are and how we can best attack those problems. This dike all the way along the beach may not be the best solution. One size doesn't fit all. We are pretty certain that something like the dike, at least in the portion will be necessary to keep the bluff from going away. If we only had buildings along the bluff, then it would be one thing. But the archeological site adds another element that complicates things and makes it difficult to look at things strictly from an economic aspect. You have the social and cultural factors that go with the site. The site may be worth protecting in its own right.

(***Dee***):
Where is this area you are talking about? *(This refers back to the erosion due to runoff from rain.)*

(***Audience***):
Talking about the area near the bingo hall. *The exact location of the problem was identified on the map, 739 Stevenson Street. There was a discussion to insure the COE knew exactly where the location. The COE was invited to come look at the situation. Dee met with the individual the next day at the bingo hall to see the erosion problem that had been identified.*

Note: The video tape was changed here. A short part of the meeting was not recorded.

(***Forest***):
You can look at our website, www.poa .usace.army.mil [Slide 19]. Click on "Civil Works and Planning" and Select "Barrow Coastal Storm Damage Reduction". We update the site from time to time and when we get back to Anchorage, we will add this presentation to it. My phone number is 907-753-2627. Lizettte Boyer is our environmental coordinator if you would like to talk to her about environmental questions. We're at the last slide [Slide 20], which is comments or questions.

(***Audience***):
There was a concern raised about ice migrating along the shore and the project design helping the ice move up and into town. Is there a way you can design the dike like a saw tooth to break up the ice, so it doesn't push ice into town? ##.

(***Dee***):
We're trying to make a more vertical face for the ice to hit, so it doesn't have a ramp to run up into town. We are trying to compromise between having a nice slope to dissipate the wave energy versus trying to stop the ice from coming in. As far as the saw tooth, we can look into that. My concern is that it will extend the length of the project as we go in and out which would require more rock.

(***Audience***):
There was a discussion [Slide 14] on the movement of sea ice along the coast. Pressure ridges [Slide 15] form along the coast and can migrate ¼ mile inland. Making a saw tooth shape dike along the beach would break up the ice.

(*Dee*):
Is it riding up there now? Is that what the ice is doing right now?

(*Audience*):
Yes, in the low lying area. Right around the bluff area it stops. Sheet ice migrates in on low lying. Flat ice forms along the beach. It is very strong. Once it starts migrating in, it will use dike as ramp into Browerville.

(*Dee*):
What we're trying to do is provide a vertical face [Slide 14] to hit first before it rides up and over into the community. We will look at that more closely. ##.

(*Dee*):
When the sea ice rides up, does it bulldoze the existing berms? Are the berms gone?

(*Audience*):
When the ice rides up, the small rock you have will not stop it. It is just going to ride right over it.

(*Dee*):
I was talking about the dirt berms you have out there right now that the NSB puts up.

(*Audience*):
You need some kind of mechanism to break up the ice before it starts migrating up. ##.

(*Audience*):
Can we look at the 50-yr slide again [Slide 7]? You said you would have to deal with the structures, possibly moving the ones that are in danger of being flooded?

(*Forest*):
Moving them would be one thing to look at. In non-structural, it might be that you can flood proof them in place. We have to look at each location on a structure by structure basis. What works at your house may not work at your neighbors because of a lot of factors. All houses are not the same. Relocating them is one thing; flood proofing it, raising it, or doing something else to it on its existing lot is another thing to look at. Those are the types of things we will look at as we continue to work on the project.

(*Audience*):
In 1970 we tried all this right here. All this area *(Barrow beachfront identified on the map and the area of Browerville southeast of the road with the AC Commercial and the Eskimo gas station)* is restricted under BIA. We tried moving from one side of lagoon, but couldn't. There were 22 residences that would not relocate because of restricted lots. Not one individual accepted. (*The Borough tried to relocate individuals in 1970. There were 22 individuals along the bluff that would not move because of the restricted lot status.)*

(*Forest*):
That is one of the problems with non-structural solutions. What makes sense for community as whole may not make sense for individuals and that where you run into trouble with it. Understanding those specific details, when we move into non-structural solutions might help us to understand things that have happened in the past and help us mold what we are proposing. We can avoid or acknowledge those problems in the future and how we may be able to get around them.

(*Audience*):
Could the idea that James had about putting the dike out serve multiple purposes? Possibly beach nourishment. *(This goes back to the saw tooth dike layout that would break up the ice and could possibly provide beach nourishment.)*

(*Forest*):
It could. Building structures in the surf zone is an art not a science. We estimate the best that we can but it would be best if you can avoid building something in that area and dealing with it otherwise.

(*Audience*):
It's not deep there. (*This refers to the fact that the water in the area where the saw tooth dike would be constructed is not very deep.)*

(*Forest*):
We realize that, but you still need a large volume of rock to create an offshore beam. This solution would have higher construction costs than the current solution, and justifying it economically is less likely than other alternatives. ##.

(*Audience*):
The off shore berm could provide multiple benefits. It could help with beach nourishment and the ivu (ice movement).

(*Audience*):
That's one of things you noted, Dennis?

(*Dennis*):
Yes.

(*Audience*):
I think money should not be a problem. We are using federal money and the government has the money to pay.

(*Forest*):
Unfortunately unless Congress tells us otherwise with special legislation, we have to develop a project using normal policies. One of the major things we have to follow is that the total net benefits to the nation have to exceed the total costs of the project. In general, we have to follow that criteria and that is one of the toughest things for us to get past in developing a project.

(*Audience*):
I would like to see you guys go all the way, not half way.

(*Forest*):
Some of us wish that we could do a lot more than we often do. We balance a lot of factors in developing and designing water resource projects. We have to do our best to provide for the communities, but we have to follow the rules Congress makes. If money wasn't a factor, we could solve any problem in the world. But unfortunately money is a factor. ##.

(*Audience*):
On that one slide [Slide 15] where you have the branches, the four arrows, you mentioned something about New Hampshire to do your model.

(*Forest*):
New Hampshire is where our Cold Regions Lab is located. That's where the model will be built.

(*Audience*):
Can they do the model with what Charlie was talking about to break up the ice? (*A short discussion showing the saw tooth dike layout on the map followed.)*

(*Forest*):
If you put what Charlie was talking about you wouldn't be able to drive on the beach anywhere. There are downsides to doing that depending on what impact that might have on sediment transport along the beach. It is difficult to say exactly what it would do.

(*Audience*):
I was wondering if you could put that as a model in New Hampshire or wherever this place is to see what effects you might come up with. You guys mentioned there is a place where you can do this kind of modeling. You have all these types of models you try out with the ice.

(*Dee*):
The main use of doing the model at the Cold Regions Lab would be to verify the rock size to make sure the ice won't move the rocks around. We're definitely going to think about doing a zigzag type footprint out there. We have to make sure that we don't interrupt the sediment transport and we would have to check on the increase in the amount of rock we would use out there. If it looks like it is feasible, we'll take a look at it.

(*Audience*):
Can you do the model to see what possible effects it might have? ##.

(*Dee*):
Does the ice *(ivu)* come in at an angle or straight along the beach? If it was a zigzag design configuration, would the rock get caught by the ice sheets? Would it get knocked down?

(*Audience*):
It comes in straight.

(*Audience*):
Sometimes as its moving it changes direction.

(*Audience*):
For the $70 million cost, it is no problem for the feds to put up the $50 million. But the local source is going to mean the local government region will have to come up with $20 million. That is where the problem is.

(*Forest*):
It may look easy to get money on the Federal side, but there's a lot of hoops to go thru to justify a project to Congress under the normal procedures. Sometimes it seems like it is easier for the local sponsor to come up with their share. It works both ways. We both have trouble coming up with money to fund water resource projects. Think about how much money they are talking about for Katrina to rebuild New Orleans. Do you rebuild it or not? How do you rebuild it? How much money do you want to spend? There is not enough money to build a perfect job there. It's always a balance between money, resources, costs, benefits, damages, the environment, cultural factors. It gets complicated. ##.

Thank you for coming out today. It's a beautiful night in Paradise in Barrow. I don't know how you could have a better day in Barrow than today. It's been pouring down rain recently—we've been washing away in the Anchorage area. On behalf of the Corps of Engineers study team and the NSB personnel, Thank you for coming, taking the time to be with us, to providing us input. If you think of things in the future, call us, write us, talk to Mike. We're getting to the stage where I will say good-bye. Maybe Mike has something else he wants to do.

***(Mike)*:**
I have no comment on the matter. Again, I am Michael Stotts of the NSB Department of CIPM. This is one of the projects, which I'm involved in. Regardless of money, Regardless of plans, I have ordered up a storm on or about October 22nd to get us thinking about a seawall. But in all seriousness, this is a serious matter. We all know the shoreline in Barrow is eroding-eroding rather rapidly. Many of us can remember a beach that was hundreds of yards out there. Thank each and every one of you for coming out tonight to see the plans-to see the program. I want to ask you to join me in thanking James Patkopak for translating. I can't speak fluently, like James. I know it isn't easy to take technical words and technical jargon and put it in your brain and come out in Inupiat language. But I am sure I know in the Inupiat language, it is easier to understand.

Mike handed out door prizes to attendees that were collected/provided by the North Slope Borough.

NOTE: During the Fall of 2006, seawalls built out of Concertainers during the summer of 2006 at Kivalina and Wainwright were severely damaged. Wave action directed against the Concertainer was able to wash the interior material out, causing partial to complete failure of the Concertainer seawall. The use of Concertainer units as an integral part of the Barrow revetment design was reconsidered by the COE during design review in the winter 2006-2007. As discussed in Appendix A, the final design of the revetted berm and the bluff revetment used various sizes of armor rock and did not include Concertainers.

BARROW COASTAL STORM DAMAGE REDUCTION FEASIBILITY STUDY
KBRW-AM RADIO BROADCAST—August 23, 2006

During the afternoon before the evening public meeting, KBRW-AM broadcast an hour-long radio show, beginning at 1:30 PM, that discussed the Barrow Feasibility Study being conducted jointly by the Corps of Engineers (COE) and the North Slope Borough (NSB). Calls were requested from the radio audience. This document is not a verbatim transcript of the radio show, but documents the information discussed during the radio show. Generally, the information was first spoken in 20-to-40-second-long English segments and then was translated into Inupiat. Locations in the text where Inupiat translation took place are shown by ##. Supplemental clarifying information is shown in [*italics*]. Those present and participating included:

James Patkopak (James), KBRW show host and translator.
Michael d. Stotts (Mike), NSB, Project Study Coordinator, panel moderator
Forest Brooks (Forest), COE, Planner
Mark Rosenberry (Mark), ASCG (NSB contractor),
Dee Ginter (Dee), COE, Hydraulic Engineer
Dennis Blackwell (Dennis), COE, Cost Engineer

{James}: I have about 1:30. ##. I'll have Mike Stotts of the NSB do the introductions.

{Mike}: Good afternoon, everybody. My name is Michael Stotts with the NSB Department of CIPM We have the Army Corps of Engineers with us today in Barrow with regards to the storm damage reduction project that has been underway for some years. Let's go around the table and get some quick introductions.

{Forest}: I am Forest Brooks, the Plan Formulator on the Corps study team.

{Dennis}: I am Dennis Blackwell, the Cost estimator on the team.

{Dee}: I am Dee Ginter, from the Hydrology and Hydraulics Section.

{Mark}: I am Mark Rosenberry from ASCG, a contractor for the NSB.

{James}: I am James Patkopak. ##.

{Mike}: Let me start off with Forest. Mr. Brooks, can you explain exactly what the Barrow storm reduction study is?
{Forest}: The study began 2003. It's a cooperative effort between the NSB and the COE to evaluate the storm damage reduction problems of Barrow and potential solutions. The impetus goes back to at least 1963 when there was an event, which flooded the area. In the 70's and 80's the NSB undertook studies, sometimes with the Corps, sometimes with others. In the 90's, the NSB began a beach nourishment project to put material on the beach. In 2000, a storm drove the

dredge onto beach [*damaging it and ending the nourishment project*]. The NSB used funds remaining from that project to support this study. ##.

{Mike}: Mark, Let me ask you What's your role in this project?
{Mark}: Three years ago we started in with the NSB and COE to collect economic data to see what the economic impact of storm damage in the area. We started with an economic study of Barrow, identifying the value of Barrow's commercial property, government property, and private property. A second project took into account economic damages to utilities and costs for restoration of electric power, shipping in water, restoring power and gas, etc. A third project took account of Barrow's social-economic impact, particularly the value of Barrow as infrastructure for shipping, governmental functions, education to local villages. ##.

{Mike}: Forest, let me ask you in the year 2006 your reason for visiting today? Does the project focus on beach erosion or possible flooding in the Barrow area?
{Forest}: The study focuses on erosion of bluffs and flooding from storms. The beach is relatively stable based on preliminary technical study results. So, this is not a beach problem. You have more like an erosion problem and a flooding problem during storms. ##.

{Mike}: Forest, some of the questions in my mind are: What are some of the scenarios the project entails? What is the potential flooding?
{Forest}: Assuming that the elevation of normal sea level is elevation zero feet, a 50 year storm would result in an ocean wave elevation 8 ft above normal. The storm would hit the beach and run up, with water reaching as much as 13 ft elevation. For a 100 year storm, sea levels would be10 feet above normal sea level and have 5 foot runup, resulting in water up to 15 foot elevation. Actual flooding would be somewhere between 10 and 15 ft above normal sea levels. A 50 year flood would be similar to the 1963 flood. ##.

{Mike}: For clarification, can you define what you mean by a 50yr/100yr flood?
{Forest}: A 100 year flood is a flood that has a recurrence interval of 100 years, or a 1% chance of happening in a particular year. Similarly a 50 year flood has a 2% chance of happening each year. A 25-year flood has a 4% chance of happening in a year. So, the chance of a storm event happing is inversely proportional to the recurrence interval. ##.

{Mike} Can you describe some of the plans the project might entail to protect Barrow? Are you planning on building a seawall?
{Forest}: The current proposal has two segments. First, the western part where the bluff is eroding. Second, the eastern part of town [*Browerville*], where flooding is a problem due to high water. We have similar designs for both parts to provide erosion protection. Near the water on the beach the design includes a composite section of rock and HASCO Concertainers. Landward from Concertainers, we will have fill material w/super sacks to protect from spray. The eastern part is much the same, except that the backside wouldn't have fill behind it. It would still have rock outboard and Concertainers forming a core. ##.

{James}: Would you use gravel to fill the western part?

{Forest}: Gravel type material will be used between the Concertainers and the bluff. Concertainers may not necessarily contain gravel because it has a liner that would hold smaller material. ##.

{Mike}: Let me clarify, So you would put a barrier from the eastern part of the beach to the northern part of the beach? How does it go?
{Forest}: The western part would begin near the airport and extend to the Top of the World hotel near where the bluff ends. The eastern portion picks up there and stops after the last road before you get to the sewage lagoons. ##.

{Mike}: What is a Concertainer?
{Forest}: There are two examples near the waterfront now. One is a wall by the sewage lagoons. There is also one beyond the supersacks by the Top of the World. The Concertainer is a wire basket 3'x 3'x 3', tied together to make walls with a volume of 1 cy each. These cubes have a geotextile membrane forming a basket that small stuff like sand won't go thru. You can put any type of sand material in it and it holds it in place. ##.

{Mike}: Let me pick on Mark now. You said you have worked for some time on the project and had done some studies on storms and damages in Barrow. Can you elaborate on studies done by ASCG for the NSB?
{Mark}: The NSB wanted information 3 or 4 years ago. We performed surveys of 50 private homes to determine values of cars, homes, furniture, property, and contents. The sample was used to estimate a total for all of Barrow. All businesses within a 20 foot surge event boundary were also surveyed. The value of buildings, contents, and services (ie down for a month value of business lost) was determined. We put the data into a GIS mapping program. We also performed a land survey to determine what roads affected. This was also entered into GIS so we can model what would happen. ##.
The second project we looked at the value of utility services, sewage, water, power, gas, what would be damaged and what would it cost to replace utilities, ie ship in water, and what alternatives to replace lost services exist. Different levels of damage were evaluated. ##.
Third, because of large population and infrastructure, Barrow is the social center of many local villages, providing services including health, education. We determined what loss of Barrow would have on villages. What social and cultural impacts result and put a value on the impacts. The COE is taking that information and putting it in a report to justify remediation to stop the erosion. ##.
Those are the three projects the Corps is taking the information from and putting into the report to justify remediations for the problems.

{James}: Is this a call in show?
{Mike}: Yes. We are going to ask if there are any questions out in radio land. Do you have any? For any Corps [*person*] or any general questions regarding this project? It's a study looking at major damage along the beach that may happen every 50-years or 100-years.The study has looked at possible storm damage and flooding of Barrow and ways to protect lives and property.

{James}: Are there problems down in the Wainwright area? in outlying coastal villages?

{Mike}: There is a project at Wainright currently ongoing. The NSB funded a seawall, called the Wainwright erosion project. Today, they are putting Concentainer units there along the beach coast. ##.

{James}: How about Point Hope?
{Mike}: I don't have any information. ##.

{Caller}: I am hoping you are not going to use sand bags again. Every fall every year they are putting sand bags or gravel. How about using rock or cement and making a hard surface. Has anybody thought of doing that?
{Forest}: The current design uses rock as the primary erosion protection measure for the bluff and ocean-side of the potential dike. Using other materials to provide bluff/dike protection farther west in town. Above flood zone, on open slopes, we want to use super sacks for spray and minor rainfall erosion control. ##.

{Mike}: Where are you going to get the rock?
{Dee}: Rock will be imported from Nome. We will minimize rock use by making the core material out of HESCO Concertainers to use the least amount of rock possible. ##.

{Mike}: Forest, a point of clarification. I would encourage listeners to attend the meeting tonight in Barrow, where they can see the drawings. They are difficult to understand over the radio. The inftrastructure we are talking about is a slanted looking wall toward the ocean about 20 to 25 feet high, is that correct? With a 10-foot-high pyramid of Concertainers with the rest of the height being made up of super sacks? ##.
{Forest}: We will be using Concertainers as the core, then rock in front. It may be 10 to 15 feet high, up to the top of the bluff, up to the level you protect against the waves. Supersacks will be placed above, with wall height depending on how high the bluff is.

{Mike}: I am trying to help our listeners get a picture in their minds of the infrastructure that we are talking about. Down toward the gravel pit it would be definitely higher. Down toward the northeast side of our beach it would shrink down to a lesser level. We are talking about a large and long wall along the seashore, that is of considerable size along our waterfront. ##.

{Mike}: Will there be spots where people can launch their boats and stuff? Will that kind of wall be consistent?
{Forest}: Four locations will probably have openings to provide vehicle access. One, west of the Top of World, one near it, and two near the gas station. Again, height will depend on the bluff height. Some places, ie near the lagoon, there will probably be no supersacks. The ground is lower on the backside than the ground [on the dike crest] would be. ##.

{James}: How high will the pyramid be?
{Mike}: About 10 to 15 feet. ##.

{Mike}: The project has been underway for some time. There have been several meetings over the couple of years.

{Mark}: ASCG was a participant in some of them. We have helped meet with smaller groups, whalers, residents, businesses and the public. The COE and NSB have coordinated w/ASCG. The COE is only involved in the seawall. Other concerns are being addressed by ASCG, like how do we launch boats? How do we design boat ramps? ASCG is working with the COE to match designs by others for boat access to accommodate the community. ##.

{Forest}: I just want to note that 10 to 15 ft means above sea level, not above the ground surface. Near Brower's Café the wall would be 3 to 5 feet above existing ground surface. Heights so far should be about the same as what the NSB has been piling near the beach. The difference is that these measures are permanent, not temporary. ##.

{Mike}: Forest, again, tonight's meeting, 7-o'clock at the Heritage Center. Why are you meeting with the public? What are you looking for from the public?
{Forest}: Two reasons. First, to tell public what we've been doing and how we've progressed. Second, to get community input on defining the problem and finding solutions. We want to know: Are we doing the right thing? Is there something that they think will work better? The costs of any project are very high. The costs of the project we've described is about 30 to 60 million dollars, depending on how high you build it. We're looking for community input both on the problems and the proposed solutions. Are we looking at things right? Do we need to incorporate other things into the project to make it right? ##.

{Mike}: Forest, you have a couple of staff members who have been making a little bit of noise. I know they wanted to stay quiet today and didn't want to say much. I want to put them on the spot and ask a couple of questions. What is a hydrologist?
{Dee}: [*I am*] a hydraulic engineer. I work on harbor design and construction issues, coastal protection design and construction issues, anything dealing with harbors, coastal issues, sometimes rivers.

{Mike}: It's engineering level rather than cosmetic level?
{Dee}: Yes. It's providing protection. ##.

{Mike}: This gentleman as well a fellow staff member that has come up with Forest. It's my intention to introduce the public and our listeners to the radio right now to the people involved with this now. The army Corps has been involved in this project for quite some time as well as many people throughout the arctic and other entities. It's always interesting to get to know the people that have been involved over many years on similar projects over time. Some of the questions that a lot of people may have are those that I have been asking. I understand you are an economist?
{Dennis}: I am a cost engineer, with a background as a structural/design engineer. We look at a whole group of different solutions and estimate their costs by looking at how we will construct it and where we'll get our materials. We look at a whole bunch of solutions. We put a cost number on each early on. ##.

{Mike}: Your job is to find the most economical way to solve the problem?

{Dennis}: Yes, we work with the design team to find the most economical way to build the designs. We find where the most economical materials will come from. What they are going to cost. We talk with suppliers at material sites to develop costs.

{Mike}: How much is this going to cost? What id the base estimate?
{Dennis}: There are 2 phases: one, the bluffs which will cost between 20 and 31 million. Two, flood protection will cost between 27 and 35 million. Projects together will cost 45 and 60 million. It depends on how much can be built in a season. How many seasons it takes. More seasons equals more cost. We need to minimize the number of times the contractor has to leave and come back. ##.

{Forest}: In addition to the project we've outlined for the meeting, we are also looking at non-structural measures. There may be more economical ways to get the same benefits, ie relocating structures. We look at those as a cost check.

{Mike}: That's why you need public involvement?
{Forest}: Yes. ##.

{Mike}: Thank you, James. We've taken just about an hour. We've given opportunity for call-in with questions. I invite you to the meeting tonight. Refreshments will be served. Dorr prizes will be given. Again, a meeting regarding a sea barrier wall along the coast of Barrow. We need your input. They are here to listen to the public in Barrow. They are here to listen to you tonight, to hear your suggestions. 7-o'clock at the Heritage Center. ##.

{James}: KBRW 680 on radio dial. Thank you folks.

NOTE: *During the Fall of 2006, seawalls built out of Concertainers during the summer of 2006 at Kivalina and Wainwright were severely damaged. Wave action directed against the Concertainer was able to wash the interior material out, causing partial to complete failure of the Concertainer seawall. The use of Concertainer units as an integral part of the Barrow revetment design is being reconsidered by the COE during a design review taking place during the winter 2006-2007.*

U.S. Army Corps
of Engineers
Alaska District

Barrow, Alaska

Coastal Storm Damage Reduction Technical Report

Appendix G – Correspondence

November 2008

1

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue
Seattle, WA 98101

July 24, 2003

Reply To
Attn Of: ECO-088

Ref: 03-034-DOD

Lizette Boyer
Environmental Resources Section (CEPOA-EN-CW-ER)
U.S. Army Corps of Engineers
P.O. Box 6898
Elmendorf Air Force Base
Anchorage, Alaska 99506-6898

Re: Coastal Storm Damage Reduction at Barrow, Alaska

Dear Ms. Boyer:

We are writing in response to the Notice of Intent (NOI) to prepare a draft Environmental Impact Statement (EIS) to evaluate options for reducing coastal storm damage at Barrow, Alaska in accordance with our responsibilities under the National Environmental Policy Act (NEPA) and Section 309 of the Clean Air Act. Thank you for the opportunity to provide comments at this stage of the EIS development process.

For your information, Section 309 of the Clean Air Act specifically directs the U.S. Environmental Protection Agency (EPA) to review and comment in writing on the environmental impacts associated with all major federal actions. Under our Section 309 authority, our review of the draft EIS will consider not only the expected environmental impacts of the project, but also the adequacy of the EIS in meeting the procedural and public disclosure requirements of NEPA. We have enclosed a copy of *EPA's Section 309 Review: The Clean Air Act and NEPA* which provides further elaboration of our EIS review responsibilities.

The scoping comments that follow are based on our evaluation of information contained in the NOI and the analysis completed in 2001 pursuant to Section 905(b) of the Water Resources Development Act. Our comments are provided to apprise the U.S. Army Corps of Engineers (Corps) of issues that EPA believes to be significant and warrant explicit treatment during the NEPA process and/or in the EIS. In providing these comments, it is our goal to have these issues addressed in the draft EIS.

Project Purpose and Need

The EIS should include a clear and concise statement of the underlying purpose and need for the proposed project, consistent with the implementing regulations for NEPA (see 40 CFR 1502.13). In presenting the purpose and need for the project, the EIS should reflect not only the purpose and need of the local sponsors, but also the broader public interest need that the Federal government would be seeking to meet. The statement of purpose and need should be short and clear - preferably 1 to 2 sentences, and certainly not more than a paragraph. Purpose and need statements that are pages long serve to cloud the statement, leaving readers unsure as to the actual need. Based on our review of the NOI, it appears that the underlying purpose and need for undertaking any action is to reduce or eliminate risks to community infrastructure (roads, utility corridor, sewage lagoon, and landfill) from storm damage, shoreline erosion, and flooding. We recommend that the EIS clearly reflect this purpose and need.

We recommend that all pertinent background information related to the purpose and need for developing the draft EIS be placed in a separate "background" discussion, either preceding or following the Purpose and Need section. This discussion should include an explanation of why the current planning effort is taking place (why now?).

Alternatives

Consistent with the implementing regulations for NEPA (40 CFR 1500.2 (e) and (f) and 1502.14), the EIS should evaluate reasonable alternatives that would result in the reduction or elimination of the known risks to community infrastructure, including potential approaches that would not require the placement of gravel for beach nourishment. This would include alternatives that would potentially relocate some or all of the infrastructure at risk or otherwise protect the infrastructure using means other than beach nourishment. Evaluating such alternatives is critically important given the current lack of a readily identifiable source of gravel suitable for beach nourishment. Such alternatives would eliminate potential environmental effects associated with gravel mining or dredging, transporting the gravel (including constructing and maintaining roads, if needed), and the placement of sands and gravel.

Assessment of Risk and the Timing for Implementing Identified Solutions

The Section 905(b) analysis includes a number of references to the immediate and imminent nature of the problem, yet the analysis also indicates that the beach erosion issue has been identified and studied by the Corps as far back as 1969 (34 years). Because the 905(b) analysis is unclear about the rate at which the shoreline is currently eroding, the magnitude and frequency of storm events that would contribute (or have contributed) to the erosion and flooding problems, or whether solutions are needed in the near term, we recommend that the EIS contain analyses of these issues. These analyses should present historical information (such as shoreline migration rate, incidents of flooding and storm damage) and include estimates of the probabilities or frequencies of events (storm events in the absence of ice, gravity flows, others) occurring that would result in damage to community infrastructure. These types of analyses will help determine the types of solutions that would be needed and when they would need to be implemented.

Potential Impacts to Elson Lagoon

The Section 905(b) analysis suggests that Elson Lagoon may be a source of gravel needed to implement beach nourishment alternatives. Dredging of those materials could potentially result in the establishment of a navigation channel and port in Elson Lagoon. Should the EIS include a detailed evaluation of dredging and creating a navigation channel and port in Elson Lagoon, we recommend that the EIS reflect a thorough assessment of the affects on fish and wildlife (and their habitats) and cultural resources in the lagoon that would result from initial dredging and construction activities and ongoing maintenance dredging and operational activities (including operation of the port). Including a comprehensive analysis of short-term and long-term effects in the EIS is particularly important given Elson Lagoon's highly productive environment for fish and wildlife and high cultural resource values of the area.

Consultation with Alaskan Native Tribal Governments

The development of the EIS should be conducted in consultation with all affected Alaskan Native tribal governments, consistent with Executive Order (EO) 13084 (*Consultation and Coordination with Indian Tribal Governments*). EO 13084 states that the U.S. government will continue "to work with Indian tribes on a government-to-government basis to address issues concerning Indian tribal self-government, trust resources, and Indian tribal treaty and other rights." Documentation of these consultations should be included in the EIS. Consistent with the July 28, 1999 memorandum from the Council on Environmental Quality (CEQ) to Heads of Federal Agencies, we suggest that the Corps consider inviting affected Tribal governments to participate in the EIS development process as cooperating agencies. This would provide for the establishment of a mechanism for addressing intergovernmental issues throughout the EIS development process, including potential effects to subsistence resources and the subsistence lifestyle of Alaskan Natives.

Environmental Justice

Identification of potential impacts and mitigation measures, developed in consultation with the minority and/or low income populations, should be included in the EIS to meet the direction of Executive Order (EO) 12898 (*Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*) and the accompanying memorandum to the heads of all Departments and Agencies. The Environmental Justice analysis presented in the EIS should include the following three major components:

> Description (including maps) of all low income and people of color communities in the area that would be impacted by the proposed project
> This should include a description of the methodology and criteria utilized for identifying the low income and people of color communities, the sources of data utilized for these analyses, and references utilized for establishing the criteria. Note: If 1990 U.S. Census data is utilized, the EIS needs to discuss any short falls that may result from utilizing this data set, and/or what steps were taken to assure the data is still appropriate for 2001 analyses.
>
> Comprehensive accounting of all the impacts on low income and people of color
> The identification of impacts needs to include (and not limited to) cumulative and indirect impacts, exposure pathways unique to the impacted communities, historic exposures, and impacts to cultural, historic and protected resources. In addition, the EIS needs to determine if the impacts on the low income and people of color communities will be disproportionately higher those impacts on non-low income and non-people of color communities. For such a determination, the EIS must identify a reference community and provide a justification for utilizing this reference community. This justification should include a discussion of the methodology for selecting the reference community.

<u>Identification of disproportionately high and adverse effects to the low income and people of color communities</u>

The EIS must demonstrate that communities bearing disproportionately high and adverse effects have had meaningful input into the decisions being made about the project. The EIS needs to provide a discussion on what was done to receive input from the effected communities (notices, mailings, fact sheets, briefings, presentation, exhibits, tours, news releases, translations, newsletters, reports, community interviews, surveys, canvassing, telephone hotlines, question and answer sessions, stakeholder meetings, and on scene information), what the input was, and how that input was utilized to shape the final outcome of the project. This discussion should include how traditional knowledge was utilized, what mitigation measures will be put in place to address the affected public's concerns, and when working with tribal members, what steps were taken to assure that concerns of individuals are being addressed, not just those of the tribal government(s).

Traditional Knowledge

We believe that it is extremely important to seek out and integrate the Traditional Knowledge of Alaskan Natives into the analyses of the EIS. We believe that the integration of Traditional Knowledge into the EIS development process will provide an important context for evaluating the impacts of proposed activities on the Alaskan Natives who would be affected by storm damage reduction activities. In order for the use of Traditional Knowledge to be meaningful in the EIS, it is critically important that the EIS clearly analyze and discuss how the various elements of the project have been developed based upon Traditional Knowledge. Specifically, the EIS should clearly identify how project design, operation, impact characterizations, or mitigation measures associated with the project have been developed in response to the information provided by the Alaskan Natives.

Thank you for the opportunity to provide input at this stage of evaluation of the proposed project. Should you have any questions about our comments, please feel free to contact me at (206) 553-8561.

Sincerely,

William M. Ryan

William M. Ryan
NEPA Review Team

Enclosure

APR 3 2003

CEPOA-EN-CW-ER (1105-2-10b)

MEMORANDUM THRU Dan Runkel, Chief, Information Management

FOR Director U.S. Army Records Management and Declassification Agency, ATTN: TAPC-PDD-RP (Mrs. Ortiz), 6000 6th Street, stop 5603, Ft. Belvoir, VA 22060-5603

SUBJECT Transmittal of Notice of Intent for Draft Environmental Impact Statement, Coastal Storm Damage Reduction, Barrow, Alaska.

Please print in the Federal Register, at the earliest convenience, the enclosed Notice of Intent for the subject project. Three signed copies are provided for your use. For more information, please contact Ms. Lizette Boyer of the Environmental Resources Section at (907) 753-2637.

Encls

Olton Swanson
OLTON SWANSON
Chief, Engineering Division

BILLING CODE: 3701-NL

DEPARTMENT OF DEFENSE

Department of the Army; Corps of Engineers

Intent to Prepare a Draft Environmental Impact Statement For Coastal Storm Damage Reduction, Barrow, AK

AGENCY: Department of the Army, U.S. Army Corps of Engineers, DoD.

ACTION: Notice of intent.

SUMMARY: The U.S. Army Engineer District, Alaska, intends to prepare a Draft Environmental Impact Statement (DEIS) for the construction of coastal storm damage reduction measures at Barrow, AK. The city of Barrow is an isolated community on the Arctic Ocean at the northern tip of Alaska. Barrow is the economic center for the North Slope Borough with a population of 4,400 residents, the majority of which are Inupiat Eskimo. The community infrastructure at risk from storm damage, shoreline erosion, and flooding consists of roads, a utilidor, a sewage lagoon, and a landfill site.

The utilidor stretches more than 3 miles and contains sewage, water, and power lines, and communication facilities for the community. Beach erosion threatens over 1 mile of the utilidor and a low-lying beach road that separates Barrow's sewage lagoon and an old landfill from the sea.

FOR FURTHER INFORMATION CONTACT: Lizette Boyer (907) 753-2637, Alaska District, U.S. Corps of Engineers, Environmental Resources Section (CEPOA-EN-CW-ER), P.O. Box 6898, Elmendorf AFB, AK 99506-6898. E-mail: Lizette.P.Boyer@poa02.usace.army.mil.

SUPPLEMENTAL INFORMATION: The DEIS will consider alternatives including the placement of sands and gravels suitable for beach nourishment along approximately 5 miles of beach, elevation of coastal roadways, and other structural and non-structural alternatives identified during scoping. The initial nourishment would require a large quantity of material. Viable borrow sources have not been identified. However, nearby Elson Lagoon could have suitable material and will be investigated as a borrow alternative. Excavation of borrow material from Elson Lagoon may have a dual purpose of creating a needed navigation channel for lightering barges and harboring local boats. Other borrow alternatives will be investigated.

ISSUES: Construction and gravel extraction for beach nourishment and other alternatives could affect protected wildlife. One of the structural constraints in developing storm damage reduction measures for Barrow is the need to identify an adequate source of sand and gravel (about 4 million cubic yards) within an economic transport range of the project site. The DEIS will consider the needs of the community to protect their infrastructure and the need to avoid significant adverse impacts to critical arctic environmental and traditional subsistence activities. The Barrow area is one of the remaining areas in Alaska where the threatened Steller's eider and spectacled eider sea ducks are known to nest. Elson Lagoon is highly productive for fish and waterfowl. Polar bears, seals, walruses, and beluga and bowhead whales are found in near shore waters at different times of the year. One known archeological site is along Elson lagoon, but the Chukchi Sea coastline has many archeological artifacts that continue to be uncovered. The DEIS will consider impacts to marine intertidal and subtidal communities, fish and wildlife, wetlands, threatened and endangered species, essential fish habitat, water quality, cultural resources, socio-economic resources, justifiable and practicable mitigation, and other resources and concerns identified through scoping, public involvement, and interagency coordination.

SCOPING: A copy of this notice and additional public information will be sent to interested parties to initiate scoping. All parties are invited to participate in the scoping process by identifying any additional concerns, issues, studies, and alternatives that should be considered. A scoping meeting will be held in June 2003 in Barrow, Alaska at a place and time to be announced. The DEIS is estimated for release in spring 2007.

Guy R McConnell

Guy R. McConnell
Chief, Environmental Resources Section

BILLING CODE: 3701-NL

DEPARTMENT OF DEFENSE

Department of the Army; Corps of Engineers

Intent to Prepare a Draft Environmental Impact Statement For Coastal Storm Damage Reduction, Barrow, AK

AGENCY: Department of the Army, U.S. Army Corps of Engineers, DoD.

ACTION: Notice of intent.

SUMMARY: The U.S. Army Engineer District, Alaska, intends to prepare a Draft Environmental Impact Statement (DEIS) for the construction of coastal storm damage reduction measures at Barrow, AK. The city of Barrow is an isolated community on the Arctic Ocean at the northern tip of Alaska. Barrow is the economic center for the North Slope Borough with a population of 4,400 residents, the majority of which are Inupiat Eskimo. The community infrastructure at risk from storm damage, shoreline erosion, and flooding consists of roads, a utilidor, a sewage lagoon, and a landfill site.

The utilidor stretches more than 3 miles and contains sewage, water, and power lines, and communication facilities for the community. Beach erosion threatens over 1 mile of the utilidor and a low-lying beach road that separates Barrow's sewage lagoon and an old landfill from the sea.

FOR FURTHER INFORMATION CONTACT: Lizette Boyer (907) 753-2637, Alaska District, U.S. Corps of Engineers, Environmental Resources Section (CEPOA-EN-CW-ER), P.O. Box 6898, Elmendorf AFB, AK 99506-6898. E-mail: Lizette.P.Boyer@poa02.usace.army.mil.

SUPPLEMENTAL INFORMATION: The DEIS will consider alternatives including the placement of sands and gravels suitable for beach nourishment along approximately 5 miles of beach, elevation of coastal roadways, and other structural and non-structural alternatives identified during scoping. The initial nourishment would require a large quantity of material. Viable borrow sources have not been identified. However, nearby Elson Lagoon could have suitable material and will be investigated as a borrow alternative. Excavation of borrow material from Elson Lagoon may have a dual purpose of creating a needed navigation channel for lightering barges and harboring local boats. Other borrow alternatives will be investigated.

ISSUES: Construction and gravel extraction for beach nourishment and other alternatives could affect protected wildlife. One of the structural constraints in developing storm damage reduction measures for Barrow is the need to identify an adequate source of sand and gravel (about 4 million cubic yards) within an economic transport range of the project site. The DEIS will consider the needs of the community to protect their infrastructure and the need to avoid significant adverse impacts to critical arctic environmental and traditional subsistence activities. The Barrow area is one of the remaining areas in Alaska where the threatened Steller's eider and spectacled eider sea ducks are known to nest. Elson Lagoon is highly productive for fish and waterfowl. Polar bears, seals, walruses, and beluga and bowhead whales are found in near shore waters at different times of the year. One known archeological site is along Elson lagoon, but the Chukchi Sea coastline has many archeological artifacts that continue to be uncovered. The DEIS will consider impacts to marine intertidal and subtidal communities, fish and wildlife, wetlands, threatened and endangered species, essential fish habitat, water quality, cultural resources, socio-economic resources, justifiable and practicable mitigation, and other resources and concerns identified through scoping, public involvement, and interagency coordination.

SCOPING: A copy of this notice and additional public information will be sent to interested parties to initiate scoping. All parties are invited to participate in the scoping process by identifying any additional concerns, issues, studies, and alternatives that should be considered. A scoping meeting will be held in June 2003 in Barrow, Alaska at a place and time to be announced. The DEIS is estimated for release in spring 2007.

Guy R McConnell

Guy R. McConnell
Chief, Environmental Resources Section

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
P.O. Box 21668
Juneau, Alaska 99802-1668

June 29, 2006

Guy McConnell
Chief, Environmental Resources Section
U.S. Army Engineer District, Alaska
P.O. Box 898
Anchorage, Alaska 99506-0898

ATTN: L. Boyer:

Dear Mr. McConnell:

This is in response to your request for information regarding the presence of threatened or endangered species and their designated critical habitat, near Barrow Alaska, which is proposed for beach protection using a storm damage reduction project. Additionally, you request to initiate consultation regarding Essential Fish Habitat (EFH) resources under the Magnuson Stevens Fishery Conservation and Management Act. (Magnuson-Stevens Act).

Endangered Species
Section 7(a)(2) of the Endangered Species Act (ESA) directs federal interagency cooperation "to insure that any action authorized, funded or carried out by such an agency is not likely to jeopardize the continued existence of any endangered or threatened species" or result in the destruction or adverse modification of critical habitat.

The following species listed under the ESA for which National Marine Fisheries Service (NMFS) bears responsibility are found in this area:

Bowhead Whale (Balaena mysticetus)....................Endangered

No designated critical habitat occurs near this area. As the action agency, the Corps of Engineers (Corps) should now determine whether this action may affect the bowhead whale. Your evaluation of potential effects should include consideration of secondary effects, including the proposed barge traffic. Should the Corps determine that this work may affect the bowhead whale, the Corps would then enter informal consultation, during which NMFS staff would work with the Corps' staff to consider means to avoid any adverse effects.

Essential Fish Habitat

Under Section 305(b)(2) of the Magnuson-Stevens Act, federal agencies are required to consult with the Secretary of Commerce on any action that may adversely affect EFH. The Corps has not determined whether the proposed action may adversely affect EFH. However, the Corps has provided information that includes a list of fish species present in the project area. From this list, EFH has been described for pink and chum salmon, sculpin, Alaska plaice, and yellowfin sole. NMFS suggests you review these species and their habitat associations found in Appendix F of the EFH EIS 2005 and online at http://www.fakr.noaa.gov/habitat/seis/final/Volume_II/Appendix_F.2.pdf.

Additionally, the information provided by the Corps is too preliminary for NMFS to offer any specific EFH conservation recommendations. NMFS, does however, suggest that the Corps consider avoiding and minimizing impacts by adjusting timing for in-water around sensitive life histories such as juvenile salmon smolt out migrations, adult salmon return migrations, or those times when juvenile sole and Alaska plaice concentrate nearshore.

We hope this information will be useful in fulfilling your requirements under the ESA and Magnuson-Stevens Act. Please direct any endangered marine mammal questions to Brad Smith in our Anchorage office, (907) 271-3023. Any EFH questions should be directed to Matthew Eagleton, also in our Anchorage office, (907) 271-6354.

Sincerely,

for D/M
Robert D. Mecum
Acting Administrator, Alaska Region

cc: *Kaja Brix – PRD
*Brad Smith
*Records File - # 1514-01 & 1503-16a

* email

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center
Auke Bay Laboratory
11305 Glacier Highway
Juneau, Alaska 99801-8626
Fax (907) 789-6094

(907)789-6005
March 9, 2005

Guy R. McConnell
Chief, Environmental Resources Section
U.S. Army Engineer District
P.O.Box 6889
Elmendorf AFB, Alaska 99506

Dear Mr. McConnell,

The National Marine Fisheries Service would be glad to have Scott Johnson and John Thedinga of the Auke Bay Laboratory participate in your Barrow Coastal Damage Reduction Study during the period July-August under the Interagency Support Agreement. The study is of mutual interest, and we are happy to assist the Corps of Engineers in evaluating essential fish habitat. Please contact Scott Johnson directly at 907-789-6063 or Scott.Johnson@noaa.gov to arrange details.

Sincerely,

Steve Ignell
Deputy Director

United States Department of the Interior
FISH AND WILDLIFE SERVICE
Fairbanks Fish and Wildlife Field Office
101 12th Avenue, Box 19, Room 110
Fairbanks, Alaska 99701
February 11, 2004

Guy R. McConnell, Chief
Environmental Resources Section
U. S. Army Engineer District, Alaska
P. O. Box 6898
Anchorage, Alaska 99506-6898

Re: Barrow Coastal Storm Damage
Reduction Project

Dear Mr. McConnell:

The U.S. Fish and Wildlife Service (Service) has reviewed documents submitted by the Army Corps of Engineers (Corps) regarding the development of storm damage reduction measures for Barrow, Alaska. The following Planning Aid Letter has been prepared under the Authority of the Fish and Wildlife Coordination Act and constitutes the Service's preliminary comments on the proposed project.

Background

At the request of the North Slope Borough (NSB), the Corps is investigating alternatives for the development of coastal storm and flood damage reduction measures and navigation improvements at Barrow, Alaska. The proposed project includes the immediate stabilization of up to 25,000 ft of eroding shoreline (beach nourishment) and the placement of beach erosion stabilization structures to prevent future erosion. The project will provide the community relief from storm-induced shoreline erosion and flooding that threatens homes, shoreline bluffs, and critical community infrastructure. Navigation improvements that will assist the loading and unloading of lightering barges also are being investigated. A reconnaissance-level 905 (b) Report, prepared by the Corps in 2001 under the authority of the Rivers and Harbors Act, indicated a Federal interest exists in the project. As a result of this finding, a feasibility study of the proposed project was begun in March 2003. The Corps subsequently published a Notice of Intent to prepare an Environmental Impact Statement (EIS) in the Federal Register on April 17, 2003.

The feasibility study is organized into three phases. Phase I, to be completed by September 2005, will include the development of project objectives and constraints, initial screening of potential alternatives, public scoping meetings, and initial site investigations. Phase II will include the development of detailed alternatives, field investigations to determine impacts to significant resources, and the formulation of mitigation plans. Phase II will be completed by

early 2007. The draft feasibility report and EIS will be prepared during Phase III and should be completed by December 2008.
The Service has been involved in Phase I of this project since March 2003. The Service has participated in public scoping and project team meetings and site visits, as well as provided comments regarding fish and wildlife resources in the project area.

The Service believes the project's gravel source location and methods of gravel extraction will be the most significant issues affecting fish and wildlife resources. As the Corps has not yet identified a gravel source, the following comments highlight the Service's general concerns based on the information thus far provided. A more detailed review of the project, including the identification of information gaps, study needs, and proposed mitigation measures will be conducted when further details are known.

Fish and Wildlife Resources

Approximately 2 million cubic yards of gravel will be required for the proposed beach nourishment at Barrow. The Corps has identified three locations in the Barrow area, Cooper Island, the Bureau of Indian Affairs (BIA) Discovery Site, and a submerged spit northeast of Point Barrow, where significant deposits of course sand and gravel may occur. Drilling to determine the quantity and quality of material at these sites will be completed in 2004. The Service provided comments to the Corps on the various drilling plans throughout Phase I of the project. The following is a summary of the Service's concerns regarding fish and wildlife resources pertaining to each of the proposed borrow locations. The Corps should develop a mining and reclamation plan for each of the sites prior to permitting gravel extraction.

Cooper Island

Cooper Island is located approximately 25 miles east of Barrow, in the Plover Island group north of Elson Lagoon. The Corps estimates that most of the estimated 2 million cubic yards of gravel required for the project could be obtained by mining approximately one quarter of the island. The following information regarding Cooper Island is primarily based on conversations between Neesha Wendling of the Service and George Divoky, Founder and Director of Friends of Cooper Island. Cooper Island provides nesting habitat for the largest colony (over 200 pairs in 1989) of black guillemots in Alaska. The number of pairs has dropped slightly in recent years averaging approximately 130 pairs between 2001 and 2003. Copper Island also supports other seabirds including nesting and prospecting puffins, Arctic Tern and Sabine's Gull colonies, and a 30-nest Black Brant colony. The island is also known to support traditional uses including hunting, camping, trapping, and providing a safe haven and stopover for vessels coming from Admiralty Bay. The Service recommends that gravel extraction at this site occur in winter months to avoid disturbance to nesting seabirds. According to Divoky, if mining were to occur during the summer, the primary problem for guillemots would be the large pile of gravel creating an attractive nuisance. He believes that and any human habitation or equipment would attract scavengers and predators like ravens, Glaucous Gulls, foxes, and possibly even polar bears with potential detrimental effects on breeding success. Furthermore, helicopter traffic would cause problems in colony and nest attendance and gravel piles on the tundra patch of the island would impact the Brant colony and small numbers of terns and Sabine's Gulls (George Divoky, Friends of Cooper Island, personal communication). If gravel extraction does take place in the summer, surveys to determine the nest sites of black guillemots and other seabirds and practices to avoid and/or minimize impacts to the seabird colonies may be required.

BIA Discovery Site

The BIA Discovery site is an onshore tundra site that geologically extends from the City of Barrow and Alaska Department of Transportation gravel sources in a southerly direction through Section 18 of Township 22N, Range 18W (Umiat Meridian). Currently, local construction companies produce gravel on the north end of the occurrence by blasting. Based on the results of two borings drilled east of Nunavak Bay by The Bureau of Indian Affairs in 1973, it is believed that the deposit of gravel continues in a southerly direction. This belief is further corroborated by staking preliminary holes in 2003 by Corps team members that identified gravel in the drainage of the north arm of Nunavak Bay. Possible gross dimensions of the prospective area are 10 miles long, 3.5 miles wide, and 3 yards thick. The Corps estimates that the site may contain approximately 300,000 cubic yards of gravelly sand. Gravel extraction at this site would occur in close vicinity to Nunavak Bay and Emaiksoun Lake. Special precautions would have to be taken to avoid erosion and sedimentation along a long stretch of Nunavak Bay. This proposed site is within the breeding ranges of spectacled (*Somateria fischeri*) and Alaska-breeding Steller's (*Polysticta stelleri*) eiders, both listed as threatened under the Endangered Species Act. Although spectacled eiders are more abundant across the Arctic Coastal Plain, Steller's eiders are more numerous in the immediate vicinity of Barrow. Steller's eiders appear to nest with greater regularity and in greater abundance near Barrow than elsewhere on the coastal plain, and both species are known to nest in the vicinity of the proposed drilling and potential gravel source site. Service recommendations for this site would include timing windows (drilling and extraction to occur before June 1 and after September 1) to avoid nesting eiders and other waterfowl, songbirds, and shorebirds and both ground and aerial surveys to determine presence and nesting of birds if extraction is to occur in summer months. If mining occurred during summer months, nests of listed species would have to be avoided with a buffer of approximately 200 meters.

The Submerged Spit

The offshore deposit lies within a submerged spit (Point Barrow shoal) located 7 miles northeast of Point Barrow, between the Chukchi and Beaufort seas. The Corps estimates that over 23 million cubic yards of gravel may be obtained from this site. The proposed site is an important area for staging migrants including Arctic Terns, Sabine's Gull, Ross' Gull, and phalaropes (George Divoky, Friends of Cooper Island, personal communication). According to Divoky, turbidity caused from excavation could potentially result in negative impacts to these pelagic, surface-feeding birds. This site also lies within a migratory corridor for waterfowl including and extending seaward from the Point Barrow spit and may provide habitat for molting or staging waterfowl (Divoky 1984a, Peterson et al. 1999, Fischer and Larned in Press). Long-term migration counts conducted at Point Barrow indicate declines in populations of Beaufort Sea common and king eiders (Suydam et al. 2000). Service recommendations for this site would include timing windows to avoid impacts to staging pelagic birds and waterfowl surveys in the area of the proposed site to ensure the lack of breeding and/or molting waterfowl prior to the commencement of excavation.

Long-term impacts to fisheries associated with excavation of the proposed site are not anticipated (Craig George, NSB Dept. of Wildlife Management, personal communication). The site lies along the Point Barrow shoal and is subjected to considerable disturbance due to sea ice ridging and strong currents. The shoal contains no structures (i.e. boulders) or reefs that would provide habitat for fish. In addition, hydrological changes due to mining are expected to be minimal. Therefore, the Service does not foresee issues regarding impacts to fisheries or changes in ocean dynamics due to mining at this site.

If the Corps should change the location of the mine site along the shoal (i.e., moves it closer to shore), the Service would need to re-examine the mining plan prior to gravel extraction for potential impacts to waterfowl and fisheries.

These comments are submitted in accordance with provisions of the Endangered Species Act of 1973 (87 Stat. 844) and the Fish and Wildlife Coordination Act (48 Stat. 401, as amended: 16 U.S.C. 661 et seq.) and constitute a Planning Aid Letter as outlined in the Scope of Work agreement prepared in May 2003 between the Service and the Corps.

We appreciate this opportunity to comment. Please contact Neesha Wendling at 456-0297 if you have questions concerning these comments.

Sincerely,

Larry Bright

Larry K. Bright
Branch Chief, Project Planning

NCW/ncw

cc: Craig George, NSB Wildlife Management, Barrow
Rex Okakok, NSB Planning, Barrow
George Divoky, Friends of Cooper Island, Seattle

Literature Cited

Divoky, G.J. 1984a. The pelagic and nearshore birds of the Alaskan Beaufort Sea. U.S Department of Commerce, NOAA, OCSEAP Final Report 23:399-513.

Fischer, J. B., and W. W. Larned. 2004. Summer distribution of marine birds in the western Beaufort Sea. Arctic: In Press.

Suydam, R.S., D.L. Dickson, J.B. Fadely, and L.T. Quakenbush. 2000. Population declines of king and common eiders of the Beaufort Sea. Condor 102:219-222.

Peterson, M.R., W.W. Larned, and D.C.Douglas. 1999. At-sea distribution of spectacled eiders: a 120-year-old mystery resolved. Auk 116:1009-1020.

STATE OF ALASKA

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF PARKS AND OUTDOOR RECREATION
OFFICE OF HISTORY AND ARCHAEOLOGY

FRANK H. MURKOWSKI, GOVERNOR

550 W. 7TH AVENUE, SUITE 1310
ANCHORAGE, ALASKA 99501-3565
PHONE: (907) 269-8721
FAX: (907) 269-8908

February 14, 2006

File No.: 3130-1R COE/Environmental

SUBJECT: Erosion and flood control, Barrow, Alaska

Guy R. McConnell
U. S. Army Engineer District Alaska
CEPOA-EN-CW-ER (C)
P. O. Box 6898
Elmendorf, AFB, AK 99506-0898

Dear Mr. McConnell,

The Alaska State Historic Preservation Office received your initiation of consultation letter regarding the referenced project on January 20, 2006. We agree that the erosion and flood control measures being considered in and around Barrow have a large likelihood of impacting archaeological and historic sites. On the other hand we acknowledge that these sites are already being affected by coastal erosion and storm driven flooding. We are therefore very interested in attending informational meetings regarding this project and consulting with you to develop measures to minimize or mitigate adverse affects to historic properties.

We also wish to correct one of your statements. Your letter indicates that the National Weather Service buildings (BAR-55, BAR-56, BAR-57 and BAR-58) have been determined to be not eligible for the National Register of Historic Places. According to our records however, the eligibility status of these buildings has been pending since January 8, 2001.

Please contact Stefanie Ludwig at 269-8720 if you have any questions or if we can be of further assistance.

Sincerely,

Judith E. Bittner

Judith E. Bittner
State Historic Preservation Officer

JEB:sll

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, ALASKA
P.O. BOX 6898
ELMENDORF AFB, ALASKA 99506-6898

REPLY TO
ATTENTION OF:

FEB -1 2005

Environmental Resources Section

Mr. Percy Nusinginya, President
Native Village of Barrow Inupiat Traditional Government
P.O. Box 1130
Barrow, Alaska 99723

Dear Mr. Nusinginya:

The purpose of this letter is to respond to your letter dated August 27, 2003, in which you expressed interest by the Native Village of Barrow Inupiat Traditional Government (NVB) to be a cooperating agency in the analysis and preparation of the environmental impact statement (EIS) for the Barrow Coastal Storm Damage Reduction (Barrow CSDR) study. Mr. Thomas Brower III, Environmental Director, was designated as the representative on environmental issues for the NVB.

Mr. Ernest Young, Tribal Liaison for the Corps of Engineers, Alaska District, contacted Mr. Brower seeking clarification of the Tribe's request. Mr. Brower stated that there might have been some confusion as to the intent of the NVB. Mr. Brower explained that it was his intent as the Environmental Director to cooperate with the Corps of Engineers and to ensure that the NVB was provided the opportunity to provide input to the environmental impact statement, but not to be a formal cooperating agency.

Please be assured that the NVB is invited to participate in planning for the Barrow CSDR study and the preparation of the environmental impact statement (EIS). Ms. Lizette Boyer is the designated representative for issues related to the EIS. To date your staff has graciously provided valuable information for the EIS. We will continue to communicate our information needs with Mr. Brower.

If we can be of further assistance, please contact Ms. Lizette Boyer at the above address by telephone at (907) 753-2637 or e-mail, Lizette.P.Boyer@poa02.usace.army.mil.

Sincerely,

Timothy J. Gallagher
Colonel, Corps of Engineers
District Engineer

STATE DEPARTMENT WATCH

☐ NATIONAL HEADQUARTERS
Post Office Box 65398
Washington, D.C. 20035
703-241-3700

☒ WEST COAST OFFICE
Post Office Box 6102
Woodland Hills, California 91365
818-223-8080

November 19, 2004

Mr. Guy R. McConnell
Chief, Environmental Resources Section
U. S. Army Engineer District, Alaska
P. O. Box 6898
Elmendorg AFB, Alaska 99506-6898

Re: Coastal Storm Damage Reduction (Barrow, Alaska), and Establishing Maritime Boundaries Between Alaska and Canada

Dear Mr. Groat:

This is two-fold request:

1. That the U. S. Army Engineers revise its project for Coastal Storm Damage Reduction (Barrow, Alaska) to reflect the fact that Cooper Island (one of the Plover Islands) is not under American sovereignty, but rather is Canadian.

2. That the Department of the Army take to heart the will of the Alaska Legislature in its HJR 26 to urge the establishment by the U. S. State Department of maritime boundaries between Alaska and Canada.

The lack of a maritime boundary line between the Alaska mainland at Barrow and the Canadian Plover Islands has resulted in the embarrassing proposal by the U. S. Army Engineers to take 1.5 million cubic yards of gravel from the Canadian Cooper Island without the consent of Canada.

In addition to the area of the Plover Islands, maritime boundaries are needed with Canada at the Arctic land boundary and at the southern land boundary with Canada.

Let me and the public know your intentions. Direct all correspondence to our West Coast Office.

Sincerely,

Carl Olson

Carl Olson
Chairman
State Department Watch

CLO:moi
Enclosures

STATE DEPARTMENT WATCH

☐ NATIONAL HEADQUARTERS
Post Office Box 65398
Washington, D.C. 20035
703-241-3700

☒ WEST COAST OFFICE
Post Office Box 6102
Woodland Hills, California 91365
818-223-8080

November 20, 2004

Mr. Guy R. McConnell
Chief, Environmental Resources Section
U. S. Army Engineer District, Alaska
P. O. Box 6898
Elmendorf AFB, Alaska 99506-6898

Re: Coastal Storm Damage Reduction (Barrow, Alaska)
And Importing Gravel from Cooper Island

Dear Mr. McConnell:

If the U. S. Army Engineers intends to consider the use of gravel from Cooper Island for the referenced project, you will find enclosed a letter from U. S. Customs and Border Protection of October 19, 2004, on the proper procedures for importation.

Let me know if you will be going forward on this potential use of gravel from Cooper Island.

Sincerely,

Carl Olson

Carl Olson
Chairman
State Department Watch

CLO:moi
Enclosure

STATE DEPARTMENT WATCH

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Post Office Box 65398
Washington, D.C. 20035
703-241-3700

☒ WEST COAST OFFICE
Post Office Box 6102
Woodland Hills, California 91365
818-223-8080

July 14, 2004

Ms. Lizette Boyer
U. S. Army Corps of Engineers
CENPA-EN-CW-ER
P. O. Box 6898
Anchorage, Alaska 99506

Re: Cooper Island, Canada

Dear Ms. Boyer:

This is a follow up to our phone conversation about the potential use of gravel from Cooper Island for the Coastal Storm Damage Reduction Project at Barrow, Alaska.

We would like to inform you that Cooper Island is in Canada. You should inquire from the owner of Cooper Island and the Canadian government for their views on your project, including the price for the gravel. These inquiries may need to be done through the Department of State.

Inasmuch as bringing gravel from Cooper Island to Barrow would be an importation of a commercial product, you should inquire from the Department of Homeland Security for appropriate customs regulations.

You mentioned that the Bureau of Land Management of the Department of the Interior had advised you that Cooper Island was somehow under its jurisdiction. This assertion needs review.

The Legislature of the State of Alaska spoke on this issue of Cooper Island and the other Plover Islands in the resolution HJR26 in 1999. You should consult with the resolution's sponsor Representative John Coghill Jr.

You will find enclosed our news release with relevant background materials. Please let us know what the Corps of Engineers will do to revise its program. A copy of this letter is being sent to relevant agencies for comment. Direct all replies to our West Coast Office.

Sincerely,

Carl Olson

Carl Olson
Chairman
State Department Watch

Cc: Asa Hutchison, Undersecretary, Department of Homeland Security
J. Curtis Struble, Acting Assistant Secretary, Department of State
Kathleen B. Clarke, Director, Bureau of Land Management, Department of the Interior
Hon. John Coghill Jr., Alaska House of Representatives

From: Arrington, Linda S POA02
Sent: Monday, July 26, 2004 2:25 PM
To: Elconin, Andrea B POA02; Trent, Sara POA02; Boyer, Lizette P POA02; Brooks, Forest C POA02
Subject: RE: Cooper Island

All,
I just got off the phone with Mike Worley of the Bureau of Land Management. We checked the BLM's master title plat and Mike confirmed that Cooper Island is under the "federal ownership" of the BLM, Dept of Interior. It is within the National Petroleum Reserve (NPR-A) withdrawal. Attached for your information is a copy of the BLM MTP. Additionally, Mike mentioned that the offshore area on the oceanside of the Island was owned by the State of Alaska and the inside area between Cooper Island and the mainland (known as Elson Lagoon) belongs to BLM.

Lizette - I'm looking into the current authorizations to see if we are okay for the upcoming work. If we are going to be doing any work on Cooper Island itself, we'll need some type of permit from BLM. I'll get with you tomorrow.

Linda

-----Original Message-----
From: Elconin, Andrea B POA02
Sent: Tuesday, July 20, 2004 4:09 PM
To: Arrington, Linda S POA02
Cc: Pontius, Karen L POA02
Subject: FW: Cooper Island

Linda, FYI.

-----Original Message-----
From: Trent, Sara POA02
Sent: Tuesday, July 20, 2004 04:07
To: Elconin, Andrea B POA02
Subject: RE: Cooper Island

Andrea

I do not believe I will be of much help until Real Estate determines whether Cooper Island is part of Canada rather than the U.S. Please give me call when you find out whether the allegations are true.

Sara

-----Original Message-----
From: Elconin, Andrea B POA02
Sent: Tuesday, July 20, 2004 8:26 AM
To: Arrington, Linda S POA02; Pontius, Karen L POA02; Trent, Sara POA02
Cc: Boyer, Lizette P POA02; Brooks, Forest C POA02; Curt Thomas (E-mail)
Subject: Cooper Island

Linda,

Please see the attached letter. It is from a group called State Department Watch, and it states that Cooper Island is part of Canada, not the U.S. (Cooper Island is a potential gravel source for the Barrow Coastal Storm Damage Reduction project).

After you have had a chance to review the issue, I'd like to have a brief meeting with you, Lizette and Sara to determine our course of action in terms of response to the letter. Let me know if you're available tomorrow.

Thanks,
Andrea

p.s. I know that Karen has looked into this once before and didn't think their claim was valid.

U.S. Department of Homeland Secu
Washington, DC 20229

**U.S. Customs and
Border Protection**

OCT 19 2004

Mr. Carl Olson
State Department Watch
1050 Connecticut Avenue, NW
P.O. Box 65398
Washington, DC 20035

Dear Mr. Olson:

Thank you for sending the Department of Homeland Security a copy of your letter of July 14, 2004, to Ms. Lizette Boyer of the U.S. Army Corps of Engineers. In your correspondence, you inquired about the appropriate regulations for importing gravel from Cooper Island to Barrow, Alaska. U.S. Customs and Border Protection (CBP) has recently completed its review of this matter. Please allow me to address your concern.

The CBP Web site, www.cbp.gov, provides a vast source of information concerning import requirements and links to regulations. The regulations concerning importation and the entry process are defined in 19 Code of Federal Regulations 142.1 to 142.29.

Merchandise imported into the United States valued over $2,000 requires the completion of a formal entry and payment of any applicable duties, taxes, and fees. A surety bond must also be posted for formal entries, with the bond liability generally equal to the value of the merchandise. The actual duty rate on the merchandise will depend on the classification in the Harmonized Tariff Schedule of the United States. Gravel is classified 2517.10.0015 and has a "Free" rate of duty.

Many importers hire Customs brokers to assist them with the clearance of international freight and the submission of the entry paperwork. Brokers charge a fee for their services but can greatly expedite the clearance of freight at the border. Listings of brokers can be found in the telephone directory of port cities or via the Internet.

I appreciate your interest in Customs and Border Protection. If we may offer further assistance, please call Mr. Richard Wallio, a member of my staff, at (202) 344-2556.

Sincerely,

Elizabeth G. Durant
Executive Director, Trade Compliance and Facilitation
Office of Field Operations

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, ALASKA
P.O. BOX 6898
ELMENDORF AFB, ALASKA 99506-0898

REPLY TO
ATTENTION OF:

OCT 26 2006

Environmental Resources Section

Ms. Judith Bittner
State Historic Preservation Officer
Office of History and Archaeology
550 West 7th Avenue, Suite 1310
Anchorage, AK 99501-3565

Dear Ms. Bittner:

The U.S. Army Corps of Engineers, Alaska District (Corps), is assessing several alternatives for erosion and flood control in and near Barrow, Alaska (Sections 14, 15, 21, and 22, T23N, R18S, USGS Barrow B-4; figure 1). The North Slope Borough has been actively managing storm damage and erosion problems for the last decade. The Corps is examining methods such as rock revetments, beach nourishment, and dikes to aid the community. The purpose of this letter is to seek your concurrence on several assessments of effect and to initiate consultation with your office on possible mitigation measures for aspects of the project that have the potential to effect historic properties eligible for and listed on the National Register of Historic Places.

Seasonal storms pose a threat to public and private infrastructure, particularly the delivery of basic utility services to Barrow's residents. The storms are also damaging archaeological sites (such as Utqiagvik) and threatening historic structures (such as the Point Barrow Whaling Station). The North Slope Borough has taken various flood and erosion control measures over the last two decades, such as beach nourishment using an offshore dredge, a variety of revetments, and earthen dams dividing the lagoon. In 1996, 1999, and 2000, the North Slope Borough used gravel and sand dredged from offshore to conduct beach nourishment at Barrow. Currently, the North Slope Borough has a beach nourishment program, which is primarily the creation of a berm from both bulldozed beach sand and borrow materials from upland areas. These efforts could be replaced by a more permanent structure.

There are two separate but overlapping problems that Barrow experiences: erosion (primarily of the bluff area) and storm driven flood damage. Although the details of the project alternatives have not been resolved, the Corps and North Slope Borough believe that the project will probably include a revetment along the bluff areas and a raised dike. The project would reach north of Browerville and south to the runway (figure 2).

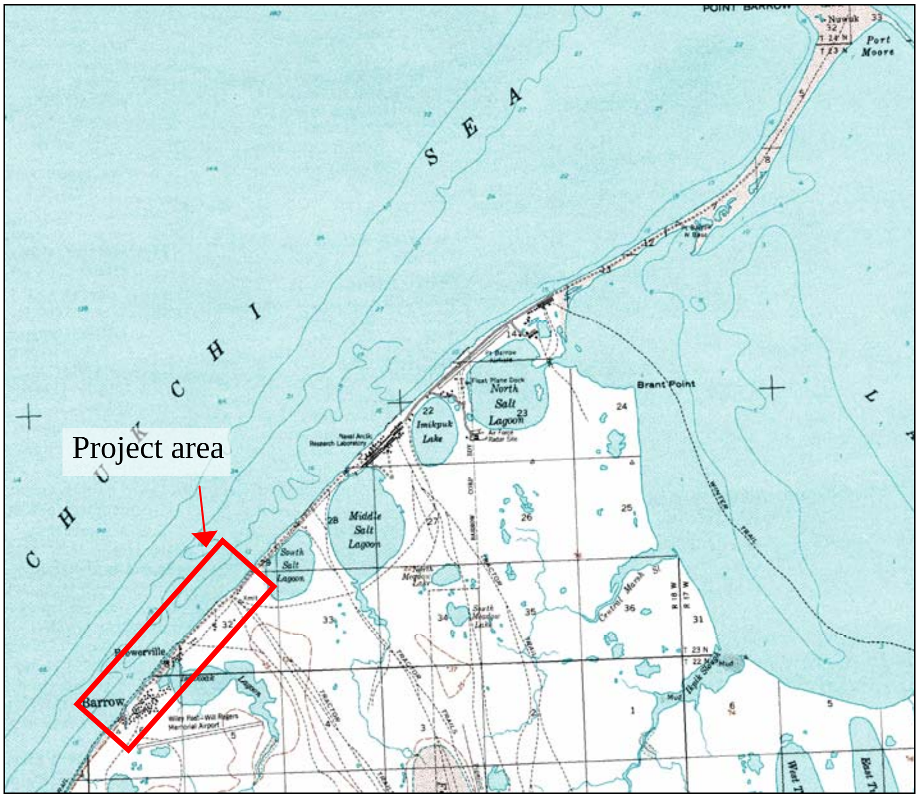

Figure 1. Project areas (red square; Barrow B-4 USGS Quad).

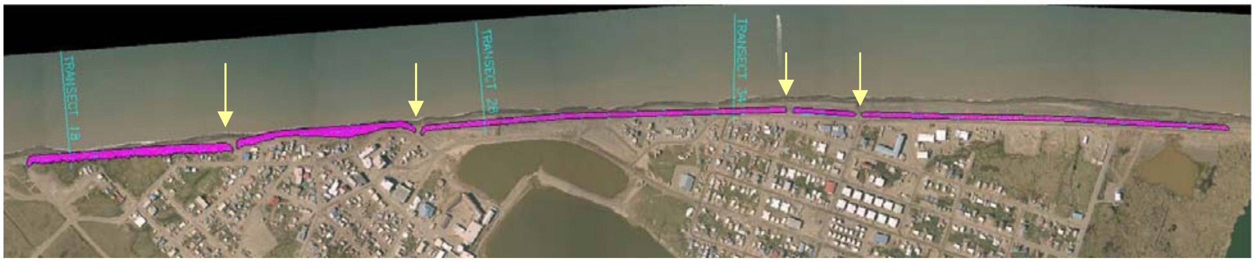

Figure 2. Project extents (pink). Yellow arrows indicate beach access points.

A revetment in the bluff area would probably consist of layers of rock, gravel, and filter fabric. A variety of cultural resources have been identified in the bluff area:

- **BAR-00002 Utqiagvik Village Site**
  Located in the center of Barrow, Utqiagvik has at least 61 semi-subterranean houses, burials, and miscellaneous features. In 1854 there were at least 200 people living at Utqiagvik. Murdoch (1988) was stationed near Utqiagvik from 1881 to 1883 and estimated that there were about 140 people living there (Murdoch 1988). The best known excavations at Utqiagvik are the excavations by the State University of New York, Binghamton, from 1981 to 1983. The work aimed to record, evaluate, and recover information from the site prior to construction of a natural gas distribution line. The preservation at the site was extraordinary, which allowed a level of analysis that was unusual (Dekin, et al. 1990). The site is known to still contain a great deal of well-preserved archaeological information about the pre-contact through contact

periods. Active erosion along the bluff, however, has been exposing and washing away portions of the site. Utqiagvik is eligible for the National Register of Historic Places.

- **BAR-00015 Sod House**
  A sod house built around 1880 represents the transition from sod to frame construction methods. The site is being evaluated by the North Slope Borough for eligibility.

- **BAR-00055, -00056, -00057, -00058 National Weather Service Buildings**
  (House 1, House 2, House 3, Recreation Hall/Storage)
  Based on information available to the Corps, the buildings were built in the late 1940s, moved to their present location in the 1950's, and minor changes were made in 1974. The National Weather Service, and later the National Oceanic and Atmospheric Administration, used the buildings for housing and office space. The buildings were determined not eligible for the National Register of Historic Places (Jensen 2006 personal communication).

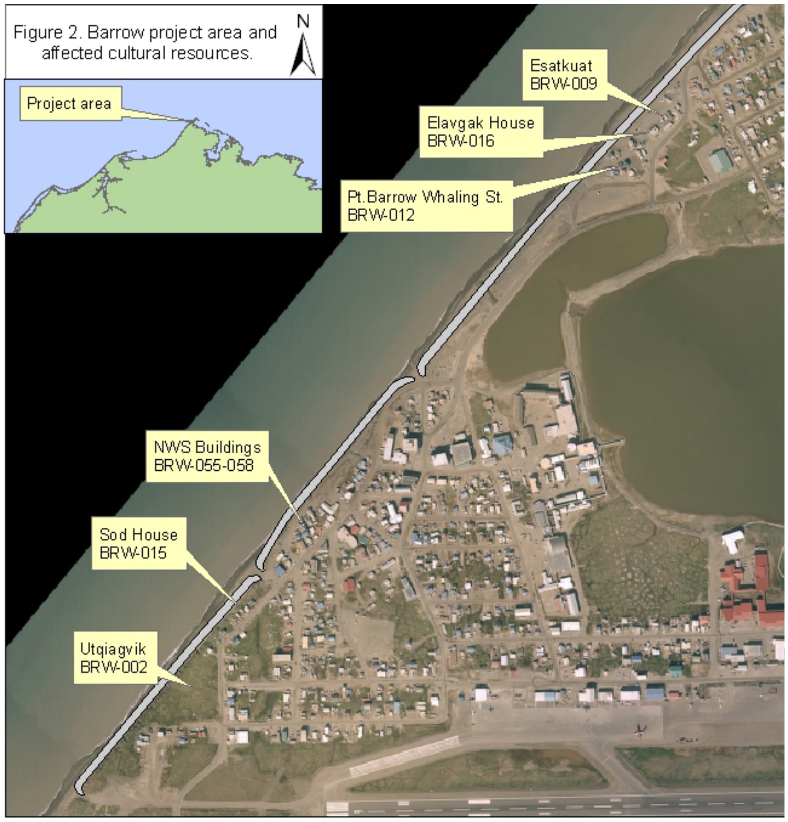

Figure 3. Cultural sites, historic properties, and project features (grey).

A raised dike would be built on the seaward side of Stevenson Street to provide increased protection to low-lying areas from flooding. The raised dike could also affect several cultural resources in the Browerville, Isatkoak Lagoon, and Middle Salt Lagoon area:

- **BAR-00007** Browerville
  The area northeast of Barrow was established when Charles D. Brower operated a whaling station beginning in 1886. He later established a trading post there. Browerville is in the process of being evaluated for the National Register of Historic Places by the Ukpeagvik Inupiat Corporation and the North Slope Borough.

- **BAR-00009** Isutkwa (Esatkuat)
  A pre-contact and contact period settlement. Murdoch reported a small camp at the site in 1892. BAR-00009 has not been evaluated for the National Register of Historic Places.

- **BAR-00012** Point Barrow Whaling Station
  The government built a refuge station here for commercial whalers in 1893. Charles D. Brower took over the station in 1897 and used it as a whaling station and trading post. It is the oldest frame building in the Arctic and is listed on the National Register of Historic Places.

- **BAR-00016** Dora Elavgak House
  The frame house was built in 1890 possibly from lumber left over from the construction of Brower’s trading post. The house is located in Browerville. The Dora Elavgak House has not been evaluated for the National Register of Historic Places.

Along the bluff at Utqiagvik, rock would be laid to a height of +16 feet MLLW (mean low lower water) over a core of “Hesco containers” (figure 4). The toe of the structure would be cut into the beach without disturbing the bluff face. A layer of gravel fill would be placed between the rock/Hesco system and the bluff then covered with “supersacks.”

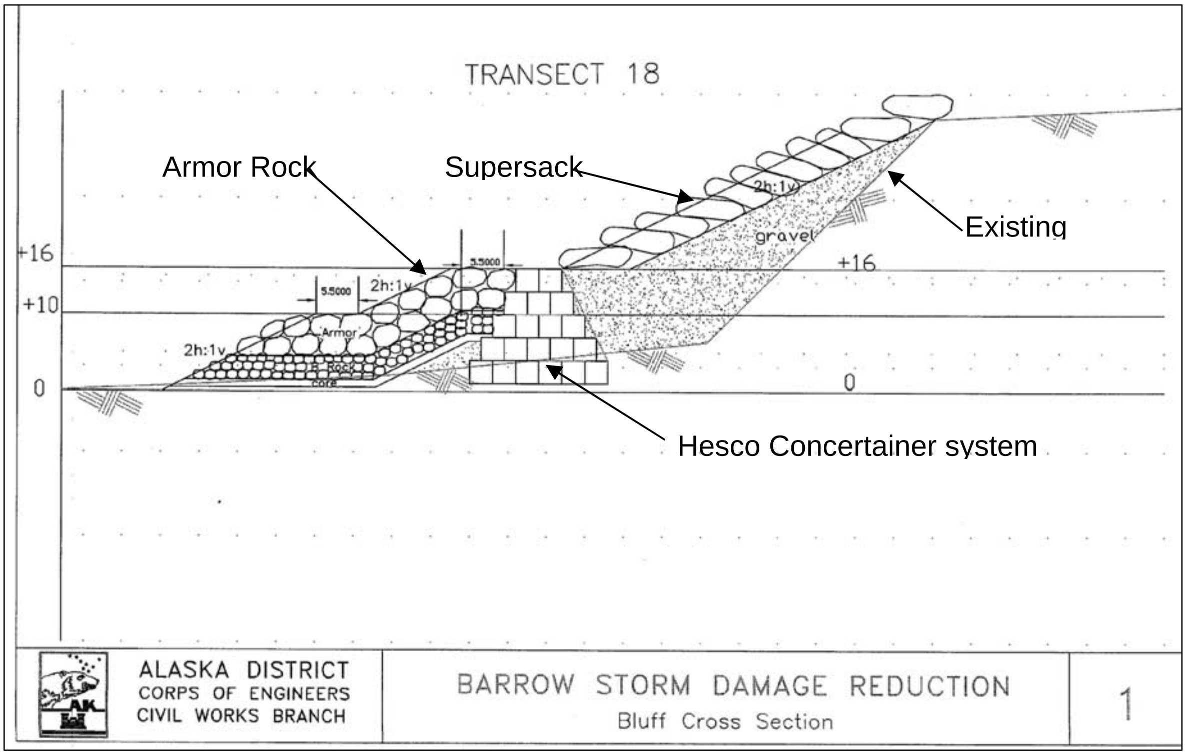

Figure 4. Cross section of bluff structure.

The dike would be similar in construction to the bluff revetment. Rock would be laid to a height of +16 feet MLLW over a core of "Hesco containers" (figure 5). The toe of the structure would be cut into the beach without disturbing the upland ground surface. Along many stretches, the structure would be visible and would block views and access to the ocean. Several access points were added to the project after consultation with various agencies and interest groups, as well as several public meetings.

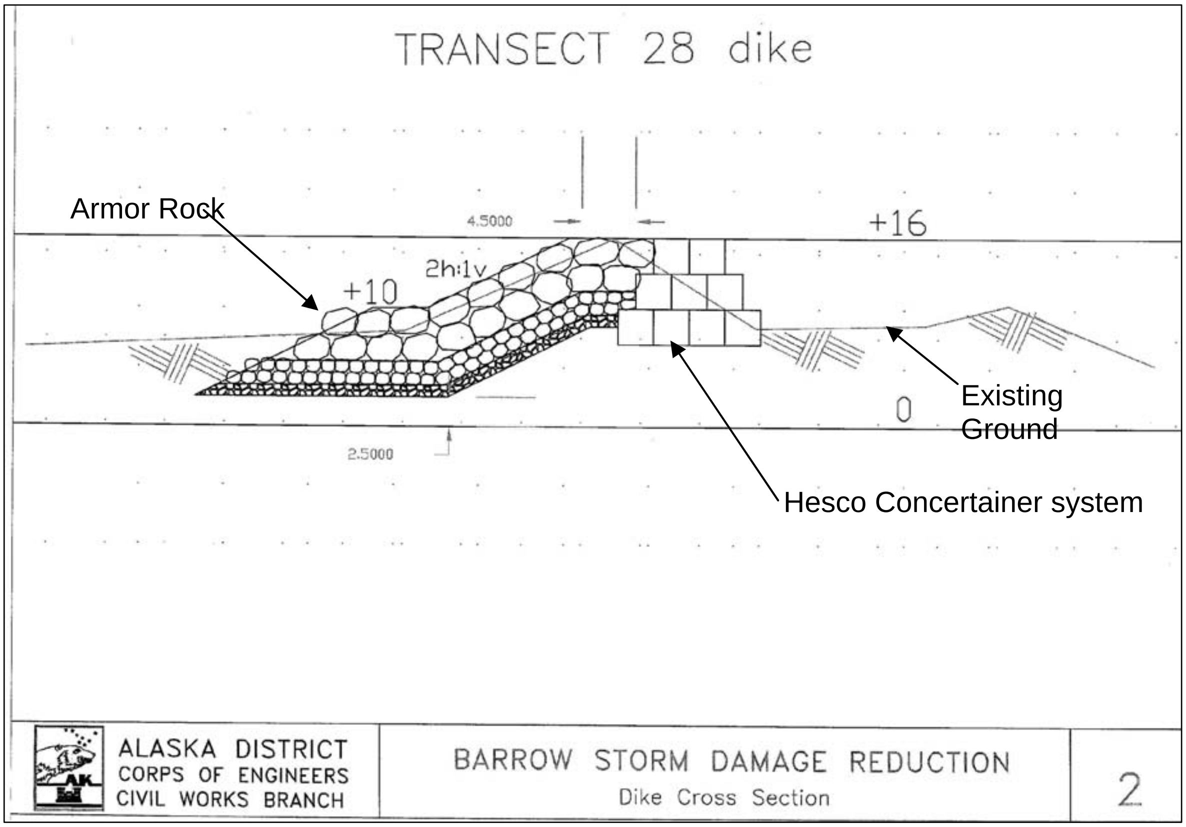

Figure 5. Cross section of dike structure.

Construction and maintenance material for a dike would require an estimated 200,000 cubic yards of material. In a January 19, 2006, letter the Corps indicated that one possible borrow site was the west shore of Point Barrow. After consultation with the City of Barrow, North Slope Borough, and Ukpeagvik Inupiat Corporation, the area was eliminated as a possible material source. The source of this material would likely be one of the existing gravel sources around Barrow. The rock source has not been selected and will be coordinated separately.

The rock revetment and dike would help protect structures and Utqiagvik (BRW-00002). Because the revetment and dike would be built along the beach and would not disturb the upland, there would be **no historic properties adversely affected** by this undertaking. The methods of construction have not been determined and the Corps recognizes that any disturbance of the uplands have the potential to affect historic properties. The Corps will continue consultation regarding these effects as they are developed.

We seek your concurrence on this determination of effect. Please send comments to Ms. Margan Grover at the above address, or via e-mail: margan.a.grover@poa02.usace.army.mil. If you have any questions about the project, please call Ms. Margan Grover at 907-753-5670.

Sincerely,

Guy R. McConnell
Chief, Environmental Resources Section

Cf:
Nathaniel Olemaun, Jr., Mayor, City of Barrow
Arnold Brower, Jr., President, Inupiat Community of the Arctic Slope
Edward S. Itta, Mayor, North Slope Borough
Tommy Olemaun, President, Native Village of Barrow Inupiat Traditional Government
Maggie Ahmaogak, Executive Director, Alaska Eskimo Whaling Commission
Max Ahgeak, President, Ukpeagvik Inupiat Corporation
Anne Jensen, Cultural Resource Management, Ukpeagvik Inupiat Corporation

DEPARTMENT OF DEFENSE

REPLY TO
ATTENTION OF:

DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, ALASKA
P.O. BOX 6898
ELMENDORF AFB, ALASKA 99506-0898

Environmental Resources Section

JUN 19 2007

Ms. Judith Bittner
State Historic Preservation Officer
Office of History and Archaeology
550 West 7th Avenue, Suite 1310
Anchorage, AK 99501-3565

Dear Ms. Bittner:

The U.S. Army Corps of Engineers, Alaska District (Corps), is assessing several alternatives for erosion and flood control in and near Barrow, Alaska (Sections 14, 15, 21, and 22, T23N, R18S, USGS Barrow B-4; figure 1). The North Slope Borough has been actively managing storm damage and erosion problems for the last decade. The Corps has determined that a combination raised dike and rock revetment could provide erosion and flood control for the community. The purpose of this letter is to seek your concurrence on several assessments of effect for aspects of the project that have the potential to effect historic properties eligible for and listed on the National Register of Historic Places. In an October 27, 2006, letter, the Corps notified your office of this undertaking and asked for your concurrence on an assessment of effect. Your November 30, 2006, reply asked the Corps to notify you when the project design was completed. The following undertaking has been selected as the preferred alternative, and we are now seeking your concurrence on the following assessments of effect.

Description of the undertaking

Seasonal storms pose a threat to public and private infrastructure, particularly the delivery of basic utility services to Barrow's residents. The storms are also damaging archaeological sites (such as Utqiagvik) and threatening historic structures (such as the Point Barrow Whaling Station). The North Slope Borough has taken various flood and erosion control measures over the last two decades, such as beach nourishment using an offshore dredge, a variety of revetments, and earthen dams dividing the lagoon. In 1996, 1999, and 2000, the North Slope Borough used gravel and sand dredged from offshore to conduct beach nourishment at Barrow. Currently, the North Slope Borough has a beach nourishment program, which is primarily the creation of a berm from both bulldozed beach sand and borrow materials from upland areas. The Corps and North Slope Borough are planning a rock revetment along the bluff areas and a raised dike along the lower beach areas. The project would reach north of Browerville and south to the runway (figure 2).

A revetment in the bluff area would probably consist of layers of rock, gravel, and filter fabric. Rock would be laid to a height of +20.5 feet MLLW (mean low lower water) over a core of smaller rock (figure 3). The toe of the structure would be cut into the beach without disturbing the bluff face. A layer of gravel fill would be placed between the rock and the bluff. The dike would be similar in construction to the bluff revetment. Rock would be laid to a height of +20.5 feet MLLW over a core of smaller rock (figure 4). The toe of the structure would be cut into the beach without disturbing the upland ground surface. Along many stretches, the structure would be visible and would block views and access to the ocean. Several access points were added to the project after consultation with various agencies and interest groups, as well as several public meetings. Construction and maintenance material for a dike would require an estimated 200,000 cubic yards of material. In a January 19, 2006, letter the Corps indicated that one possible borrow site was the west shore of Point Barrow. After consultation with the City of Barrow, North Slope Borough, and Ukpeagvik Inupiat Corporation, the area was eliminated as a possible material source. The source of this material would likely be one of the existing gravel sources around Barrow. The rock source has not been selected and will be coordinated separately.

Identified Cultural Resources in Area of Potential Effect

There is one historic property reported in the bluff area–BAR-00002 Utqiagvik Village Site. Utqiagvik has at least 61 semi-subterranean houses, burials, and miscellaneous features. In 1854 there were at least 200 people living at Utqiagvik. Murdoch (1988) was stationed near Utqiagvik from 1881 to 1883 and estimated that there were about 140 people living there (Murdoch 1988). The best known excavations at Utqiagvik are the excavations by the State University of New York, Binghamton, from 1981 to 1983. The work aimed to record, evaluate, and recover information from the site prior to construction of a natural gas distribution line. The preservation at the site was extraordinary, which allowed a level of analysis that was unusual (Dekin, et al. 1990). The site is known to still contain a great deal of well-preserved archaeological information about the pre-contact through contact periods. Active erosion along the bluff, however, has been exposing and washing away portions of the site. Ukpeagvik Inupiat Corporation has annually monitored the erosion of the site and conducted limited archaeological excavation of eroding features. Utqiagvik is eligible for the National Register of Historic Places.

A raised dike would be built on the seaward side of Stevenson Street to provide increased protection to low-lying areas from flooding. The raised dike could also affect several cultural resources in the Browerville, Isatkoak Lagoon, and Middle Salt Lagoon area:

- **BAR-00007** Browerville
  The area northeast of Barrow was established when Charles D. Brower operated a whaling station beginning in 1886. He later established a trading post there. Browerville is being evaluated for the National Register of Historic Places by the Ukpeagvik Inupiat Corporation and the North Slope Borough.

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  This is a pre-contact and contact period settlement. Murdoch reported a small camp at the site in 1892. BAR-00009 has not been evaluated for the National Register of Historic Places.

- **BAR-00012** Point Barrow Whaling Station
  The government built a refuge station here for commercial whalers in 1893. Charles D. Brower took over the station in 1897 and used it as a whaling station and trading post. It is the oldest frame building in the Arctic and is listed on the National Register of Historic Places.

Assessment of Effects

The rock revetment and dike would help protect structures and Utqiagvik Village Site (BRW-00002). During construction of the rock revetment, the Corps will ensure an archaeologist meeting the Secretary of the Interior's qualifications as an archaeologist (36 CFR Part 61, Appendix A(b)) is present to ensure effects to Utqiagvik Village Site are avoided. Because the revetment and dike would be built along the beach and would not disturb the upland, and provided an archaeological monitor is present during construction of the revetment, there would be **no historic properties adversely affected** by this undertaking. The methods of construction have not been determined and the Corps recognizes that any disturbance of the uplands have the potential to affect historic properties. We seek your concurrence on this assessment of effect. Please send comments to Ms. Margan Grover at the above address, or via e-mail: margan.a.grover@poa02.usace.army.mil. If you have any questions about the project, please call Ms. Margan Grover at 907-753-5670.

Sincerely,

Guy R. McConnell
Chief, Environmental Resources Section

Cf:
Nathaniel Olemaun, Jr., Mayor, City of Barrow
Arnold Brower, Jr., President, Inupiat Community of the Arctic Slope
Edward S. Itta, Mayor, North Slope Borough
Tommy Olemaun, President, Native Village of Barrow Inupiat Traditional Government
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Anne Jensen, Cultural Resource Management, Ukpeagvik Inupiat Corporation

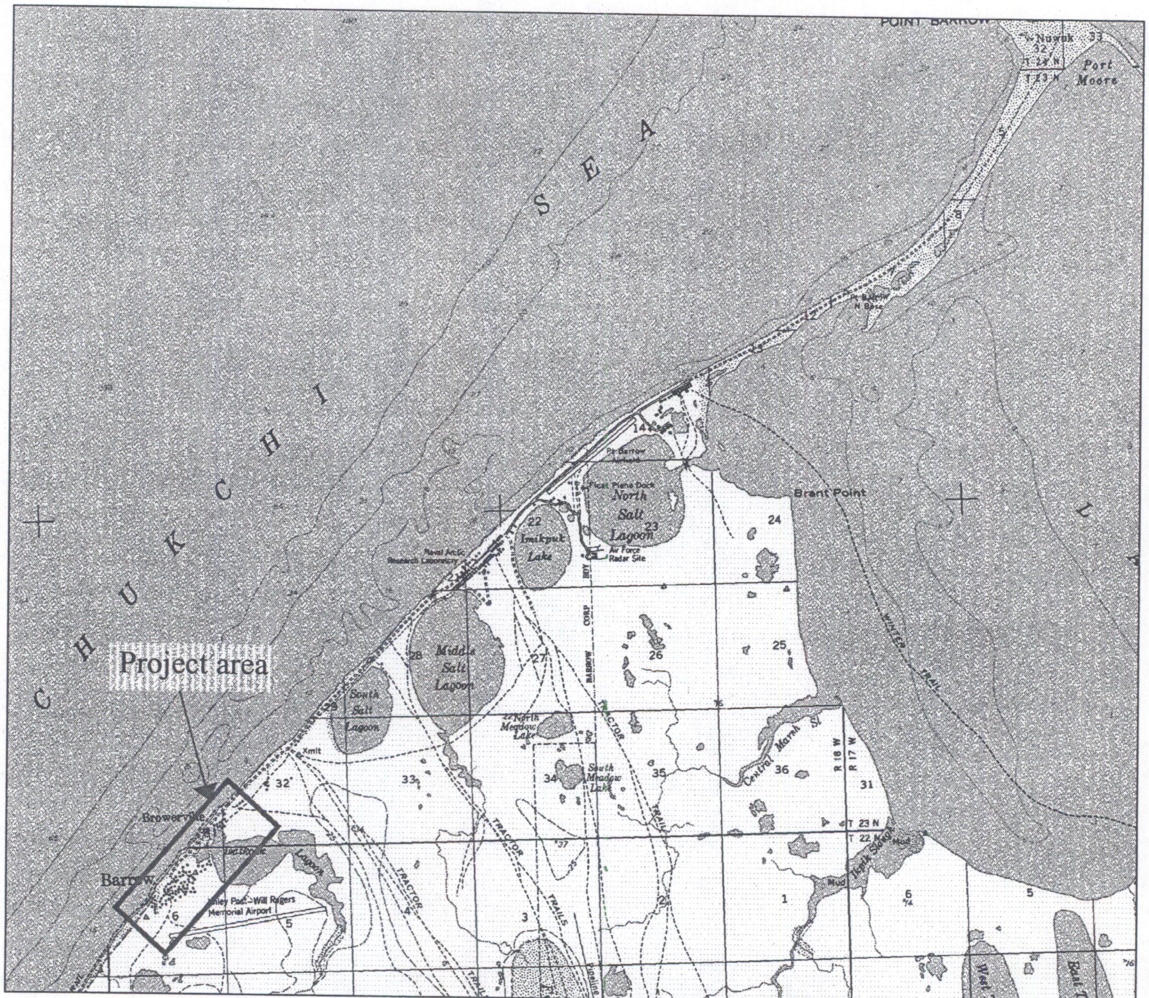

Figure 1. Project areas (red square; Barrow B-4 USGS Quad).

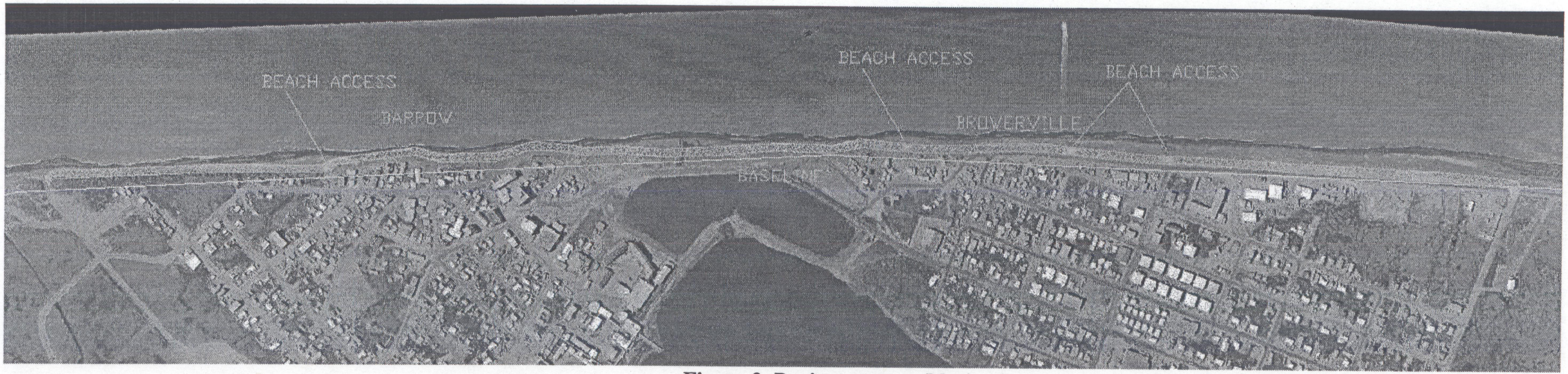

Figure 2. Project extents (blue).

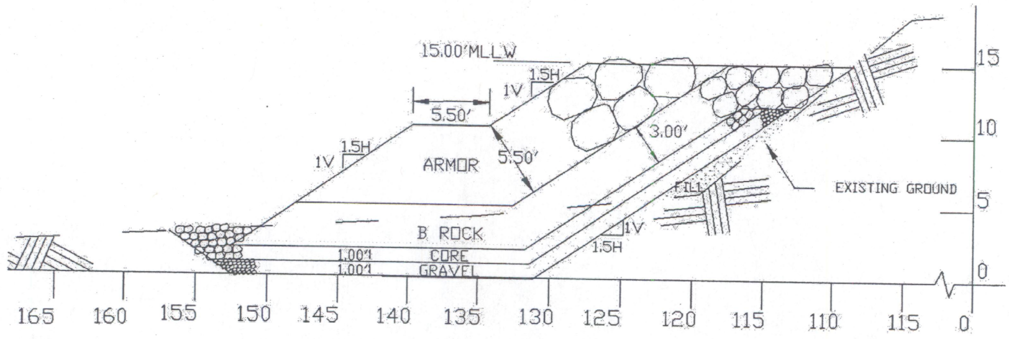

Figure 3. Cross section of bluff structure.

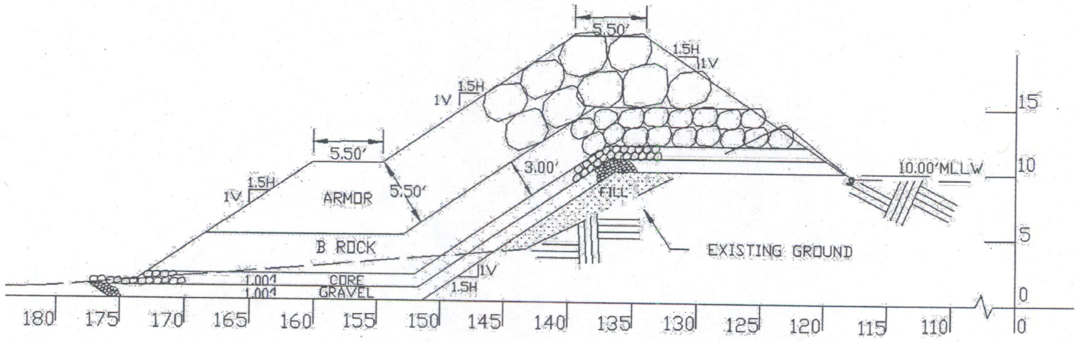

Figure 4. Cross section of dike structure.

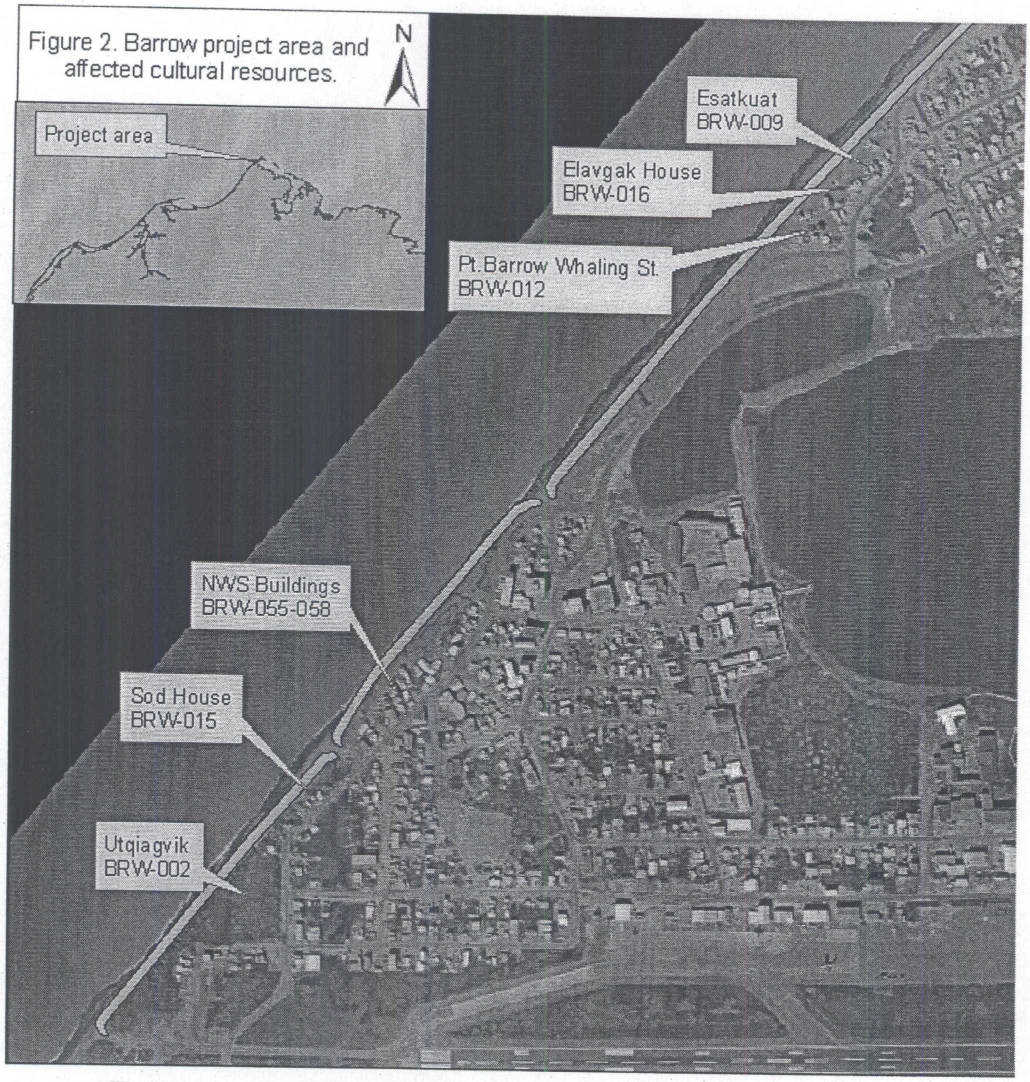

Figure 5. Cultural sites, historic properties, and project features (grey).

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, ALASKA
P.O. BOX 6898
ELMENDORF AFB, ALASKA 99506-0898

REPLY TO
ATTENTION OF:

Environmental Resources Section

AUG 0 7 2007

Ms. Judith Bittner
State Historic Preservation Officer
Office of History and Archaeology
550 West 7th Avenue, Suite 1310
Anchorage, AK 99501-3565

Dear Ms. Bittner:

The U.S. Army Corps of Engineers, Alaska District (Corps), is planning to construct erosion and flood control structures in and near Barrow, Alaska (Sections 14, 15, 21, and 22, T23N, R18S, USGS Barrow B-4; figure 1). In a June 19, 2007 letter, we stated that the undertaking would consist of a combination raised dike and rock revetment. We concluded that the proposed undertaking would help protect structures and Utqiagvik Village Site (BRW-00002 - a site eligible for the National Register of Historic Places) and would result in **no historic properties adversely affected,** provided an archaeologist meeting the Secretary of the Interior's qualifications as an archaeologist (36 CFR Part 61, Appendix A(b)) is present to ensure effects to Utqiagvik Village Site are avoided.

Because we have not received a letter from you since providing you with this assessment, we are proceeding with the assumption that you concur with our assessment per 36 CFR 800.5(c)(1). If you have any questions about this project, please contact Ms. Margan Grover at the above address, or via e-mail: margan.a.grover@poa02.usace.army.mil. If you have any questions about the project, please call Ms. Grover at 907-753-5670.

Sincerely,

7 Aug 07

Guy R. McConnell
Chief, Environmental Resources Section

Cf:
Nathaniel Olemaun, Jr., Mayor, City of Barrow
Arnold Brower, Jr., President, Inupiat Community of the Arctic Slope
Edward S. Itta, Mayor, North Slope Borough
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Max Ahgeak, President, Ukpeagvik Inupiat Corporation
Anne Jensen, Cultural Resource Management, Ukpeagvik Inupiat Corporation

CONCUR
Walters
Boyer

TYPED: Grover/ 07 August 2007/x5670
FILE: g:/en-cw/en-cw-er/Grover/Barrow/proceeding_SHPO_Barrow_SDR.doc

Honorable Nathaniel Olemaun, Jr.
Mayor, City of Barrow
PO Box 629
Barrow AK 99723

Mr. Arnold Brower, Jr.
President, Inupiat Community of the Arctic Slope
PO Box 934
Barrow AK 99723

Honorable Edward S. Itta
Mayor, North Slope Borough
PO Box 69
Barrow AK 99723

Mr. Tommy Olemaun
President, Native Village of Barrow Inupiat Traditional Government
PO Box 1130
Barrow AK 99723

Ms. Maggie Ahmaogak
Executive Director, Alaska Eskimo Whaling Commission
PO Box 570
Barrow AK 99723

Mr. Max Ahgeak
President, Ukpeagvik Inupiat Corporation
PO Box 890
Barrow AK 99723

Ms. Anne Jensen
Cultural Resource Management, Ukpeagvik Inupiat Corporation
PO Box 577
Barrow AK 99723

United States Department of the Interior

FISH AND WILDLIFE SERVICE
1011 E. Tudor Rd.
Anchorage, Alaska 99503-6199

IN REPLY REFER TO:

FWS/AFES

MAR 2 0 2007

Memorandum

To: District Commander – U.S. Army Corps of Engineers

From: Acting Regional Director – Region 7 Gary Edwards

Subject: Endangered Species Act Section 7 Compliance for Polar Bears

The U.S. Fish and Wildlife Service (Service) published a 12-month finding and proposed rule in the Federal Register on January 9, 2007, that found listing of the polar bear as threatened under the Endangered Species Act (Act) to be warranted. The Service did not propose designation of critical habitat. The Service is now in the process of receiving public comment on the proposed rule, and will publish a final listing decision by January 9, 2008.

We have received numerous inquiries regarding implementation of Section 7 (Interagency Cooperation) of the Act during the coming year, as well as more conjectural inquiries regarding the consultation process if the species is listed. The intent of this memorandum is to clarify our intended process during the proposal period, and to outline our intended approach to amend existing Section 7 consultations or initiate new consultations should the bear be listed.

Section 7 consultations are required only for actions authorized, funded or carried out by Federal agencies that may affect the continued existence of *listed* species or their designated critical habitat. The Service now consults with Federal agencies on these actions for several currently listed species whose range overlaps that of the polar bear, including Steller's and spectacled eiders. For proposed species, such as the polar bear, the Act requires action agencies to *conference* with the Service. Conference is a process of early interagency cooperation designed to identify potential conflicts between an action and species conservation, and to minimize or avoid adverse effects to proposed species or proposed critical habitat.

Several key distinctions between the consultation and conference processes are important to identify. First, the "trigger" for consultation and conference is different. While agencies are required to consult with the Service when their actions "may affect" the continued existence of listed species or critical habitat, action agencies are only required to confer with the Service for those actions "likely to jeopardize" the continued existence of the proposed species or result in the "destruction or adverse modification" of proposed critical habitat. For the purpose of this requirement, the term "jeopardize" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species. The Service's product at completion of the consultation process is a concurrence letter or a biological opinion, whereas the product of a conference is a conference report or conference opinion.

Both the consultation process and the conference process may involve either an informal or a formal phase, or sometimes both. The advantage of informal consultation or conference is that there may be more flexibility in project design early in the planning process, and therefore more opportunities to incorporate conservation measures. There are few mandatory timelines associated with the informal phase, whereas the formal phase has designated timelines.

Based on our experience to date with agency consultations in northern Alaska, including those related to oil and gas development, and given that Alaska comprises only a small portion of the circumpolar range inhabited by the species proposed for listing, we believe that conference will technically be required in few if any instances in the coming months. However, because the intent of the conference process is to provide a mechanism for identifying and resolving potential conflicts at an early planning stage, even if the expected impacts to the species do not reach the jeopardy standard, we strongly encourage action agencies to engage our staff at the Fairbanks Fish and Wildlife Field Office in informal discussions to identify, avoid, and minimize adverse effects on polar bears. These discussions can be undertaken and documented either electronically or in person. It is possible that our recommendations may be closely aligned with the mitigation steps identified in Section 18.128 of the Marine Mammal Incidental Take Regulations for the Beaufort Sea published in the Federal Register on August 2, 2006. We are currently in the process of developing similar incidental take regulations and associated mitigation actions for oil and gas development activities in the Chukchi Sea. We anticipate these regulations may be in place by late 2007. We will be happy to work with action agencies on projects not covered by existing incidental take regulations (non-oil and gas activities) to ensure that conference requirements are met.

Should a final rule be issued at a later date listing the polar bear under the Act, existing conferences could be converted to consultations with minimal effort by action agencies and the Service, assuming the project and its expected impacts remain unchanged. In this case, we would seek to minimize Service and action agency workload by conducting programmatic consultations when possible. We would also work with agencies to prioritize any conferences or consultations so that we work on the action agency's priorities first.

U.S. Army Corps
of Engineers
Alaska District

Barrow, Alaska

Coastal Storm Damage Reduction Technical Report

Appendix H – Affected Environment

December 2008

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APPENDIX H

AFFECTED ENVIRONMENT

This appendix provides information from the Affected Environment section of the draft environmental impact statement originally prepared for the Barrow Storm Damage Reduction project.

1.0 Community Setting and Regional Context

Barrow is the administrative, economic, educational, and transportation hub for the North Slope Borough. Eight communities are in the North Slope Borough: Anaktuvuk Pass, Atqasuk, Barrow, Kaktovik, Nuiqsut, Point Hope, Point Lay, and Wainwright. Slightly more than half of the borough's residents live in Barrow (4,199 in 2005). Barrow is the seat of the North Slope Borough's government, the regional center for health care and social services, and has an extension of the University of Alaska system – Ilisagvik College. Barrow also has a senior center, a teen center, a women's shelter, a family services center, and recreational facilities.

The City of Barrow operates *Piuraagvik*, a recreation center that offers affordable public access ($1 a day) to a gymnasium, weight room, a climbing wall, and other facilities. The center is home to the Barrow Basketball Association, the Barrow Volleyball Association, the Boys & Girls Club, and the Barrow Tae-Kwon Do Academy. The Barrow Hockey and Curling Club meets at *Tupiqpak* ("the Big Tent"), which is also used for flag football and track and field events. The City of Barrow's roller rink has a stage and sound system that is used by the community for performances, potlucks, dances, and parties. The Community Center, known for bingo and pulltabs, also has pool tables, darts, chess, and card games. The city's Recreation Department also maintains four playgrounds, two softball fields, the *Nalukataq* site in the spring (the lagoons between Barrow and Browerville), hiking trails, and boardwalks, as well as developing and maintaining cross-country ski trails (City of Barrow website).

1.1 Demographics and General Community Description

Table 1 shows the population of Barrow, the North Slope Borough, and other borough communities. In general, the population in Alaska over the last half-century has been growing. This also holds true for Barrow and other North Slope Borough communities, except in the last 5 years, when the population has generally decreased.

Table 1. Population.

	2005	2000	1990	1980	1970	1960	1950	1940
Barrow	**4,199**	**4,581**	**3,469**	**2,268**	**2,104**	**1,314**	**951**	**363**
NSB	**6,894**	**7,385**	**5,979**	**4,199**	**2,663**	**2,133**	**n/a**	**n/a**
Anaktuvuk	308	282	259	203	99	n/a	66	n/a
Atqasuk	247	228	216	107	n/a	n/a	n/a	78
Kaktovik	276	293	224	165	123	n/a	n/a	n/a
Nuiqsut	411	433	354	208	n/a	n/a	n/a	n/a
Point Hope	702	757	639	464	386	324	264	257
Point Lay	238	247	139	68	n/a	n/a	n/a	117
Wainwright	520	546	492	405	315	253	227	341

(Source 2000 U.S. Census and Alaska Department of Commerce, Community, and Economic Development)

Table 2 shows the racial characteristics of Barrow and the North Slope Borough. Overall, 78.2 percent of Barrow residents and 82.9 percent of North Slope Borough residents were non-White in the 2000 U.S. Census. A majority of Barrow residents are Alaska Native or American Indian, but the North Slope Borough has a somewhat higher proportion. As demonstrated in the table, few other minorities live outside Barrow (Asian Americans, Native Hawaiian or Pacific Islander, and Hispanic or Latino). About half the homes in Barrow are multi-lingual (primarily English and Inupiaq Eskimo). This is also true generally throughout the borough, although in some borough communities, a greater percentage of people speak only Inupiaq at home.

Table 2. Racial demographics.

	White	African Am.	Am. Indian / AK Native	Asian Am.	Native HI / Pacific Is.	Other race	2+ race	Hispanic / Latino
Barrow	1,000 (21.8%)	46 (1.0%)	2,620 (57.2%)	431 (9.4%)	62 (1.4%)	32 (0.7%)	390 (8.5%)	153 (3.3%)
NSB	1,262 (17.1%)	53 (0.7%)	5,050 (68.4%)	437 (5.9%)	62 (0.8%)	37 (0.5%)	484 (6.6%)	175 (2.4%)

(Source 2000 U.S. Census)

There are 2,623 students enrolled in North Slope Borough schools. Nearly two-thirds (1,592) are students in Barrow schools. A high percentage of adults in the North Slope Borough have received at least a high school diploma (77.4 percent), and 81.9 percent of Barrow adults have at least graduated from high school.

Three-quarters of the Barrow work force had jobs in 2000, and the unemployment rate was 9.4 percent. This is slightly better than the borough (61.3 percent employed and 10.8 percent unemployed). Throughout the North Slope Borough, government provides the most jobs for residents (61.5 percent), followed by private wage and salary jobs (36.1 percent). Barrow has similar types of employment (government 59.2 percent and private wage and salary 38.5 percent).

Generally, income and poverty rates are also similar between Barrow and the borough, although income is slightly higher and poverty somewhat lower in Barrow (table 3). The average household size in Barrow is 3.27 and the average family size is 3.9. Similarly, average household size in the borough is 3.45 and average family size is 4.05. There is a distinct difference between the number of housing units in Barrow with plumbing and telephones (11.1 percent and 3.7 percent, respectively) and the number in the borough (no plumbing 28.4 percent and no phone 9.0 percent.)

Table 3. Income and poverty.

	Median household income	Median family income	Per capita income	Individuals living below poverty level	Families living below poverty level
Barrow	$67,097	$68,203	$22,902	390 (8.6%)	73 (7.7%)
NSB	$63,173	$63,810	$20,540	663 (9.1%)	132 (8.6%)

(Source 2000 U.S. Census)

1.2 Socio/Cultural Environment

Several community festivals and celebrations center on subsistence activities and seasons. Most people are familiar with *Nalukataq,* "the Eskimo blanket toss celebration," celebrating a successful spring whale hunt. Whaling captains, their wives, and crewmembers prepare and serve food at a feast open to the community and visitors. Food includes Eskimo donuts, caribou, duck, muktak (whale skin with blubber), Eskimo ice cream (berries whipped in lard or shortening), fish, and fruit. There are also games for all ages. In recent years, the all day celebration was held several times because of the number of participants (City of Barrow 2005).

Not as well known is *Piuraagiaqta,* the annual spring festival. Usually, *Piuraagiaqta* is started with a parade and followed by winter games such as snow machine, sled, and foot races. The Fourth of July is also an important day of celebration in Barrow. Games for children are held during the day and for adults in the evening. There is also a native dress contest for the infants and women. Winners of the games are sent to the World Eskimo - Indian Olympics (WEIO) to represent the town in competitions based on traditional Native American and Native Alaskan games and competitions such as the seal hop, ear pull, two-foot high kick, and Indian stick pull. Around Christmas, Barrow hosts the *Qitik* Games, which is about a week of games similar to the Fourth of July Games. One festival held in Barrow about every 3 years is *Kivgiq*. During *Kivgiq* residents from other Alaska communities are invited. The celebration is hosted by the North Slope Borough mayor and there are a variety of feasts and Eskimo Dances where people may exchange gifts. Dance groups have come from as far away as Canada, Russia, and Greenland.

The beach is also used for recreation. People walk the beaches to look for shells, artifacts, and interesting flotsam. Most people in Barrow, both Inupiat and non-Inupiat, enjoy traveling and being "out on the land" during all seasons. People maintain camps along the coast within a few hours of Barrow, where they can meet family members and visit relatives.

1.2.1 Subsistence Activities

The term "subsistence" has been defined in federal, state, and local legislation, but it is also widely used and understood by the people of Alaska. This section discusses the legal definition of subsistence, the practice of subsistence, and its meaning as a social, economic, and cultural system.

Subsistence, in general, is thought of as hunting, fishing, and gathering for the purpose of acquiring food. The Alaska National Interest Land Conservation Act (ANILCA), which set aside millions of acres of national parks and wildlife refuges while seeking to acknowledge Alaska's cultural and traditional subsistence heritage, defines "subsistence uses" as (16 U.S.C. 3113):

> the customary and traditional uses by rural Alaska residents of wild, renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools, or transportation; for the making and selling of handicraft articles out of nonedible byproducts of fish and wildlife resources taken for personal or family consumption; for barter or sharing for personal or family consumption; and for customary trade. For the purposes of this section, the term --
> (1) "family" means all persons related by blood, marriage, or adoption, or any person living within the household on a permanent basis; and
> (2) "barter" means the exchange of fish or wildlife or their parts, taken for subsistence uses --
>
> > (a) for other fish or game or their parts; or
> > (b) for other food or for nonedible items other than money if the exchange is of a limited and noncommercial nature.

ANILCA also provides that motorized vehicles may be used on federal lands, in designated wildernesses, and other conservation system units for customary and traditional uses.

Until January 1989, Alaska statutes defined subsistence use as "non-commercial, customary and traditional uses of wild, renewable resources by a resident domiciled in a rural area of the state for personal or family consumption" (AS l6.05.940). In 1989, the Alaska Supreme Court found that the Alaska Constitution prohibited exclusive or special privilege for taking fish and wildlife resources (*McDowell vs. State of Alaska;* Case and Voluck 2002:295). As a result, federal agencies took over management of subsistence resources on federal lands. The other result of this ruling was that Alaska law could not establish a rural preference for subsistence. The Alaska Legislature has not been able to pass any subsistence legislation that clarifies whether a rural preference exists or not. At this time, the State of Alaska manages subsistence uses on state and private lands (including ANCSA Corporation lands) with no rural preference given. On federal public lands, the rural preference continues. In navigable waters, the State of Alaska manages the fisheries, unless they were reserved as part of a public land withdrawal or lands withdrawn before statehood (Case and Voluck 2002:301-302).

The North Slope Borough Municipal Code defines subsistence as:

> an activity performed in support of the basic beliefs and nutritional needs of the residents of the borough and includes hunting, whaling, fishing, trapping, camping, food gathering, and other traditional and cultural activities (North Slope Borough Municipal Code 19.20.020 (67)).

This definition takes into account activities and beliefs that fit the values placed on animals, activities, and understandings that are deeply held by Inupiat people (Langdon and Worl 1981). This is sometimes presented as "traditional ecological knowledge," or the cumulative body of knowledge and beliefs that is passed through generations by cultural transmission. In part, traditional ecological knowledge serves as a foundation for understanding the relationship of living beings with one another and the environment. Subsistence and traditional ecological knowledge are constructed from knowledge based in harvesting, processing, sharing, and trading. That knowledge and understanding results in a system of cultural, social, and spiritual values that are the central to Inupiaq cultures, and also forms the basis of those values and simultaneously reinforces them.

1.2.2 Barrow Subsistence Patterns

This section presents general information on what resources are harvested, when they are harvested, and methods for harvesting. Throughout Alaska's North Slope, both marine and terrestrial resources are harvested, including plants, animals, water, and ice. The primary areas of harvesting activity are near communities, high production areas, and along rivers and coastlines, although some of the most important harvest areas are used infrequently. Thus, over extended periods of time and among communities, there may appear to be a great deal of variation in what, when, and how a resource is harvested. This is because successful hunters know they must vary their approach to harvesting resources depending on environmental conditions, resource population size and migration patterns, and needs of their own family and community (Braund and ISER 1993; Department of the Interior 2003).

The peak of all subsistence activity is April to October (Braund and Moorehead 1995:259). Today, Barrow residents live in a mixed cash-subsistence economy, and many subsistence activities must be coordinated with the weekends, leave, and holidays. While full time employment provides cash income for snow machines, boats, fuel, and equipment, it also limits the amount of time individuals can invest in subsistence activities. The shorter days and difficult weather conditions from December to February limits the time people can safely spend pursuing subsistence activities, while the endless hours of daylight in the summer provide nearly limitless time to be active outdoors.

Figure 1 is referred to as the "seasonal round" of Barrow residents. This generally illustrates what resources residents are pursuing, how heavily the resource is focused on, and the time of year or season these harvest activities take place. For Barrow, it is also important to note events like break-up, freeze-up, and *Nalukataq* because they play an important role in subsistence activities.

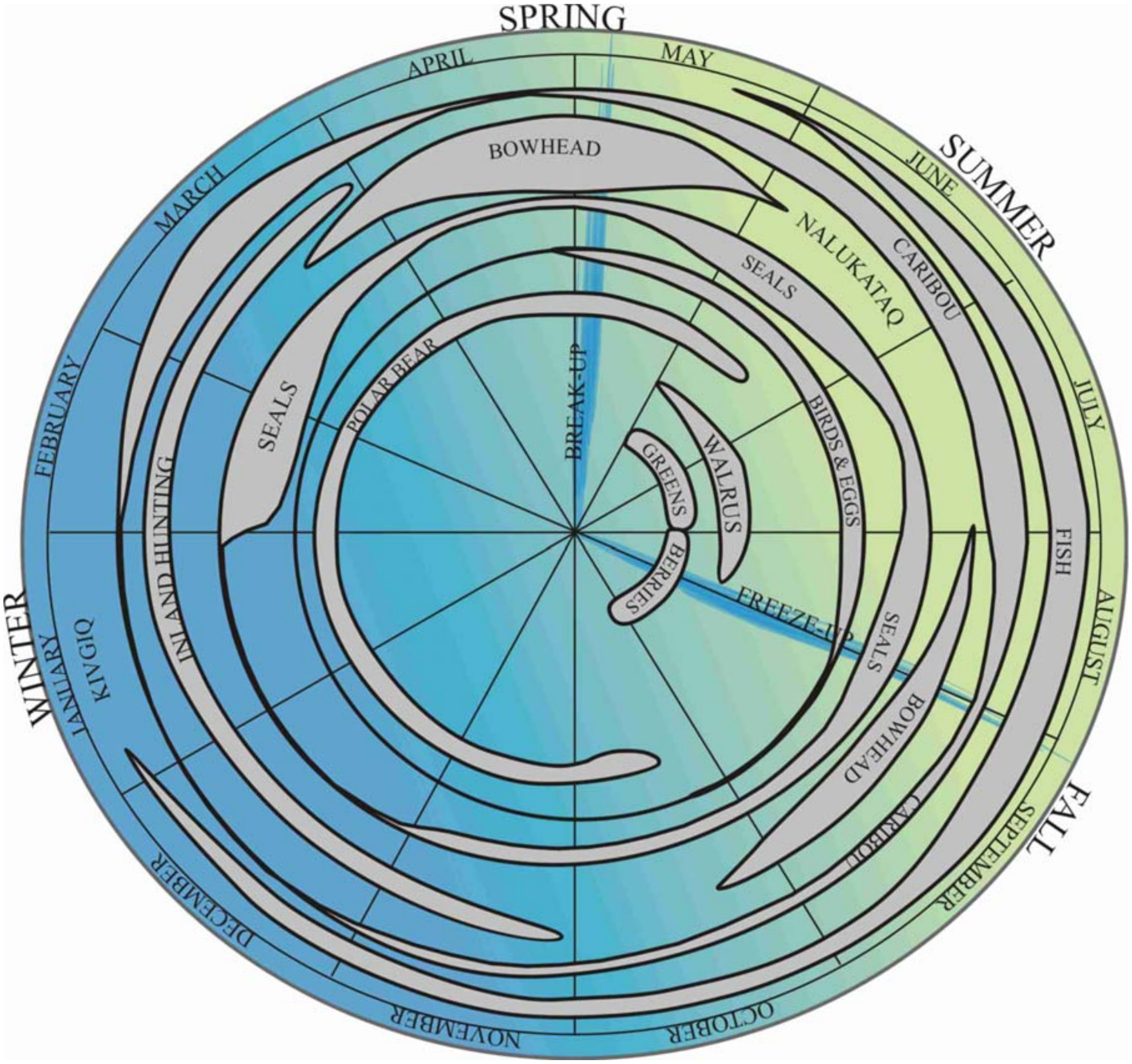

Figure 1. Generalized seasonal round of Barrow residents (compiled from Pedersen and NSB 1979; Braund and ISER 1993).

The most important factor in all subsistence activities is environmental conditions. Ice conditions, fog, and bad weather can affect marine mammal hunting. If the marine mammal hunting season is good or cut short, it can influence when residents travel inland for caribou hunting and fishing. Fall freeze-up can influence fall whaling as well as inland hunting and fishing. Snow cover and weather affect furbearer hunting and trapping. Break-up can influence access to inland goose hunting in the spring.

Barrow is well situated for many subsistence activities. The Chukchi and Beaufort seas meet in this area. As early as April, long stretches of open water may form as close as 10 miles from Point Barrow. Bowhead, walrus, seals, and waterfowl are attracted to these leads, making them relatively easy to access. Huge varieties of waterfowl are found near Barrow, both along the coast and into the interior. Throughout the summer and fall, fish can be found in most rivers. However, fish are also caught through the ice or along the ice edge in the summer and spring. Most hunting and trapping for fox, wolverine, and wolf is done away from the coast late in the winter. Caribou may be found within a relatively reasonable distance from Barrow all year (Braund and ISER 1993:6-9).

Between 1987 and 1990, Barrow residents harvested a minimum of 46 species of birds, fish, marine and terrestrial mammals, plants, invertebrates, and water (Braund and ISER 1993; DOI 2003). Caribou, bowhead whales, and fish have been identified as the preferred combination of resources harvested. While the most effort and a large quantity of resources are provided through harvesting caribou, bowhead is the preferred source of meat. The role of bowhead in the community and across the region as a shared resource of unique cultural and socioeconomic importance is well documented. Other species that are important include various fish, bearded seal, and birds. At a time in the 1970s when bowhead quotas were artificially low and the caribou herds were small, harvest levels of bearded seals, birds, and fish increased (Schneider, Pedersen, and Libbey 1980; Braund and ISER 1993; DOI 2003). Water and ice are also important resources. The harvest of vegetation, such as wood, berries, and greens, are much harder to quantify because most subsistence research to date has focused on marine, terrestrial, bird, and fish resources. However, some studies (e.g. Reimer 1999) clearly indicate that plant resources are an important resource, and harvesting them is an activity many individuals enjoy.

Most Barrow residents participate in some way in subsistence activities. According to recent studies, 87 percent of households participated generally in activities that resulted in successful harvesting of subsistence resources. During the same study period (1987-1990), approximately 77 percent of households successfully harvested terrestrial mammals, 76 percent successfully harvested marine mammals, 65 percent successfully harvested birds, and 60 percent successfully harvested fish. Factors such as time, resources, and funds invested and the type of harvest activity has some effect on the percent of Barrow households that successfully participate in the harvest of each resource type (Braund and ISER 1993; Pedersen, 1995a, 1995b; DOI 2003). Success is also affected by changes in species populations, seasonal migration, weather, and ice conditions. Finally, employment (or unemployment) can influence success rates, as cash is needed to buy equipment, fuel, and supplies, and workers may need to take time off from work to participate in subsistence activities. These factors must all be considered by families as part of the household subsistence strategy and harvest levels (Braund and ISER 1993:4)

> Successful harvests usually result from knowing where to intercept the resources as they migrate, and from being there at the right time. A few days delay in a hunting trip, adverse weather conditions, or equipment problems can mean missing the bulk of the migration and thus having a smaller harvest or missing out altogether. (Braund and ISER 1993:8)

Since 1977, the proportion of foods obtained from subsistence resources in Barrow has increased. Figure 2 illustrates that 13 percent of households used no subsistence resources in 1977, which decreased to 2 percent in 1998. Similarly, in 1977, 30 percent of household food was primarily from subsistence resources and by 1998 that proportion increased to 47 percent (North Slope Borough 1999; DOI 2003).

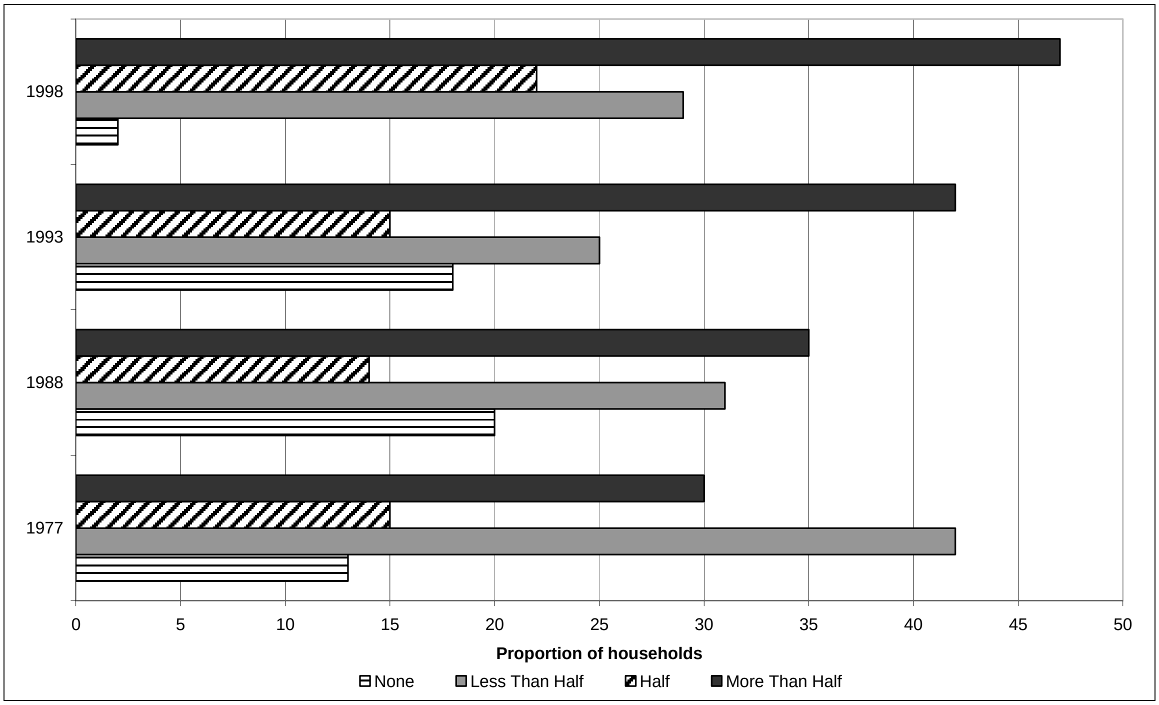

Figure 2. Proportion (in percent) of Inupiat household food obtained from subsistence activities (from North Slope Borough 1999 and DOI 2003).

Table 4 provides a summary of the edible pounds of all subsistence resources for Barrow. Between 1962 and 1982, Barrow residents harvested an average of 928,205 usable pounds a year of marine mammals, terrestrial mammals, birds, and fish, or 540 pounds per capita. Between 1980 and 1990, Barrow residents harvested an average of 702,660 usable pounds a year. The average household harvested 750 pounds a year or 233 pounds per capita a year. Throughout the past few generations, bowheads, caribou, walrus, and whitefish contributed the most to the Barrow subsistence harvest by weight. Residents have named 46 items harvested including animals, plants, water, and ice (Braund and Moorehead 1995:269-271). More detail about resources harvested and edible pounds per resource is provided in the following section.

Table 4. Edible pounds of all subsistence resources for Barrow.

Resource	1962-82	1980-90
Terrestrial mammals	27.0 %	30.2 %
Marine mammals	35.3 %	53.0 %
Birds and bird eggs	0.9 %	3.5 %
Fish	6.6 %	11.3 %
Total Harvest	928,205 (lbs)	702,660 (lbs)
Per capita Harvest	540.0 (lbs)	233.1 (lbs)

Source: Compiled from DOI 2003

Terrestrial Mammals. Barrow subsistence activities that focus on terrestrial mammals occur throughout the year, across the region, and take many forms. Table 5 provides a list of some species harvested by Barrow residents. More than three-quarters of Barrow residents participate in harvesting terrestrial mammals. As shown in table 6, most households participate in caribou hunting. Moose, Dall sheep, and Arctic fox also are important terrestrial mammals in terms of subsistence. Caribou, moose, and Dall sheep are the primary mammals consumed as subsistence foods. The remainder (e.g. foxes, wolverines, and wolves) are taken for their pelts (see table 7).

Table 5. Terrestrial mammals harvested by Barrow Residents (1987-1990)

Resource	Inupiat name	Scientific name
Arctic fox (Blue)	*Tigiganniaq*	*Alopex lagopus*
Red fox	*Kayuqtuq*	*Vulpes fulva*
Porcupine	*Qinagluk*	*Erethizon dorsatum*
Ground squirrel	*Siksrik*	*Spermophilus parryii*
Wolverine	*Qavvik*	*Gulo gulo*
Wolf	*Amaguk*	*Canis lupus*
Caribou	*Tuttu*	*Rangifer tarandus*
Moose	*Tuttuvak*	*Alces alces*
Brown bear	*Aklaq*	*Ursus arctos*
Dall sheep	*Imnaiq*	*Ovis dalli*

Source: Department of the Interior 2003

Table 6. Participation in Successful Harvests of Terrestrial Mammals by Percentage of Households (1987-1990)

Resource	Households
Caribou	77%
Moose	7%
Brown Bear	0%
Dall Sheep	3%
Wolverine	1%
Arctic Fox	5%
Red Fox	>0.1%

Sources: Braund and ISER 1993; Pedersen, 1995a, 1995b; Braund 1996.

Table 7. Proportion of Terrestrial Mammals in Edible Pounds of all Subsistence Resources

Resource	1962-82	1980-90
Caribou	58.2%	26.6%
Moose	0.3%	3.4%
Dall sheep	0.0%	0.1%
Small land mammals	0.1%	0.1%

Source: DOI 2003

Barrow residents may choose to hunt or trap small mammals, sometimes referred to as furbearers. Trap lines around Barrow extend far inland, but animals are also hunted using firearms. Ground squirrels are typically taken inland beginning in November, while fox, wolverine, and wolves are usually harvested beginning in February or March. Hunting and trapping small terrestrial mammals gained intensity in the late nineteenth century, as commercial fur trading and opportunities to participate in the cash economy increased. The Arctic fox comprises a majority of small mammals taken, but regional value is still placed on wolverine and wolf. Wolf and wolverine skins are used in ruffs and trim on parkas. The season for trapping and hunting small mammals is concurrent with mid-winter seal hunting, late winter caribou hunting, and winter fish resources (Braund and ISER 1993; NSB 1978). Because terrestrial mammals are taken primarily for their use in clothing or for commercial sale, they contribute very little to a household's edible subsistence quantities (less 0.1% per year between 1980 and 1990; DOI 2003).

Caribou are taken year-round near Barrow through a variety of means and across a broad area. Caribou may be harvested inland in late May and early June if they are encountered during geese hunting. Adult females are avoided because fawning is near. Caribou may be hunted using boats, ATVs, or snow machines. As families move to camp in June for hunting ptarmigan and fishing, they often take caribou as well. As summer reaches its peak in July, there is less focus on caribou, as they are considered too lean. Caribou move to the coast during cooler August weather to escape heat and bugs. Most are hunted using boats. In the fall caribou have good fat layers and thick coats. In addition to meat, caribou provide skins for clothing, and antlers and sinew for tools and traditional art (Braund and ISER 1993). Before the annual fall rut, hunters will take adult males and during the fall rut, hunters will focus on young animals. Late in the winter (e.g. December to February), many residents hunt near town using snow machines. As weather permits and depending on the movement of the caribou herd, hunters will travel farther inland using snow machines (Braund and ISER 1993). Between 1962 and 1982, caribou comprised 58.2 percent of the edible pounds of subsistence foods in Barrow. Between 1980 and 1990, that number dropped significantly to 26.6 percent (DOI 2003). This change is most likely related to regulatory limits on bowhead hunting. Several studies have indicated that if there is a great deal of whale available, then fewer caribou and fish are taken (NSB 1978).

Similar to other regions of Alaska, Barrow residents hunt moose in late August and early September. Moose populations have slowly been increasing along the Colville River in the last four decades. Ikpikpuk, Meade, and Chipp rivers are not uncommon drainages for hunters to harvest moose. Some residents charter planes and fly into Colville River and Umiat areas to hunt moose. More fortunate hunters encounter moose while boating into the interior for fishing or caribou hunting (Braund and ISER 1993; NSB 1978). Because moose populations are still generally low in the Barrow area and a considerable time and financial investment is needed to hunt them, moose comprised only about 3.4 percent of the edible pounds of all subsistence resources. Like moose, brown or grizzly bears are hunted opportunistically. During a 1987-1990 study, only two brown bears were harvested. They are typically found while hunting, fishing, or traveling in the interior and along river drainages (DOI 1993). The amount of edible meat contributed to Barrow diets from brown bear is negligible. North Slope hunters prize the meat of Dall sheep, but like moose, they are difficult and expensive to gain access to. Dall sheep comprised less than 0.1 percent of all edible pounds of subsistence resources (DOI 1993).

Marine Mammals. Marine mammals are an important resource for Barrow. Some species are available at various times throughout the year, while others (like bowhead and walrus) only migrate through the area during certain seasons. Table 8 is a list of some marine mammal species harvested by Barrow residents. More than three-quarters of Barrow residents participate in harvesting marine mammals. As shown in table 9, most households participate in bowhead whaling and hunting seals and walrus. Beluga whales are taken when they migrate through the area during favorable conditions. Polar bears are usually taken when they come near the community or people. All marine mammals provide not only subsistence foods, but also materials for clothing, boats, traditional art, and other goods. Table 10 illustrates the proportion contributed to Barrow residents' diets from marine mammal resources.

Table 8. Marine mammals harvested by Barrow residents (1987-1990)

Resource	Inupiat name	Scientific name
Walrus	*Aiviq*	*Odobenus rosmarus*
Beluga whale	*Quilalugaq*	*Delphinapterus leucas*
Bowhead whale	*Agviq*	*Balaena mysticetus*
Bearded seal	*Ugruk*	*Erignathus barbatus*
Ringed seal	*Natchiq*	*Phoca hispida*
Spotted seal	*Qasigiaq*	*Phoca largha*
Ribbon seal	*Qaigulik*	*Phoca fasciata*
Polar bear	*Nanuq*	*Ursus maritimus*

Source: DOI 2003

Table 9. Participation in Successful Harvests of Marine Mammals by Percentage of Households (1987-1990)

Resource	Households
Bowhead Whale	75%
Walrus	29%
Bearded Seal	46%
Ringed Seal	19%
Spotted Seal	1%
Polar Bear	7%

Sources: Braund and ISER 1993; Pedersen, 1995a, 1995b; Braund 1996.

Table 10. Proportion of Marine Mammals in Edible Pounds of all Subsistence Resources

Resource	1962-82	1980-90
Bowhead whale	21.3%	37.7%
Walrus	4.6%	9.0%
Bearded seal	4.3%	2.4%
Hair seal	4.3%	2.4%
Beluga whale	0.5%	0.0%
Polar bear	0.3%	1.5%

Source: DOI 2003

Between April and October, about 97 percent of marine mammal resources are obtained. May and October are peak marine mammal hunting months. This is in part due to bowhead whaling, which occurs in the spring and fall. July is also an important time of year because it is the peak month for walrus, bearded seal, and ringed seal harvests. All marine mammal subsistence activities are influenced by ice, weather, and migration patterns. Some species, particularly walrus and bearded seal, are harvested on the drifting pack ice in summer months, and as the ice disappears, harvest of these animals drops dramatically (Braund and ISER 1993).

The marine mammal hunting area for Barrow residents ranges from the Colville River west to Kugrua Bay (inside Peard Bay) and well into the Arctic Ocean. Over time, the traditional hunting range has increased, most likely due to technologies that allow hunters to travel farther, more safely, and more efficiently.

> …generally most of the seal harvests were concentrated (between 1987 and 1989) within 12 miles of shore, while walrus harvests occurred in a broad area extending from near shore to over 50 miles offshore. Walrus harvests occurred almost exclusively amid the floating pack ice, which tends to remain offshore; in contrast, seal harvests may occur not only amid the pack ice but also in the waters closer to shore. (Braund and ISER 1993)

Bowhead whale and polar bear are harvested generally in the same range as other marine mammals. Hunters will travel along the Chukchi Sea coast, off Point Barrow, as far west as Peard Bay, and as far east as Smith Bay (Braund and ISER 1993).

Marine mammal subsistence activities between June and October are conducted from boats on the open water. Between November and May, the pursuit of marine mammals takes place on the ice at open leads. Open water hunting allows participants to travel over a much broader area than hunting from leads, which typically form parallel to shore and offshore a few miles. As a result, most hunts along the ice edge and leads take place closer to shore than open water hunts (Braund and ISER 1993).

Almost all walrus harvesting is done in July and August, depending on movement of pack ice. Before Barrow residents can launch their boats, they must wait for the shorefast ice to be blown out to sea. Hunters may travel as far as 50 to 70 miles to find the proper combination of ice conditions and animals, thus these trips are often combined with seal or bird hunting. The ice must be close enough to shore, however, for hunting to be safe. Walrus hunting is usually done from open boats by a crew, among whom the meat and ivory are divided equally (Braund and ISER 1993). Twenty-nine percent of Barrow households participate in the walrus harvest, which made up approximately 9 percent of the subsistence diet in the period 1980 to 1990 (NSB 1978; Braund and ISER 1993; Pedersen, 1995a, 1995b; Braund 1996; DOI 2003). Between 1987 and 1990, Barrow residents harvested an average of 81 walrus, but some reports indicate as many as 200 walrus were harvested in past years (NSB 1978; DOI 2003).

Four species of seal are found near Barrow: bearded seal, ringed seal, harbor seal, and ribbon seal. Generally, seals are harvested any time during the year, provided the ice and weather conditions are suitable and the animals appear close to Barrow. Hunting usually occurs along the ice edge using boats. Thanksgiving is a popular weekend to hunt seals, but the pack ice must be close enough to shore for hunting to be safe and ice conditions must be suitable. Some seal harvesting takes place from late May to July on open water using a diverse strategy (Braund and ISER 1993; DOI 2003).

Bearded seal (commonly referred to as *ugruk*) are typically hunted in late spring and through the summer months. Bearded seals may also be harvested from boats along the ice edge. In addition to being a source of food and oil, bearded seal is used to make boat skins, equipment, clothing, and traditional art. Ringed seal is considered important as a traditional food. Barrow residents usually harvest ringed seals early in January and August (NSB 1978; Braund and ISER 1993; DOI 2003).

As many as half the households in Barrow participate in harvesting seals. Table 40 illustrates numbers of seals harvested between 1987 and 1990. Despite the large number of seals harvested, the proportion of the total subsistence diet during the same period is relatively small (see table 11). Meat is not the only commodity provided by seal; seal oil is an important and highly valued product that can be used as a preservative for other foods such as caribou meat, berries, and birds. Seal skins are used in clothing, boat covers, traditional art, and other items (NSB 1978; Sheehan 1995).

Table 11. Number of seals by species reported harvested by Barrow residents (1987-1990)

Resource	Year 1	Year 2	Year 3	Household participation
Bearded seal	236	179	109	46%
Ringed seal	466	388	378	19%
Spotted seal	2	4	4	1%

Source: DOI 2003

Most polar bears harvested by Barrow hunters are the result of incidental encounters. The meat is considered a delicacy and the hides are used in parka ruffs and trim, sleeping pads, or traditional art. Polar bears are usually harvested in late winter and early spring. Seven percent of Barrow households report participating in harvesting polar bears and between 1980 and 1990, polar bear contributed 1.5 percent in edible pounds of all subsistence resources (NSB 1978; Braund and ISER 1993; DOI 2003).

The subsistence pursuit of bowhead whales is of major importance to Barrow residents. Barrow is well-placed to participate in both spring and fall whaling (Braund and Moorehead 1995:258-259). Some whaling crews include members from other communities. Whale *muktuk*, or fat and whale meat, is shared among communities across Alaska and is highly valued. Traditionally, whaling is conducted by kinship-based crews using boats. Meat is distributed, and the entire community participates and shares in the activity. All aspects of whaling follow deeply held, understood, and shared traditions that fundamentally have not changed for generations. Whaling is the center of North Slope Inupiat values and activities, forms a common Inupiat heritage, culture, and way of life, and strengthens family and community ties (NSB 1998).

> The high degree of risk, the high level of community cooperation required, and the high volume of product combine to make bowhead whaling one of the most culturally significant activities in each of these whaling communities (Braund and Moorehead 1995:259)

In spring, bowhead whales migrate east and north along Alaska's western and northern coast. As they reach the Beaufort Sea, they move away from the coast. In fall, bowhead whales migrate west along the Beaufort Sea coast until they reach Point Barrow. At that point, they continue west far into the sea towards the Russian coast, then travel south through the Bering Strait. Therefore, the whales travel close to Barrow in both spring and fall, but environmental conditions require different methods for the two seasons. Spring whaling success depends on ice conditions, ice formations, ice movements, and the presence or absence of open leads (the ice has to support hunters, their camp and gear, and the whale). Fall whaling success can be affected by environmental conditions such as fall storms, high winds, and rough seas. These conditions can affect the crews' ability to pursue and land the whale (Braund and Moorehead 1995).

Since 1978, bowhead whaling has taken place under a quota system imposed by the International Whaling Commission (IWC) and implemented by the Alaska Eskimo Whaling Commission (AEWC). Each community is represented by a commissioner on the AEWC, which meets annually to divide the strike quota and transfer strikes from their own community to another. Alaska whaling communities are given a specific number of strikes per year, so fall whaling depends on the number of strikes left over from spring. Strikes may be transferred among communities and a spring whaling community may also transfer their unused strikes to a fall whaling community. In addition, if the spring whaling was unsatisfactory, there's more motivation to whale in the fall. In many years, crews could have landed more whales without the quota restrictions (Braund and Moorehead 1995).

In March, whaling crews begin preparing for the spring whaling season by gathering food and gear for their crews. The skin covers on *umiat* (open skin-on-frame boats) are checked and women may sew new covers or repair old ones. Women may also make new mukluks and parkas for the crews from skins prepared the previous year. Bearded seal skins are used for *umiak* covers and mukluks. Parka covers are made from white canvas and parkas usually have fur ruffs and trim. Caribou skins may be used for sleeping mats at whaling camps. Whaling captains may intensify their harvest of caribou and seals to provide food for their crews and for celebrations. Spring whaling usually occurs between April and June. Crews travel onto the ice, pulling their *umiat* and gear with snow machines. Camps are made on the edge of an open lead, which generally form as close as 3 to 4 miles west of Point Barrow and parallel to shore. When a crew pursues a whale, they push the *umiak* into the lead and paddle after the animal. Outboard motors are only used after a whale is stricken in order to tow it to the ice. The first bowhead harvested is distributed among all whaling crews, no matter who brought the whale in. Each whale harvested after is shared among crews who have camped on the ice and participated in the harvest, towing, or butchering of the whale. When a bowhead is landed, a call is made on the VHF radios and a few crewmembers from other crew are sent to help butcher and to claim their crew's portion. The day after a bowhead is landed, successful crews hold open houses at the captain's home where whale is served to all visitors. At the end of spring whaling in late June, Barrow celebrates *Nalukataq*, or the spring whaling festival. There is another intensification of harvesting caribou, seals, and other resources in preparation for *Nalukataq*. These festivities include the famous blanket-toss and many games and dances, but most important is the sharing of the whale *muktuk* and meat and other foods by whaling captains, their crews, and families through distribution with the rest of the community. Bowhead *muktuk* and meat is shared throughout the year at various other celebrations and festivals (NSB 1978; Braund and Moorehead 1995).

Fall bowhead whaling is influenced by several factors – favorable ice conditions and the success of the spring hunt. The whales typically reappear near Barrow in mid-August and hunting may continue into October. This activity takes place on open water and crews use motorized aluminum or fiberglass skiffs that hold fewer people. Crews don't usually set up a camp, instead they launch from the Barrow vicinity and may travel as far as 50 miles to find a whale, but will try to meet a whale close to Barrow. The whale is hauled back to Barrow and butchered on the beach. Fall whaling crews are less formally organized and there is more individual participation, rather than as part of a crew they have registered with. There are fewer fall whaling captains and fewer crews, primarily because it coincides with prime caribou hunting and fishing seasons (Braund and Moorehead 1995).

In 1994, there were 44 Barrow whaling captains registered with the Alaska Eskimo Whaling Commission. Between 1987 and 1990, at least three-quarters of Barrow households participated in bowhead whaling. During that period, an average of nine bowheads were landed in Barrow (figure 3), providing almost 38 percent of the subsistence diet (NSB 1978; Braund and ISER 1993; Braund and Moorehead 1995; DOI 2003).

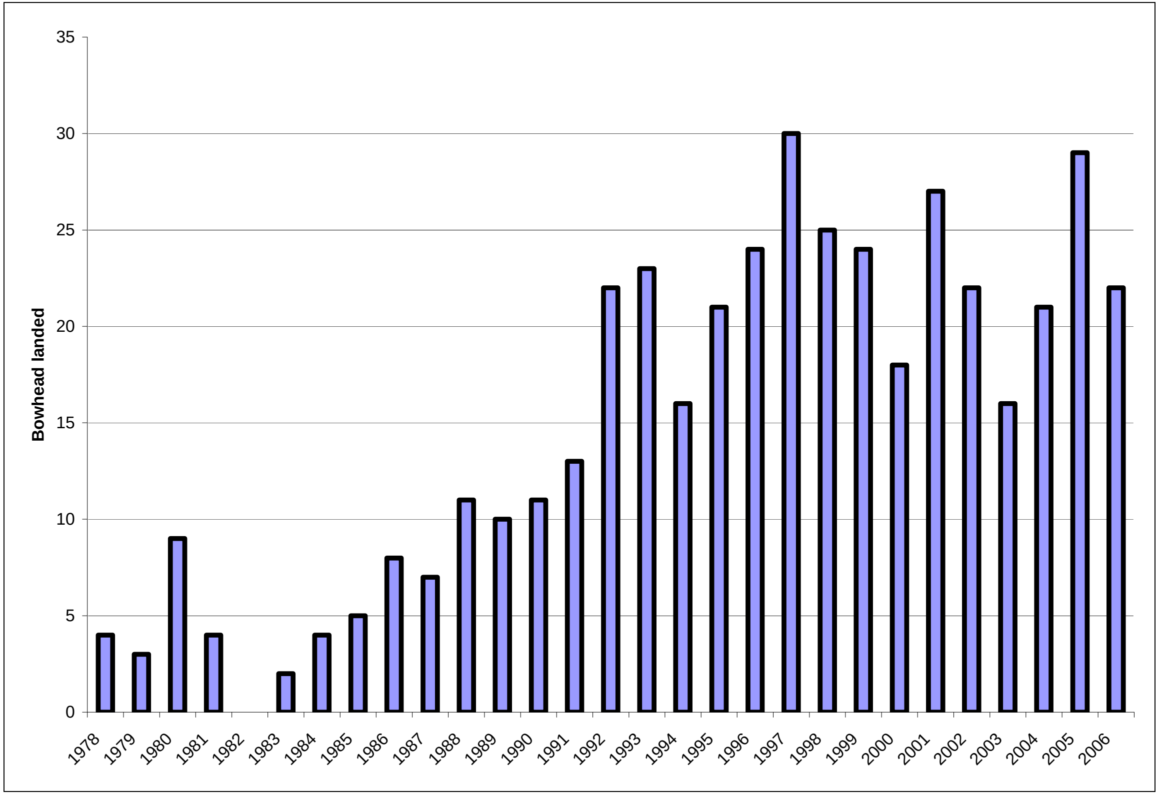

Figure 3. Bowhead landed by Barrow whaling crews 1978-2006 (from MMS 2006).

Beluga whales are occasionally harvested by Barrow residents. Although few beluga have been harvested in past years, it is considered an important and valued resource. Figure 33 illustrates some reported numbers of beluga harvests. Between 1967 and 1982, beluga comprised 0.5 percent of the average Barrow subsistence diet. According to one study this proportion dropped between 1980 and 1990 (see table 4). There is no data available on how many Barrow households participate in beluga harvest activities.

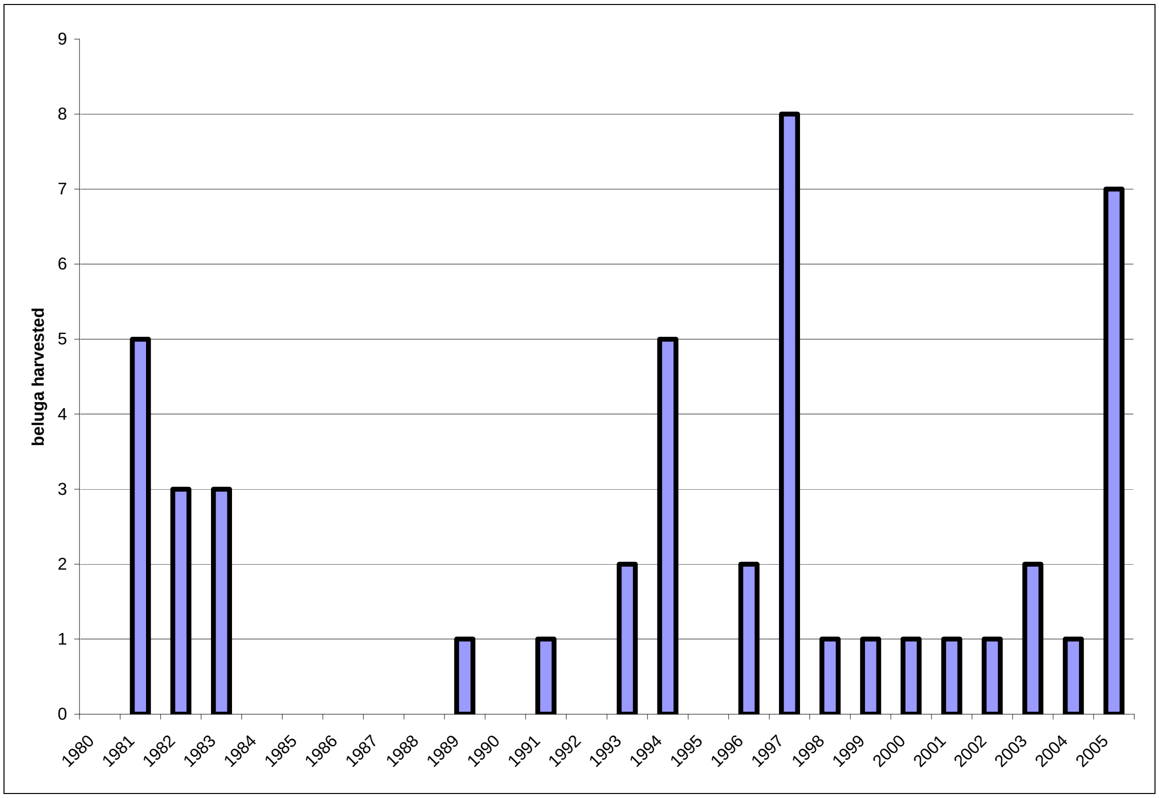

Figure 4. Beluga harvested by Barrow hunters 1980-2005 (from MMS 2006).

Other Marine Resources. The other marine resource that is occasionally harvested by Barrow residents is invertebrates. Collecting invertebrates is a subsistence activity usually paired with the pursuit of resources considered more important. Clams are the main marine resource in this category and are called *imaniq* in Inupiat. During a 1987-1990 study, harvesting clams was only reported in the third year of the study, after a fall storm washed “thousands of clams onto the beach.” (Braund and ISER 1993:192). Based on that study, clam harvesting activity seems to be primarily opportunistic, but enjoyed by many Barrow residents (Braund and ISER 1993; DOI 2003).

Birds. Many residents participate in harvesting birds and their eggs, which is an important subsistence activity, and residents harvest many species of birds (tables 12, 13, and 14). Most studies group birds harvested into five main categories: eggs, geese, eiders, ptarmigan, and other birds. Each category requires different strategies, and is affected by weather conditions, migration patterns, and regulatory limits. An annual average of 24,720 usable pounds (about 26 pounds per household) of the Barrow subsistence harvest comes from birds (Braund and ISER 1993).

Table 12. Birds harvested by Barrow residents (1987-1990)

Resource	Inupiat name	Scientific name
Other birds		
Red-throated loon	*Qaqsraupiagruk*	*Gavia stellata*
Other ducks (nonspecific)	*Qaugak*	
Long-tailed ducks	*Aaqhaaliq*	*Clangula hyemalis*
Surf scoter	*Aviluktuq*	*Melanitta perspicillata*
Eiders		
Common eider	*Amauligruaq*	*Somateria mollissima*
King eider	*Qinalik*	*Somateria spectabilis*
Spectacled eider	*Tuutalluk*	*Somateria fischeri*
Steller's eider	*Igniqauqtuq*	*Polysticta stelleri*
Eider eggs		
Geese		
Brant	*Niglingaq*	*Branta bernicla n.*
White-fronted goose	*Niglivialuk*	*Anser albifrons*
Snow goose	*Kanuq*	*Chen caerulescens*
Canada goose	*Iqsragutilik*	*Branta canadensis*
Ptarmigan (nonspecific)	*Aqargiq*	*Lagopus sp.*
Willow ptarmigan	*Nasaullik*	*Lagopus lagopus*
Bird eggs (nonspecific)	*Mannik*	

Source: DOI 2003

Table 13. Participation in Successful Harvests of Birds by Barrow Households (1987-1990)

Resource	Households
Geese	40%
Eiders	52%
Ptarmigan	26%
Other Birds	65%

Sources: Braund and ISER 1993; Pedersen, 1995a, b; Braund 1996.

Table 14. Proportion of Birds in Edible Pounds of all Subsistence Resources

Resource	1962-82	1980-90	1987-1990
Birds and bird eggs	0.9%	3.5%	
Geese			59%
Eiders			37%
Ptarmigan			4%
Other Birds			>0.1%

Source: DOI 2003

Birds are harvested from a vast area, but primarily along major rivers or along the coast west to Point Belcher and east to Cape Halkett. As leads appear in the sea ice in the spring, waterfowl begin to migrate into the region. Residents begin hunting geese in early or mid-May depending on how long whaling lasts and weather conditions. The majority of harvesting of birds takes place between April and September, with a concentration of activity taking place in May. After whaling, many residents focus more on harvesting these geese, eiders, and brant. By July, many families move to "duck camps" along the coast. Entire families move to duck camp and may spend the summer, while others may just go on weekends. The camps are used as a base for other activities as well, such as caribou hunting and fishing. Pigniq is well-liked among Barrow residents as a duck camp because its location allows residents to travel quickly back to Barrow for work or supplies. While it's possible to use snow machines in the spring, some hunting of geese and brant along lakes and rivers in the interior also takes place. After the snow melts, residents harvest geese and brant on interior lakes and rivers using boats or ATVs. This continues until the end of September. Ptarmigan are harvested year-round, although it is an activity commonly paired with harvesting other animals such as caribou. The eggs of waterfowl, coastal birds, and inland birds (e.g. ducks, gulls, terns, and ptarmigan) are collected in the summer (NSB 1978; Braund and ISER 1993; DOI 2003).

Vegetation. Not as much data has been compiled about harvesting vegetation as other resources for several reasons. This activity is typically coupled with hunting or fishing and it is perceived by agencies as less likely to be effected by development. Thus, harvest quantities and participation are probably under-reported (table 15). In addition, the crop of plants like berries and participation in harvesting them depends on environmental conditions such as precipitation and temperature. Residents in all age groups will spend hours picking berries and greens. Blueberries, cranberries, and salmonberries are harvested in late August and early September. The most popular areas for these species are inland near camps along the Meade and Inaru rivers and near Atqasuk. Greens such as rhubarb and chives are gathered more sporadically but in similar areas (Braund and ISER 1993; DOI 2003). Other non-edible items in this category that have not been quantified, but residents report harvesting are driftwood, willow, and sod (NSB 1978).

Table 15. Vegetation harvested by Barrow residents (1987-1990)

Resource	Inupiat name	Scientific name
Berries (nonspecific)		
Blueberry	*Asiaq*	*Vaccinium uliginosum*
Cranberry	*Kimminnaq*	*Vaccinium vitis-idaea*
Salmonberry	*Aqpik*	*Rubus spectabilis*
Greens/roots (nonspecific)		
Wild rhubarb	*Qunulliq*	*Oxyric digyna*
Wild chives	*Quagaq*	*Allium schoenoprasum*

Source: DOI 2003

2.0 Physical Setting

Barrow is at latitude 71°18'N, longitude 156°47'W, approximately 530 km north of the Arctic Circle and within the region of continuous permafrost. The Chukchi Sea of the Arctic Ocean borders the city to the northwest, and Point Barrow, the northernmost point in Alaska, is 16 km to the northeast.

2.1 Climate

Barrow has an arctic climate that is characterized by long cold winters, short cool summers, and persistent wind. The effects of the nearby Arctic Ocean cause summers to be generally cooler, windier, and moister than more inland locations.

Annual precipitation is light, averaging 5 inches. Annual snowfall is 20 inches. Temperatures range from -56 to 78 degrees Fahrenheit, with an average temperature of 40 degrees Fahrenheit during summer. The daily minimum temperature is below freezing 324 days of the year. Prevailing winds are easterly and average 12 mph. Mean annual temperature is 9 degrees Fahrenheit with January daily averages of –14 degrees Fahrenheit

More than 50 percent of the annual precipitation typically falls during the months of July, August, and September. Although most precipitation in July and August occurs as rain or fog, snow can occur during any month and is the predominant form of precipitation from September through June.

The University of Colorado produced a report, *Climatic and Environmental Conditions in Barrow 2005* and compiled the data summarized below. Barrow has experienced a warming trend over the last 80 years, but this warming trend is not uniform over the entire period. The information per decade shows that there is a trend of increasing temperatures and that these trends may be accelerating. These trends can have a significant impact on permafrost layers and sea ice extent, as well as observed rising sea levels. With this warming trend, it is estimated that the sea level will rise up to 18 cm by 2030 and up to 44 cm by 2070. Studies have shown that the minimum sea ice extent in the fall has declined 3.6 percent every decade since 1961, creating a longer “vulnerable” period in Barrow. The melt season has varied between 55 and 75 days between 1979 and 1996, and has lengthened at a rate of 5.3 days per decade during that time. Coastal wetlands and moist tundra regions are particularly vulnerable to climatic variation and extreme events. Many of these areas are unstable and easily or frequently changed by erosion and flooding. Erosion has been observed along the north slope of Alaska in large part due to seasonal storm surges.

The trend of increasing minimum, maximum, and average daily temperature in the years before 1990 has reversed in the last decade. However, the frequency of extremely cold days and persistence of cold snaps have both been decreasing. Snow cover onset has changed little. Snowmelt onset occurs almost a month earlier than 50 years ago. Annual ice concentrations have decreased by 3 percent to 9 percent for the Beaufort and Chukchi seas. Shorefast ice is forming later in the year. The total area of multiyear ice is decreasing. Ocean surface temperatures along the Chukchi Sea coast near Barrow have increased by about 2 percent over the period from 1982 to 2002, with a slight cooling near shore in January and February. High latitude coasts are susceptible to increases in global temperature through extended periods of ice thaw and reduced summer sea-ice extent, thereby creating greater wave exposure. The increased frequency of winter and early spring break-off events and shortened sea-ice seasons suggests that the coastal sea-ice system has been responding to some of the recent changes observed in the Arctic atmospheric and ocean data. The shorefast ice regime has become more dynamic (George 2004).

2.2 Ice Conditions

At Barrow, freeze up typically occurs in November, but the formation of stable shorefast ice may be delayed. Stability is achieved after one or more significant pack ice “shoves” deform and ground the ice. Grounding can take place as late as January, or not at all. Thin, ungrounded, maturing ice in the near-shore area is vulnerable. A strong offshore wind can tear away young ice all the way to the beach, leaving open water even when winter temperatures are low. In “cold years,” the ice tends to stabilize by November, but recently ice has been (more) unstable, with episodes of shorefast ice breaking off at the beach as late as January or February. Once grounded and stabilized, the shorefast ice cover remains in place until the start of breakup in late spring and early summer. The Chukchi Sea is typically ice-free from mid-June through October.

In late summer, beaches near Barrow show normal profiles fully shaped by waves. However, where sea ice is present, there are major changes from the typical, sloped beach of temperate regions. Point Barrow juts northward and is a major barrier to ice movement. As a result, the beaches near Barrow are subjected to the pushing action of ice more than most regions. There are several possibilities when ice moves on to a beach. The ice sheet may glide over the beach, gouging it much like a miniature glacier and pushing a small pile of debris ahead of it. After the ice melts, the striations show the passage of the ice and the ridge-like pile of debris marks the terminus of flow much like an end moraine. The ice, instead of gliding over the beach, may dig its leading edge into the beach and buckle up into piles of ice blocks as high as 30 feet. When this ice melts, it leaves depressions where it pushed into the beach, but any depression will be obliterated eventually by wave action. The ice, however, when it buckles may also push gravel ahead of it in a mound several feet high. Sometimes the ice carries additional sediment that was frozen to its base when in shallow water or washed or blown onto its surface. After melting, an ice-push mound is left on the beach until storm waves smooth it beyond recognition (Shalk 1973). The effect of sediment transport by ice was not considered in this feasibility study. Ice can serve as a limiting factor on the fetch over which waves are generated.

2.3 Tides

Barrow is in an area of semi-diurnal tides, with two high waters and two low waters each lunar day. Tidal parameters at Barrow are similar to those predicted for Point Barrow. The tidal parameters in table 16 were determined using a tide prediction program.

Table 16. Tidal Parameters – Point Barrow

Parameter	Elevation (ft MLLW)
Mean Higher High Water (MHHW)	0.50
Mean Sea Level (MSL)	0.25
Mean Lower Low Water (MLLW)	0.00

2.4 Wave Climate

The Barrow area has an extremely complex wave environment, dominated by local wind-sea conditions. Wave generation in the Chukchi and the Beaufort Seas has an impact on extremes at the project site. Storms that impact the project site are typically generated by rapidly moving weather systems that last between 24 and 48 hours. In September 1986, the largest storm on record came from the northwest and had waves 17 feet high with a period of 10.5 seconds.

2.5 Currents

Two measurement gages were deployed in 2003 and 2004 to acquire data on the near-shore waves, water levels, and local current climate, including vertical structure of the currents. Tidal fluctuation at the site is minimal, so the predominant source of currents is wind generation. According to model results, depth averaged currents during storm events range between 1 and 1.4 knots. These currents were generally maintained for 12 hours or less. On one occasion these currents were maintained for 24 hours. For the storm events modeled, the currents flowed predominantly to the northwest along the coast.

2.6 Sediment Movement

The SBEACH model was used to model onshore and offshore movement of beach sediments. The D_{50} sediment grain size was analyzed for 11 samples taken from the beach. The sediment size ranged from 0.3 and 20 mm with an average D_{50} of 3 mm. Model runs with SBEACH indicate that beach sediments generally do not move in the cross-shore direction. The threshold sediment size to get movement is 0.8 mm, which results in minor changes below the water level only. Significant net sediment transport is not occurring in the near-shore zone.

2.7 Erosion Rate Data

An analysis of erosion was performed using aerial photography from 1948[1] to 2003, by digitizing the shorelines and bluff lines. Location along the shore and bluff lines was identified by transect lines from a 1987 survey. The transect lines also define the reaches identified as follows:

Reach 1 – Gravel Pit to Barrow	Transects 9 to 18	5,000 lf
Reach 2 – Barrow	Transects 18 to 29	4,400 lf
Reach 3 – Isatquaq Lagoon	Transects 29 to 32	1,200 lf

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[1] The 1948 aerial photography was supplemented with the use of 1947 photography.

Reach 4 – Browerville	Transects 32 to 43	4,400 lf
Reach 5 – South Salt Lagoon	Transects 43 to 55	7,200 lf

Table17 lists average bluff and shoreline erosion/accretion rates based on the aerial photography analysis.

Table 17. Bluff and Shoreline Accretion (+)/Erosion(-)

Reach	Bluff[2] [ft/yr]	Shore [ft/yr]
1 - South of Gravel Pit		-1.04
2 - Barrow*	-1.08	-1.05
3 – Isatkoak Lagoon (Water Supply)	NA	-0.72
4 – Browerville	NA	+1.12
5 – South Salt Lagoon (Sewage/Landfill)	NA	-0.61
Maximum bluff erosion rate is 1.5 ft/yr and maximum shoreline erosion rate is 1.93 ft/yr.		

Beach mining in the late 1950's and early 1960's caused major shoreline erosion. Before this time the beach was fairly stable. In subsequent years, periods of accretion have occurred, but there is a predominance of erosion that leaves the bluffs in jeopardy.

2.8 Hydrogeologic Conditions

Most of the following discussion on hydrogeologic conditions in Barrow is from a U.S. Geological Survey report (USGS 1994).

The Barrow peninsula is the northernmost extremity of the Arctic Coastal Plain, which extends from the foothills of the Brooks Range in the south to the Arctic Ocean in the north. The area is characterized by low relief, numerous lakes, ponds, and drained thaw lake basins, and continuous permafrost. Permafrost is rock or soil that has remained continuously below 0 degrees C for 2 or more years. In the Barrow area, permafrost extends to depths of up to 300 meters. The layer above the permafrost that thaws each summer and refreezes each winter is referred to as the "active layer." The maximum depth of the active layer is typically less than 0.5 meter in areas where the vegetation and soil of the tundra surface are undisturbed. In areas that have been disturbed or are not vegetated, the seasonal thaw generally extends to 2 meters or less.

Beneath heated buildings, other artificial structures, and lakes that are more than approximately 2 meters in depth, a zone of permanently thawed ground is commonly present. Such zones, referred to as thaw bulbs or thermal taliks, may extend to considerable depths. For example, Brewer (1958) reported measurable warming of the permafrost at a depth of 15 meters beneath a 12-by-30-meter building near Barrow. Beneath Imikpuk Lake, a small freshwater lake (approximately 750 meters in diameter) located 8 km northeast of Barrow, the depth to permafrost is more than 50 meters. Although such aberrations in the permafrost are common, especially in developed areas where the ground surface has been disturbed, they are generally limited in aerial extent.

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[2] Bluff erosion was evaluated between Stations 18 and 21. Evaluation of stations west of 18 would be subject to interference from gravel pit activities. Aerial photography along the gravel pit was difficult to interpret, so the bluff lines are questionable. Bluffs dissipate beyond station 21.

The geology of the Arctic Coastal Plain is relatively well characterized, due in part to the extensive exploration for petroleum that has occurred in the region over the past several decades. As discussed in the later section on hydrology, surface water and shallow ground water in the region are generally isolated from deeper ground water by permafrost.

Bedrock in the region forms a broad, low-relief surface known as the North Beringian Marine Abrasion Platform. The uppermost bedrock unit in the Barrow area, which consists primarily of shale, is not exposed on the surface, but is commonly found in boreholes at depths ranging from 10 to 30 meters. The bedrock is overlain by unconsolidated marine, eolian, and lacustrine-lagoonal deposits of late Tertiary and Quaternary age. These deposits are a mixture of sand, silt, gravel, and clay, and shallow ground water in the Barrow area generally occurs entirely within the uppermost materials. In coastal areas, deposits include sand dunes and beach gravels.

2.8.1 Soils

Soils and Permafrost. The community of Barrow's near-shore zone borders the Chukchi Sea and the Beaufort Sea. Inland is a broad coastal plain with predominantly low-lying, wetland tundra, dotted by numerous thaw lakes. Elevations range from 0 to 60 feet above mean sea level within a 100-mile radius of Barrow. Thick, continuous permafrost underlies the entire region, overlain by a shallow active layer 1 to 3 feet thick, which thaws and freezes seasonally. Due to the shallow permafrost, peaty surface layer and flat terrain, soils are poorly drained. The active permafrost layer depth has increased until recent years. The relationship between thawing degree-days and average thaw depth has changed. The same surface energy input in the 1990's has produced around 70 percent of the thaw depth achieved in the 1960's. The thick organic content of these soils is due to the cold temperatures, which restrict biodegradation. Because organic material has a lower thermal conductivity than mineral soils, it serves to insulate the underlying permafrost. As a result, the permafrost table is typically within 1.6 feet of the surface in such soils. Thaw lakes begin as depressions in ground surfaces, which initiate pooling of standing water. Water begins to thaw the permafrost immediately beneath, which causes subsidence and in turn creates a larger depression, which collects more water. The majority of the lakes are not connected by perennial steams to the Chukchi Sea or Elson Lagoon. Most of these lakes are shallow and freeze to the bottom in winter. Use of shallow lakes is limited to ice-free periods in lakes with stream connections. Emmaikson Lake is a large lake near the Bureau of Indian Affairs gravel borrow source alternative. In the past, it served as the emergency water supply for the city of Barrow. However, it no longer serves that purpose because of the presence of lead shot in bottom sediments.

Soils in the Barrow area are classified as wet, loamy, histic pergelic cryaquepts (Rieger et al., 1979). These soils are included in the order Inceptisol and are generally characterized by thick accumulations of organic matter at the surface, persistent cold temperatures, shallow permafrost, and very high moisture content. The considerable organic content of these soils is due largely to the persistent cold temperatures, which restrict biodegradation and thus promote the accumulation of organic material from vegetation. Because organic material has a lower thermal conductivity than mineral soils, it serves to insulate the underlying permafrost. As a result, the permafrost table is typically within 0.5 meter of the surface in such soils, provided the surface has not been disturbed.

Physical churning of the soils above the permafrost results from cyclic freezing and thawing. Because of this churning, distinct soil layers are often absent, and organic material from plants at the surface is commonly distributed downward. Cyclic freezing of the soils also causes contraction cracks to form, fill with water, and refreeze. As this cycle repeats, the fissures grow. Extensive networks of interconnected cracks, referred to as patterned ground or ice-wedge polygons, are common in the Barrow area. A more detailed discussion of the formation of ice-wedge polygons is provided by Carter et al. (1987).

Soils throughout the area generally have a very fine-grained texture and are characterized by high porosity and low permeability. However, gravelly soils also occur in the area, particularly near the beach. The permeability of soil in the area thus spans several orders of magnitude. All soils, however, have a substantially reduced permeability to water once their temperature drops below freezing. As a result, hydraulic conductivities are extremely low for most of the year, and vertical movement of water is restricted year round by the presence of near-surface permafrost.

2.8.2 Environmental Susceptibility

The tundra environment in the Barrow area is much more susceptible to damage by human activity than environments typical of regions that are more temperate. Disturbances to Arctic tundra resulting from vehicle traffic or construction activities can cause long-term or even permanent changes that often result in damage to vegetation, compaction of the surface organic mat and underlying soils, or a combination of these. Vegetation and the surface organic mat help insulate underlying permafrost. If this insulating layer is damaged or destroyed, the thermal regime in the soil will be altered and the depth of seasonal thaw may increase substantially. Thawing of ice-rich permafrost may lead to considerable subsidence of the local land surface. In the flat terrain of the Barrow area, even small changes in land-surface elevation can have large effects on drainage patterns, and the formation of new lakes where surface disturbances have occurred is common. Once a lake has formed, the thermal regime of the underlying permafrost is further disturbed by heat from the water. Thawing of permafrost beneath the lake may thus occur, resulting in further subsidence of the lake bed and gradual expansion of the lake. This process is similar to the natural cycle of lake formation, expansion, and drainage–referred to as the thaw lake cycle–which occurs commonly on the Arctic Coastal Plain (Billings and Peterson, 1980; Edwards and Brigham-Grette, 1990; Harry and French, 1983; Kidd, 1988).

Lakes in the Barrow area are also highly susceptible to degradation. One reason for this susceptibility is the process of concentration by freezing. As the surface freezes, impurities in the water tend to be excluded from the ice and are thus concentrated in the remaining unfrozen water. Because of this phenomenon, water quality in lakes and lagoons generally decreases throughout the winter and spring as the ice cover grows and the volume of unfrozen water decreases: In lakes and lagoons that remain partially unfrozen year round, water quality is generally poorest just prior to the thaw season, when the volume of unfrozen water is smallest. Water quality problems in the Arctic are further exacerbated by the limited availability of water. Annual runoff on the Arctic Coastal Plain averages approximately 11.0 cm (Dingman et al. 1980) and a large part of this limited runoff occurs during the brief snowmelt period, typically no more than 2 weeks in duration. A considerable portion of this snowmelt runoff occurs while lakes and lagoons are still covered with ice. As a result, a portion of the annual inflow to surface-water bodies commonly flows over the ice cover and leaves through the outlet of the lake without mixing with the water beneath the ice. Dilution of the water remaining beneath the ice with fresh snowmelt water is thus reduced.

The arctic environment also has a limited capacity to attenuate contaminants in soil and active-layer water. Low soil temperatures restrict the activity of microorganisms and thus reduce rates of biodegradation. The presence of near-surface permafrost also decreases the ability of the environment to attenuate contamination by restricting the downward flow of water, thereby reducing the dilution of contaminants by dispersion.

The environment in the Barrow area is clearly sensitive to both physical disturbances and chemical contamination resulting from human activity. Potential damage to the environment from such activities is of particular interest to the community because the subsistence lifestyle of many residents makes them highly dependent on the environment for their livelihood.

2.8.3 Hydrology and Water Quality

Hydrology in the Barrow area is largely controlled by how close permafrost is to the surface and the great depths to which it extends. Permafrost is much less permeable than unfrozen ground and thus acts as a hydrologic confining layer, limiting the vertical movement of water. The presence of this shallow confining layer greatly impedes infiltration and, as a result, water remains at the surface or within the shallow subsurface. Permafrost isolates the near-surface flow system, including surface water and ground water within the active layer, from the deeper, regional flow system. Beneath the ocean and deep lakes, however, thermal taliks (thaw bulbs) may penetrate the entire thickness of the permafrost. Chemical taliks–subsurface zones that remain unfrozen because of the chemical composition of the water–also occur in the Barrow area as a result of saline ground water. High-salinity ground water is common throughout the region, particularly beneath the active layer. In some cases thermal or chemical taliks may form conduits between the active layer and deeper ground water. Flow through such conduits will be negligible, however, because salinity, and therefore density, generally increase with depth. Relatively fresh shallow ground water and deeper saline ground water tend to remain stratified.

In addition to the presence of permafrost, the limited relief of the tundra contributes to the unique hydrology of the Barrow area. This limited relief greatly impedes drainage and, as a result, lakes and ponds are ubiquitous, and few well-developed stream channels exist. The flat terrain also affects the configuration of drainage basins. Because even slight topographic highs often serve as drainage divides in this region, relatively small changes in the surface, such as soil cracks and the formation of ice-wedge polygon troughs, can breach these divides and significantly alter area drainage patterns. Snow drifts and plugging of streams, polygon troughs, or culverts by ice can also result in temporary changes in surface drainage patterns. Although such surface-drainage phenomena are more evident, formation of polygon troughs and differential thawing of the active layer may lead to analogous changes in subsurface drainage patterns and, hence, ground-water flow directions. Furthermore, as a result of the limited vertical thickness of the active layer, distinct ground-water flow regimes in this shallow system are likely to exist at scales ranging from centimeters to tens of meters rather than at more extensive, regional scales. For example, the depth of thaw within ice-wedge polygons may not extend below the level of the polygon troughs. In such cases, no really continuous ground-water flow system will exist, and ground water within each polygon will discharge into the adjacent polygon trough.

Sublimation, evaporation, and transpiration are also significant to hydrologic budgets of the Arctic Coastal Plain. Average annual recorded precipitation of less than 120 mm qualifies the Barrow area as a desert.

2.8.4 Transport of Contaminants by Surface and Ground Water

Because both streams and the active layer ground-water system in the Barrow area remain frozen for most of the year, transport of contaminants by flowing water would be restricted to the brief thaw season. Directions of surface transport could be highly variable as a result of changes in drainage patterns resulting from soil cracks, snow drifts, or the plugging of streams, polygon troughs, or culverts by ice. Directions of ground-water transport could also vary considerably as a result of ice-wedge polygon formation, differential thawing as the active layer develops throughout the summer, and the small scales at which distinct flow regimes exist in the shallow active layer flow system. These changes in directions of surface- and ground-water flow are likely to occur over the course of individual thaw seasons, as well as from year to year.

The large volume of runoff that occurs during the snowmelt period—up to 90 percent of the annual total—has important implications for environmental contamination. Because flowing water is a primary mechanism of contaminant transport, most of the annual migration of surface contaminants may occur during this brief period.

Storm surges may also transport contaminants. It is possible that a storm surge, within a period of hours, could transport contaminants over distances that would take several years, or even decades, under more typical conditions. Furthermore, storm-surge transport may occur in directions contrary to prevailing flow paths.

2.8.5 Drinking Water

Barrow’s water supply is Esatkuat Lagoon. Most freshwater lakes in the Barrow area are less than 2 meters deep and freeze to the bottom in winter. Esatkuat Creek and Nunavak Creek are the only substantial streams in the Barrow area. Esatkuat Creek drains approximately 3.7 km^2 and discharges into Esatkuat Lagoon. Nunavak Creek drains approximately 7.2 km^2, including Emaiksoun Lake 4 km south of Barrow, and discharges to Nunavak Bay, approximately 5 km southwest of the city. Flow in both streams is limited to the short thaw season.

Esatkuat Lagoon remains partially unfrozen year round. The lagoon is separated into sections by artificial berms, and the upper lagoon serves as the primary source of drinking water for Barrow. Water drawn from the lagoon is treated by filtration and distributed through a utilidor system to multiple watering points throughout the city. Approximately 97 percent of the housing units in Barrow are served by this distribution system.

Alternative Drinking-Water Sources. Few sources of drinking water are available in the Barrow area because stream flow ceases entirely during the winter, and only a small number of lakes, including Emaiksoun and Imikpuk lakes, remain partially unfrozen year round. Even these lakes, however, are not well suited as alternative drinking water sources for the city because they have limited volumes and relatively far from the city.

The Barrow area currently has no water wells, and development of wells as a source of drinking water is impractical because of permafrost. Shallow ground water within the active layer is not suitable as a source of drinking water for two reasons. First, this water remains frozen for most of the year and second, even during the period of maximum thaw, the volume of water available in this shallow system is not adequate to meet the needs of even a small part of Barrow. Some attempts have been made to explore the availability of deeper, sub-permafrost ground water, but in many places the permafrost extends too deep to allow economical development of wells. Sub-permafrost ground water is also generally too saline to serve as a source of drinking water. In a few places, such as beneath Esatkuat Lagoon, unfrozen ground water is present at relatively shallow depths, but it has a salt content approximately twice that of seawater and is unsuitable for drinking water.

2.9 Air Quality

North Slope air quality exceeds the standards set by the National Ambient Air Quality Standards and Alaska air quality laws and regulations. Concentrations of regulated air pollutants are far less than the maximum allowed levels. The Environmental Protection Agency calls this an attainment area because it meets the standards of the Clean Air Act. Limited industrial development, low population density, and strong meteorological influences combine to maintain good to excellent air quality in the Barrow area. No non-attainment areas exist in the region. Air pollution sources in the vicinity include automobiles, aircraft, fishing vessels, incinerating solid wastes, electrical power generating facilities, and dusty or unpaved roads. Despite the presence of air pollution point sources, air quality is generally considered to be good because of the predominant winds that occur in the area year round.

2.10 Biological Resources

2.10.1 Mammals

Marine Mammals. Point Barrow geographically separates the northeast Chukchi Sea from the west Beaufort Sea (figure 5), and most marine mammals found in the northeastern Chukchi Sea are also found in the western Beaufort Sea. Johnson et al. (1966) compiled a list of marine mammals that were reported to occur in the Chukchi Sea from literature available through 1966. The list is presented in Table 18.

Table 18. Marine Mammals Reported in the Chukchi Sea as of 1966

Whales and Porpoises	Seals and Walrus	Bears
Sei whale	Bearded seal	Polar bear
Minke whale	Ringed seal	
Humpback whale	Ribbon seal	
Bowhead whale	Spotted seal	
Finback whale	Fur seal	
Gray whale	Pacific walrus	
Beluga whale		
Orca whale		
Harbor porpoise		
Narwhal		

Source: Johnson et al. (1966).

Many of the marine mammal occurrences that formed the basis of the 1966 list compiled by Johnson et al. dated back to earlier reports by Scammon (1874) and Tomilin (1957). More recently available literature indicates that some of the species listed by Johnson are no longer reported to occur in the Chukchi Sea, and especially in the eastern Chukchi Sea, and occurrences of these species in the eastern Chukchi Sea would be rare. Examples of these include the following:

- Sei whales are not recently reported north of the Aleutian Islands (ADFG, et al. 1996)
- Humpback whales are not reported north of the Bering Straits (Ferrero et al. 2000).
- Fin whales are now known to occur in the western Chukchi Sea, but not in the eastern Chukchi Sea (Ferrero et al. 2000).
- The modern range of the northern right whale is believed to be the Bering Sea and North Pacific Ocean (ADF&G et al.1996, CBD 2000, Ferrero et al. 2000).
- Fur seal: Fur seals migrate from southern latitudes to the Pribilof Islands in the Bering Sea where about 75 percent of the world’s population form large breeding colonies. Fur seals are not common north of Bering Strait.

Some species listed by Johnson, et al. (1966) are known to be occasional migrants through the eastern Chukchi Sea to Point Barrow. Orca (killer) whales are an example. In the Chukchi Sea killer whales are likely the “transient” variety that feed on other marine mammals and are occasionally reported to harass beluga whales during the open water season. Gray whales are found in the eastern Chukchi Sea, but are only occasionally found east of Point Barrow.

Fur seals were unknown along the eastern Chukchi coast until the 1960's when three animals were harvested near Point Hope, and the eastern Chukchi Sea is considered to be well outside their normal range. Harbor porpoise and spotted seal are occasionally seen in the Point Barrow area during the summer months. Narwhals are relatively common in eastern Canadian and western Siberian Arctic regions, but are rarely seen in the Beaufort Sea as far west as Point Barrow.

Marine mammals that do not or rarely occur near Point Barrow are not discussed further. These marine mammals include the sei whale, humpback whale, fin whale, right whale, orca whale, narwhal whale, ribbon seal, and fur seal.

Marine mammals discussed in more detail in this section are those that are more likely to be at least occasionally seen at Barrow and that might be directly affected by project activity. These species include the bearded seal, ringed seal, spotted seal, Pacific walrus, beluga whale, bowhead whale, gray whale, harbor porpoise, and polar bear.

Bearded Seal

Distribution. Bearded seals are circumpolar in distribution. They are represented by two subspecies, *Erignathus barbatus barbatus* and *E. barbatus nauticus*. Bearded seals in the eastern Chukchi Sea and western Beaufort Sea are members of the subspecies *E. barbatus nauticus,* which ranges from about 80° to 85° north to within about 400 miles from the pole, and south through the Bering and Okhotsk seas to Hokkaido, Japan (SCS 2000a). Although the Alaska population of bearded seal has not been reliably estimated (Hill and DeMaster 1999), worldwide numbers during the 1970's and 1980's were estimated at approximately 600,000 with *E. barbatus nauticus* ranging from about 250,000 to 300,000 (SCS 2000a).

Bearded seals generally migrate north and south with the advancing and retreating edge of polar ice (figure 5). The typical wintering range is along the ice edge in the Bering Sea and along leads and polynyas in the Chukchi Sea. Most bearded seals near Point Barrow arrive with the retreating ice in spring and early summer. They follow the retreating ice north of Point Barrow during mid-summer and return as the ice advances in late fall. Some juvenile bearded seals can be found in the Point Barrow area during the open water season. The local density of bearded seals typically changes with ice conditions. Bearded seals are more often found in broken ice with open leads and show a pattern of increasing abundance as the spring progresses.

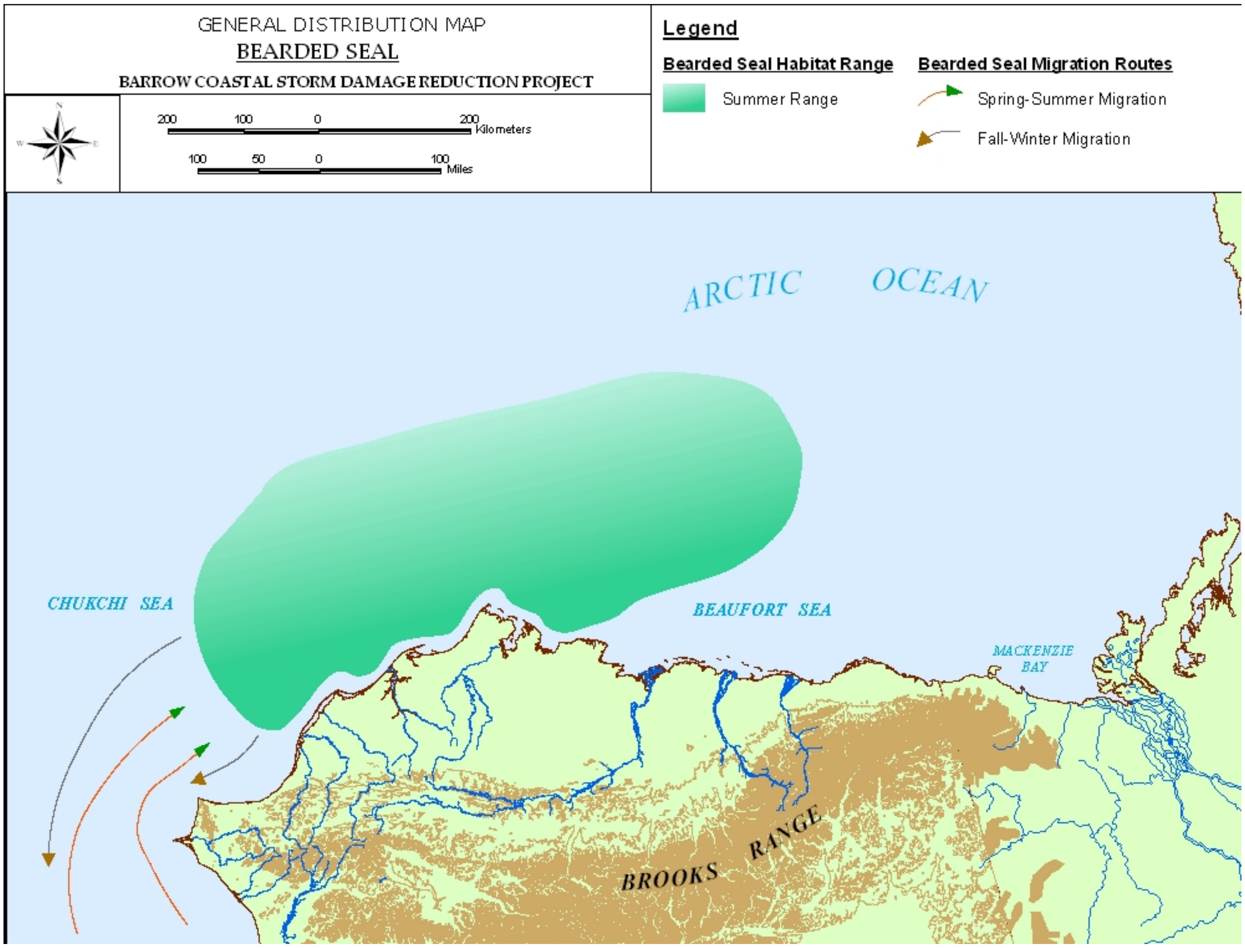

Figure 5. Seasonal movements of bearded seals through Bering Strait to the east Chukchi Sea and west Beaufort Sea.

Life History. Bearded seals get their common name from their comparatively long whiskers (mystacial vibrissae). Adult female bearded seals are slightly longer, an average of about 7.5 feet in length, than adult males whose average length is about 7 feet (2.1 meters). Both adult males and females, however, average about 500 pounds (227 kg), although they can attain a weight of more then 750 pounds (340 kg) during winter and early spring (Burns 1994). Their color varies from a tawny-brown or silver gray to dark brown. They are the only Alaskan seal without bands or spots. They are also distinguished from other seals by their rounded foreflippers on which the middle of five digits is the longest, relatively small eyes, and four mammary teats rather than two as on other Alaskan seals. Bearded seals live to about 30 years old, but their teeth wear rapidly. Most bearded seals older than about 8 or 9 years appear toothless, which sometimes leads to estimates of a much greater age.

Most female bearded seals bear a single pup between March and early May. They nurse the pups for 12 to 18 days, while the pup gains weight rapidly. Females typically breed within 2 weeks of weaning the pup, but implantation is delayed until about July. Gestation is 11 months including delayed implantation, and the average weight of newborn pups is about 75 pounds (34 kg). The incidence of pregnancy is about 85 percent and the sex ratio of the Alaska population slightly favors females (Burns 1994). Bearded seals pup and molt on the ice. They usually molt during the May and June peak haul-out period, but molting is reported to take place during other times of the year in some areas (SCS 2000). The predators of bearded seals include polar bears, orca whales, certain predatory walruses, and people. Other sources of mortality might include disease and parasitism.

Bearded seals eat mostly benthic invertebrates including crab, shrimp, snails, and clams, although benthic fish including sculpins, flatfish, and cod are also sometimes eaten (Johnson et al. 1966, Burns and Frost 1979, Lowery et al. 1980). Bearded seals prefer to feed in areas less than about 425 feet deep where the bottom is relatively flat. The continental shelf underlying the Bering and Chukchi seas provides the largest continuous area of favorable bearded seal habitat in the world (Burns and Frost 1979).

Bearded seals can reach the bottom in shelf areas in the Chukchi and Beaufort seas, and could use the same food species as ringed seals, but do not depend on fish to the same degree as ringed seals. Johnson et al. (1966) found that during February, when the diet of ringed seals was 90 percent fish, the diet of bearded seals was only 24 percent fish. Shrimp and other bottom organisms were of major importance in the diet of bearded seals near Point Hope during the 1996 study by Johnson et al. Shrimp also are a major food in the diets of newly weaned pups (Burns and Frost 1979).

Ringed Seal

Distribution. The ringed seal (Phoca hispida) is the most abundant marine mammal along the Arctic coast of Northwest Alaska (figure 6). Ringed seal are circumpolar in distribution and are represented by five subspecies (Webster and Zibell 1970; Anderson et al. 1977). The Arctic ringed seal is the most abundant and widely dispersed of the subspecies. Isolated populations in Europe and northern Asia represent the other four ringed seals subspecies. Arctic ringed seals are found in all Arctic Ocean seas and the Bering Sea. They range as far south as Newfoundland and northern Norway in the Atlantic Ocean, and the Aleutian Islands in the Pacific Ocean (SCS 2000b). Only the Alaska stock of the Arctic ringed seal is recognized in U. S. waters (Hill and DeMaster 1999).

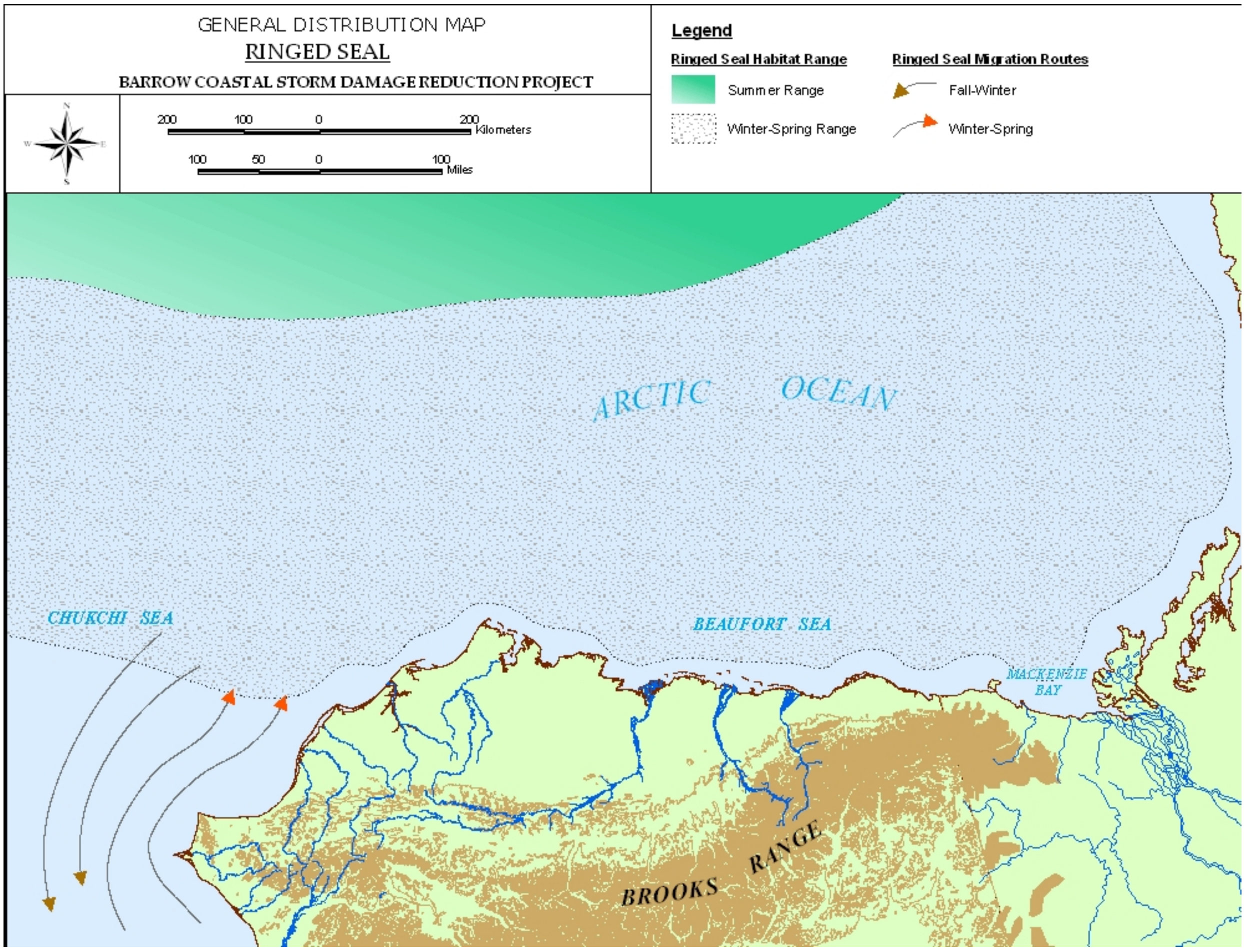

Figure 6. This figure shows the general direction of the spring and fall migration and dispersal patterns of ringed seals in the Bering and Chukchi seas.

Ringed seals are closely associated with sea ice, and much of the population migrates north and south with the advancing and retreating polar ice pack. They spend the winter dispersed along the southern edge of the ice pack. In the spring they move north with the receding ice edge and join other ringed seals that may have stayed behind on the pack ice during the winter. Many ringed seals in Alaska migrate north into the Chukchi and west Beaufort seas during early summer, where they spend the summer dispersed along the edge of the polar ice. In late fall, most ringed seals migrate south with the advancing ice edge to the southern wintering area. Aerial surveys in the Chukchi Sea show that ringed seals are more abundant with a few miles of shore when ice and feeding conditions are favorable (Johnson. et al. 1966, Bengtson et al. 2001, NMML 2006). Ringed seals are common in the Point Barrow area during the months when ice cover is present.

There are no accurate population estimates of Arctic ringed seals, but they are believed to be the most abundant subspecies due to their widespread distribution. A very rough estimate of 2.3 to 7 million for all subspecies was made in the late 1980's, with 1 to 1.5 million in Alaska waters (Hill and DeMaster 1999, SCS 2000). The estimated population of ringed seals in the Beaufort Sea is 80,000 seals in the summer and 40,000 seals in the winter (Frost and Lowry, 1981). Densities of ringed seals in the floating shorefast-ice zone of the Beaufort Sea generally range from 1.5 to 2.4 seals per square nautical mile (2.8-4.4 seals/km2) (Frost, Lowry, and Burns, 1983).

Life History. Ringed seals are the smallest of the Arctic seals, and adults rarely exceed 5 feet in length and 150 pounds (68 kg) in weight. Adult males are larger than adult females. Although the color of ringed seals is quite variable, most ringed seals have a gray back with black spots, and a light belly. They get their common name from the pattern of black spots ringed with light marks that is characteristic on their hair. Mature bull ringed seals sometimes have a dark-colored face and head.

Ringed seals have strong claws on their fore flippers that they use to scratch breathing holes through the ice and to construct lairs under the snow. Lairs are often multi-chambered and are used for protection from predators, extreme environmental conditions, and birthing. Ringed seals typically construct and maintain two or more lairs up to about 3 miles apart. Predators of the ringed seal include polar bears, orca whales, certain predatory walruses, Arctic fox, wolverines, wolves, Steller sea lions in the Bering Sea, large birds such as gulls and ravens, and humans.

Ringed seals molt on the ice during May and June when they spend long periods of time on the ice basking in the sun. The haul-out behavior of ringed seals may change abruptly from using lairs beneath the snow to basking on the surface in late May.

Female ringed seals become sexually mature between 4 and 8 years old, while males become sexually mature between 5 and 7 years old (SCS 2000). Females bear one pup from mid-March to mid-April in a lair. Unlike the bearded seal, it is born with a white coat that is shed 4 to 6 weeks after birth. Pups nurse up to about 8 weeks after birth and wean as the ice breaks up. The average weight of pups at birth is about 10 pounds, but they double their weight before weaning. There is evidence that females that construct their birthing lairs on solid, shorefast ice are more successful in raising pups than females that construct birthing lairs on drifting pack ice (Eley 1994). Female ringed seals breed within 1 month after giving birth, but implantation is delayed until July or August. Pregnancy from conception lasts about 11 months. Ringed seals are known to live up to 43 years of age (SCS 2000).

Ringed seals see and hear well underwater, and some phocid seals may have the most efficient hearing of all pinnipeds in the air (King 1983). Phocid seals (seals with no external ear), however, are not as sensitive as otarid seals (seals with external ears) to sounds in the air.

Ringed seals have several under water vocalizations, including barks, yelps, and chirps (Calvert and Stirling 1985), that are not audible above water and whose function is not known (Eley 1994), but may be involved with reproduction and territoriality (Calvert and Sterling 1985). Vocalizations on the surface consist of moans, whines, and grunts.

Johnson et al. (1966) examined the stomachs of 1,923 ringed seals in the eastern Chukchi Sea. They reported that the diet of ringed seals consisted predominantly of small fish less than 20 cm (8 inches) long, *Sclerocrangon* shrimp, and *Hyas* crabs. This extensive study suggests that ringed seals take whatever food species is available to them.

Johnson and his team reported that the quantity and diversity of prey species varied by month of sampling. They speculated that the diversity in prey species observed in seal stomachs was associated with the availability of food species, but that preferences could also have been a factor. Arctic cod were often the only food present in the stomachs during winter, while food became more diversified during spring and included more invertebrate species.

Spotted Seal

Distribution. Spotted seals (*Phoca largha*) are closely related to harbor seals (*P. vitulina richardsi*), and their ranges overlap along the southern range of the spotted seal. Little is known about the migration of the spotted seal, but tagging studies indicate they follow the receding ice edge north from the Bering Sea to about latitude 72° N in the Chukchi and Beaufort seas, and inhabit near shore areas of the Russian and Alaska coasts along the way (figure 7). Spotted seals winter in the Bering Sea along the edge of the ice field. A recent population estimate for spotted seals is not available, but early estimates suggest the population ranged from 335,000 to 450,000 seals in the 1970's (Ferrero et al. 2000). Spotted seals are sometimes seen near the mouth of rivers and lagoons during summer where subsistence hunters sometimes harvest them. Only one stock exists in Alaska waters and it is not considered depleted, threatened, or endangered.

Figure 7. Seasonal movements of spotted seals through Bering Strait into the east Chukchi Sea.

Pacific Walrus

Distribution. Walrus are Arctic circumpolar in distribution and are represented by two subspecies, the Atlantic walrus (*Obdobenus rosmarus rosmarus*) and the Pacific walrus (*Obdobenus rosmarus divergens*). Pacific walrus, the larger of the two, are found in the North Pacific Ocean and Arctic Ocean from the East Siberian Sea to the western Beaufort Sea.

A 1990 population estimate for the Pacific walrus was 201,000 animals, but recent calf-to-cow ratios suggest the population is in decline (Kelly and Taras 2000).

Most Pacific walrus spend the winter in the Bering Sea then migrate north with the receding ice pack in the spring. They pause around the rich feeding grounds near Saint Lawrence Island, and after passing through the relatively constricted Bering Strait, they disperse northward through the central Chukchi Sea and spend the summer along the edge of the polar ice. In the fall, walrus migrate south through the Bering Strait along the edge of the advancing ice pack.

Compared with other Arctic pinnipeds, Pacific walrus have a fairly complex migration pattern (figure 8). Most of the eastern Bering Sea stock winters in the Bristol Bay region.

In spring females and juveniles typically follow the edge of the sea ice as it retreats north into the Chukchi Sea. Most of the bulls stay behind on Round Island in Bristol Bay through the summer, then migrate north in late fall to meet the females and juveniles near Saint Lawrence Island as they migrate south along with the advancing winter ice pack. Some local populations may not migrate at all. Walrus are more accessible for hunting from the villages of Point Hope, Wainwright, and Barrow in July and August. Walrus are observed close to shore in Barrow.

Life History. Walrus are easily differentiated from other northern Pacific Ocean marine pinnipeds by their immense size, elongated canine tusks, and high mobility on solid surfaces. Walrus tusks are used for display, fighting, defense, and for mobility on land and ice. Walrus can weigh as much as 2 tons (1,814 kg) and attain a length of 12 feet (3.7 m). They are highly gregarious and mass in herds of hundreds of animals.

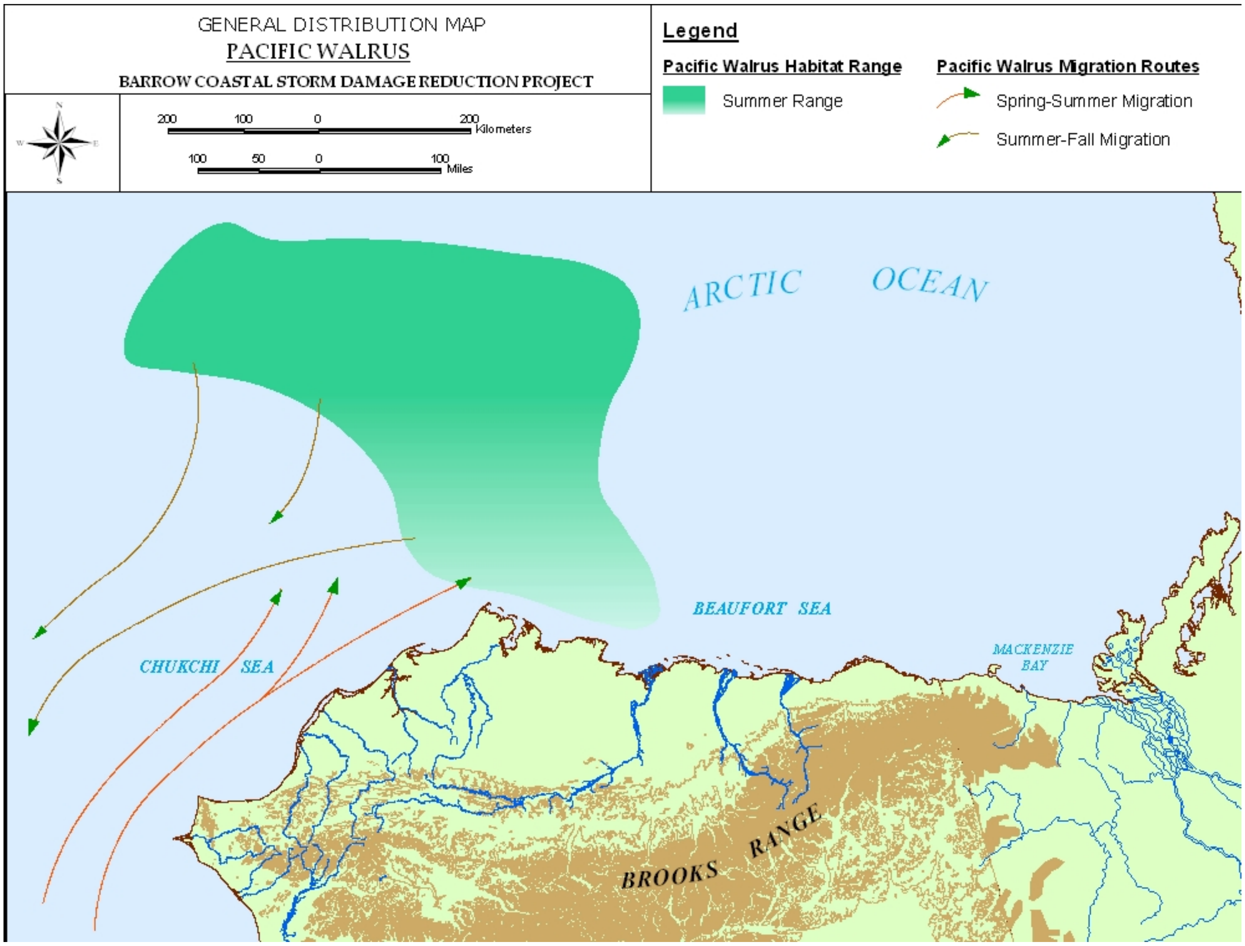

Figure 8. Seasonal movements of Pacific walrus through Bering Strait into the east Chukchi Sea and west Beaufort Sea.

Walrus have poor eyesight, but excellent senses of smell and hearing. They are vocal and communicate with a variety of grunts, clangs, and bell-like sounds.

Like all pinnipeds, walrus undergo molt. Most molting takes place gradually from June through August, but females may molt over a longer period.

Predators of Pacific walrus include polar bear, orca whale, and humans. Other sources of mortality might include disease, parasitism, and starvation, trampling and crushing in the herd, and fighting among the bulls.

Walrus are long-lived and have a relatively low reproduction rate compared with most other pinnipeds. Most females do not breed until they are 6 or 7 years old. They breed in January or February, but implantation does not occur until about mid-June. The actual period of fetal growth, therefore, is about 11 months. Female walrus calve on the ice in late April or May. Calves weigh about 100 to 160 pounds (45 to 73 kg) at birth and are nursed for at least 18 months and up to 2 ½ years. Most females reproduce only every 2 years and older females every 3 to 4 years. Female walrus aggressively defend their calves.

Walrus are generally associated with areas of more plentiful bottom-dwelling life forms. They gather prey from the sea floor by brushing the substrate with their broad, whiskered muzzles and propelling jets of water through their mouths. Walrus in the Chukchi and Bering seas depend primarily on clams for their diet (Lowery et al. 1980), although they also eat worms, snails, shrimp, crabs, fish, and seabirds. Some walrus, however, also eat the skin and blubber of seals.

Clams typically are a large part of the walrus diet (Fay 1982, Nelson et al. 1994, Ray et al. 2006). Higher populations of calms are associated with areas of high benthic biomass and the distribution of walrus may correlate at times with an abundance of clams and other invertebrates (Lowery et al. 1980). Areas of higher benthic biomass are found in the northern Bering Sea, central Chukchi Sea, an area of the eastern Chukchi Sea west of Point Barrow known as Hanna Shoal, and in the Beaufort Sea east of Point Barrow (Grebmeier and Dunton 2000, Dunton et al. 2003).

Major Environmental Influences. There is much traditional knowledge on walrus, particularly in the Bering Strait area including Saint Lawrence Island, where they are hunted in large numbers. However, relatively little traditional knowledge about walrus has been compiled in printed form.

Hunters note that walrus are largely restricted to certain ice conditions that support large herds over areas with an abundance of food. The type of ice also influences the distribution of walrus. Young, thin ice does not support large herds, and old ice is sometimes too thick for walrus to haul out on because of its cliff-like edge. Females need the correct ice conditions to haul out on for giving birth and nursing their calves. Native hunters compare current ice conditions to traditional knowledge and have concluded: (1) Arctic ice is thinning, and (2) thinner ice appears to be affecting the migration timing, migration paths, and seasonal distribution of walrus.

Beluga Whale

Distribution. Beluga whales are Arctic and subarctic in range. In Alaska waters, five distinct stocks of beluga whales have been identified (Hill and DeMaster 1999). These stocks comprise (1) the Beaufort Sea stock, (2) the Eastern Chukchi Sea stock, (3) the Eastern Bering Sea stock, (4) the Bristol Bay stock, and (5) the Cook Inlet stock. A recent molecular genetic study by O'Corry-Crowe (2001) confirmed the presence of the five distinct stocks.

The O'Corry-Crowe study, and previous studies (e.g., Frost et al. 1983) indicate that two of the five stocks in Alaska waters – the Beaufort Sea stock and the Eastern Chukchi Sea stock – pass by Point Hope during their spring and fall migrations. The Beaufort Sea stock continues past Barrow to the Mackenzie River delta in Arctic Canada and the eastern Chukchi Sea stock might spend most of the summer months in Kasegaluk Lagoon at Point Lay southeast of Point Barrow. Figures 9 and 10 show the general direction of the spring and fall migration and dispersal patterns of the Beaufort Sea and Eastern Chukchi Sea stocks. The spring and fall migration and dispersal patterns of these two stocks are described below.

Beaufort Sea Stock. The Beaufort Sea stock spends the summer in the Mackenzie River estuary in western Arctic Canada and the winter in coastal areas of the Bering Sea (figure 9), possibly off Cape Navarin in the Gulf of Anadyr (Smirnov and Litovka 2001). This stock migrates north through leads in the ice along the eastern Chukchi Sea coastline in April and May, while the Eastern Chukchi Sea stock typically migrates through broken ice or open water during June and July.

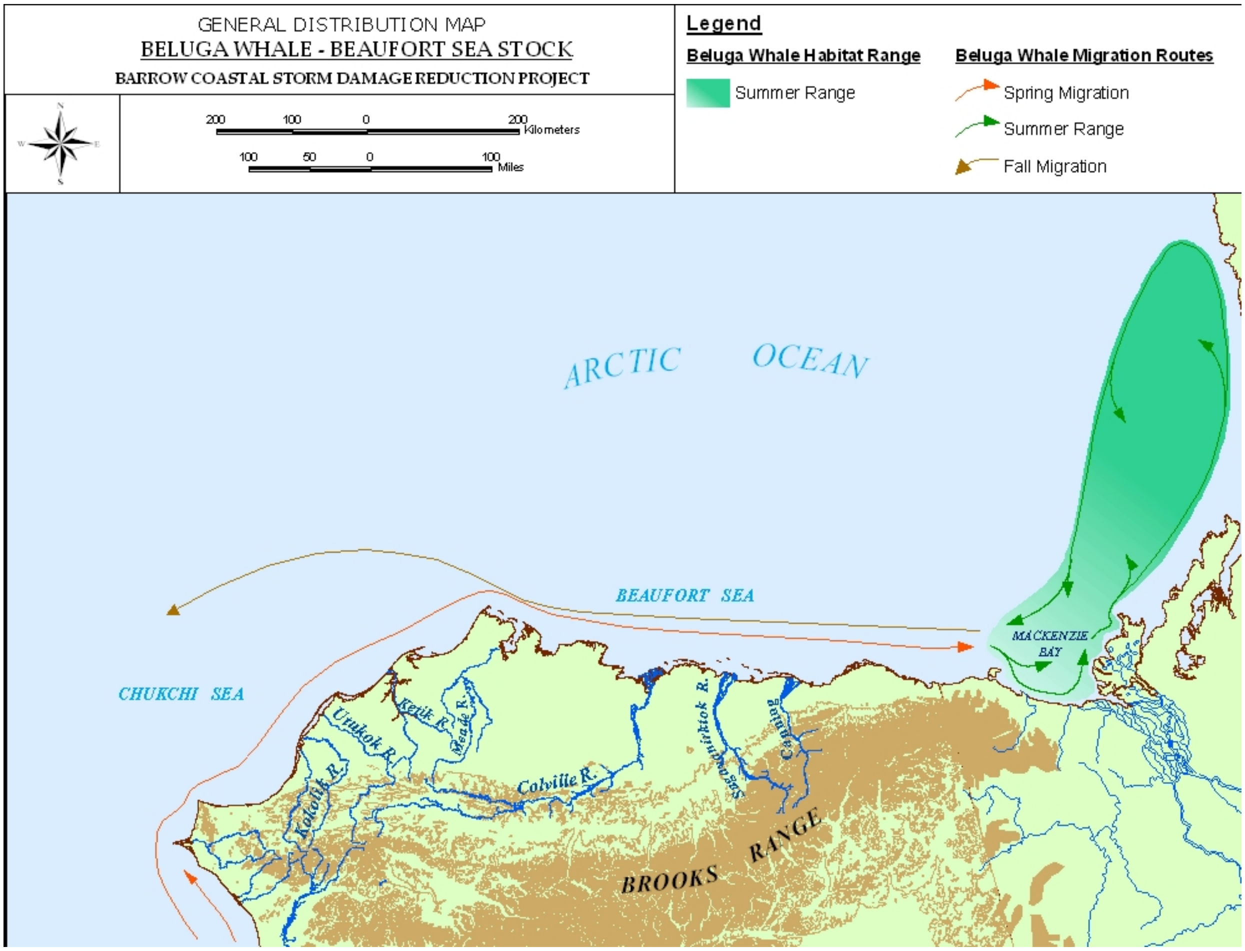

Figure 9. Seasonal movements of the Beaufort Sea stocks of beluga whale

Offshore leads determine how close to the shorefast ice the Beaufort Sea stock migrates during spring. Traditional knowledge from Native hunters tells us that if more than one lead is available, these early beluga naturally take the farthest seaward lead, making it very difficult or impossible for hunters to intercept them from the shore.

Many beluga of the Beaufort Sea stock appear attracted to the warm estuarine waters of the Mackenzie River estuary during July. At one time, it was concluded that the warm waters were beneficial to the beluga for calf-rearing, but more recent evidence indicates they are seeking appropriate substrate for "rubbing," to facilitate the annual molt (WMAC (NS) 2006).

While thousands of Beaufort Sea stock beluga gather in the Mackenzie River estuary, others are widely distributed throughout the cold and clear offshore waters of the Beaufort Sea. It also appears that the whales regularly move between the warm near-shore water and the cold offshore waters during July, but by August are widely distributed offshore. Large numbers of males are now known to travel east to Viscount Melville Sound, presumably to feed (WMAC (NS) 2000). Adult males are typically segregated from females and juveniles during the summer (Richard et al. 2001).

Beginning in mid-August the Beaufort Sea stock migrates from the Mackenzie River estuary and northern Arctic summering areas west across the Beaufort and Chukchi seas to near Wrangel Island and then south down the Siberian coast and through the Bering Strait where many spend the winter in the Anadyr Gulf. Recent satellite tagging studies (Richard et al. 2001) and Russian observations (Kochnev 2001) confirm this general fall migration pattern.

The best index of stock size is obtained during aerial surveys reported in Alaska Marine Mammal Assessments (Ferrero et al. 2000). The minimum number of beluga in the Beaufort Sea stock is believed to be about 40,000 animals and increasing.

Eastern Chukchi Sea Stock. The Eastern Chukchi Sea stock shares their winter area in the Bering Sea coastal areas with the Beaufort Sea stock and other stocks (figure 10) (Simirov and Litovka 2001). In the spring they migrate to the Kotzebue Sound/ Eschscholtz Bay area to calve and molt. In late June and early July some of this stock leaves Kotzebue Sound and migrates north along the coastline to the Kasegaluk Lagoon at Point Lay and Icy Cape southeast of Point Barrow.

Recent research shows that some individual whales of the eastern Chukchi stock leave Kasegaluk Lagoon during summer and venture into the Arctic Ocean as far as 80 degrees north latitude in late July and early August (Suydam et al. 2001)

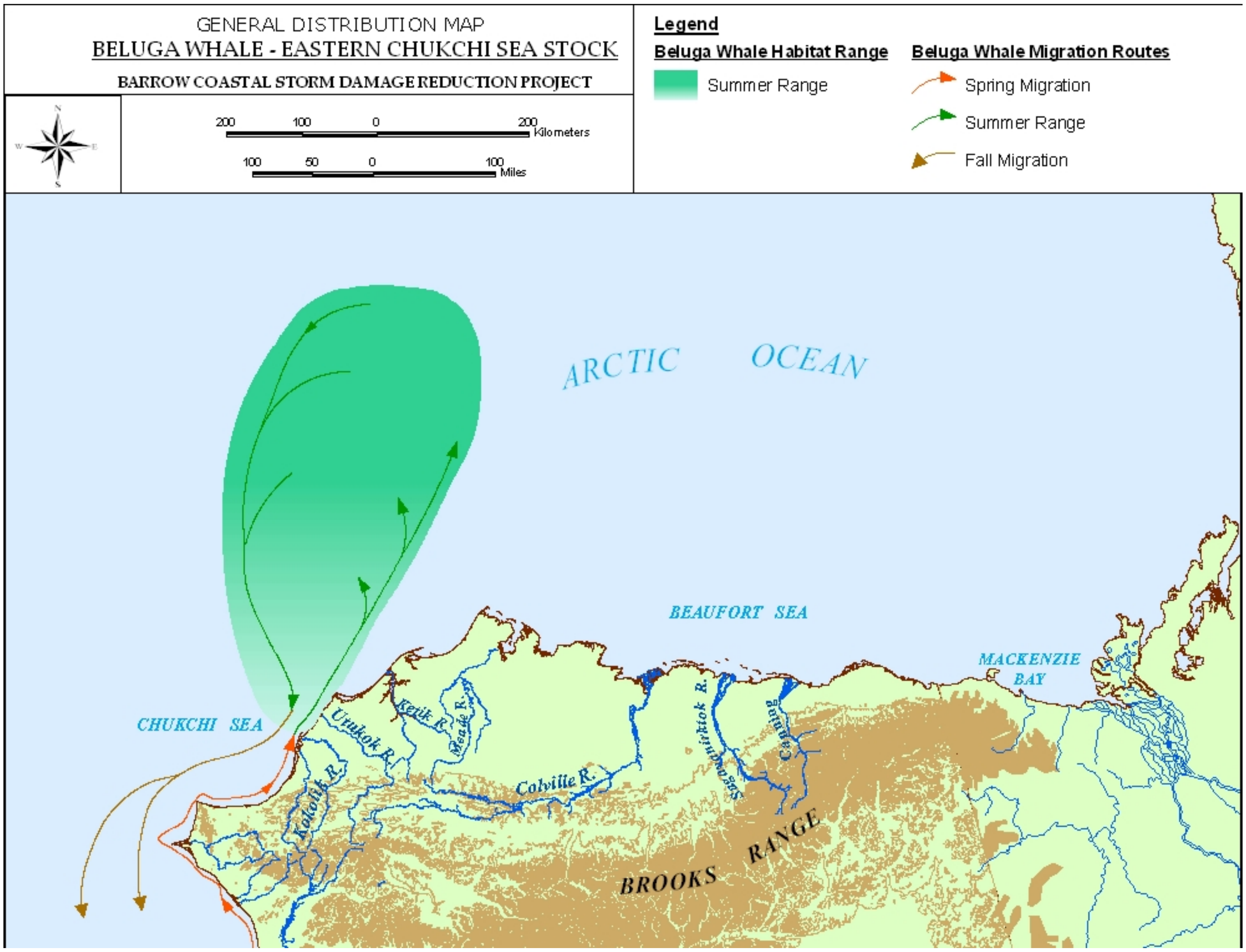

Figure 10. Seasonal movements of the eastern Chukchi Sea stocks of beluga whale.

In the fall the eastern Chukchi Sea stock leaves the Point Lay/Icy Cape summering area and migrates south through the Chukchi Sea and the Bering Strait to winter in the coastal areas of Anadyr Gulf and the Bering Sea. A few individuals may migrate south near shore, but it is likely that the main fall migration route is far offshore.

Life History. Beluga whales are toothed whales in the family Monodontidae. Narwhal, another Arctic species, is the only other member of this family. Beluga whales actively pursue and catch fish and other marine organisms. They can generate sounds that are used to communicate with others of their species, and use a type of audible “echo locating sonar” (echolocation) to identify what is around them and to help find food. Belugas are extremely vocal and as a result have been given the nickname “sea canary.” Hearing and vision senses are also highly developed.

Beluga whales are opportunistic predators and feed on a wide variety of fish and benthic animals. Principal prey includes octopus, squid, crabs, clams, snails, worms, and a variety of fish species. They forage mostly in shallow water up to 100 feet (30 meters) deep and swallow their food whole. Belugas may have taste receptors, but have no olfactory lobes and no sense of smell.

Belugas are perhaps the best adapted of all the cetaceans (whales and dolphins) for life in shallow, turbid, and icy waters because of their agility and superb echolocation capabilities. They appear to be unaffected by freshwater or salinity changes, or by turbidity. They are adapted to maneuver in very shallow, turbid water with narrow, twisting channels, and they readily move over habitat with sharply varying depths. They are known to ascend rivers and have been seen at least 830 miles (1,336 km) up the Yukon River drainage and 1,240 miles up the Amur River in Asia. In some parts of their range, their ability to move into and survive in shallow, turbid water appears to be an effective strategy for avoiding predatory orca whales.

In addition to orcas, predators of beluga whales include polar bears and humans. Other sources of beluga mortality include stranding, disease, pollution, starvation, entrapment under ice, entanglement in fishing nets, and collisions with boats (Huntington and Mymrin 1996, Martineau 2001).

Belugas live in cohesive social groups called pods. A pod may consist of 2 to 12 individuals, but the average pod size is 10 whales. A single male usually leads a pod and females with calves often form separate pods during calving season. Pods often join into large groups of several hundred and even several thousand whales. Male beluga whales grow to about 15 feet (4.6 meters) long and 3,300 pounds, while females grow to about 13 feet (4 meters) long and 3,000 pounds (1,361 kg). Beluga whales can live 25 to 30 years, and reach full size in about 10 years.

Female belugas become sexually mature at 4 to 5 years old, while males mature slightly later (Lowry 1994). Breeding is in March and April, and gestation is about 14 ½ months. Traditional knowledge is that female belugas calve near ice, and use the ice to assist in the birth (Huntington and Mymrin 1996). If ice is not present at calving, two males are said to assist the female during delivery. Calves are born tail first, are closely attended by their mother, and nurse for about 2 years. Beluga calves are dark skinned when born and turn white with age. The shade of color, dark to light, is sometimes used to estimate the age of belugas in their natural environment because belugas become paler with age.

Estuaries serve as nurseries for birthing and nurturing calves, and as a place to molt. Belugas show a fidelity to summering areas. Females bring their calves back to their birth site, thereby ensuring subsequent generations will continue to migrate to their ancestral grounds (O'Corry-Crowe 2001). A known calving area for the eastern Chukchi Sea stock is Eschscholtz Bay in Kotzebue Sound (Huntington and Mymrin 1996), and particularly in Goodhope Bay where they are undisturbed by noise (W. Goodwin personal communication). Point Lay hunters see females with young calves in Kasegaluk Lagoon at Point Lay (Huntington and Mymrin 1996). Female belugas harvested at Point Lay are occasionally pregnant, or have recently given birth, suggesting that calving could take place in the Point Lay area. Most calves in the Beaufort Sea stock appear to be born en route to the Mackenzie River delta where this stock temporarily congregates before dispersing farther north and east into Melville Sound.

Major Environmental Influences. Belugas are sensitive to disturbance in certain circumstances where waterborne, airborne, and onshore noise might affect their distribution and behavior (Smith and Geraci 1990). A common theme in traditional knowledge among villages along the northwest Alaska coast and villages on the eastern shore of the Chukotka Peninsula is that beluga whales are sensitive to noise and outboard motors in particular (Huntington and Mymrin 1996). Negative reactions of belugas to outboard engines in the Kotzebue Sound area were recognized in the 1950's and early 1960's (Fejes 1996, Foote and Cook 1969), and in the 1970's and early 1980's (Morseth 1997, Frost et al. 1983).

Noise from large aircraft has also been blamed for shifts in migration patterns of the beluga in Kotzebue Sound (Morseth 1997). Beluga in the Beaufort Sea are said not to be disturbed by single-engine piston aircraft flying under 1,000 feet unless the aircraft is circling or repeatedly flying over the same area (Fraker 1984).

Belugas are said to be sensitive to disturbances onshore (Huntington and Mymrin 1996, Morseth 1997). Traditional knowledge required relative silence onshore while preparing for cooperative hunts so as not to frighten belugas from the area, but with increased use of fast outboard engines, hunting has become more individualized and the requirement for silence is not practiced to the same degree it once was (Morseth 1997). Scientists who observed belugas in the Mackenzie Estuary of the Beaufort Sea concluded that neither logistics nor the construction of artificial islands had any serious effects on the use of areas by belugas or the success of Native hunters (Fraker 1984).

In the Russian community of Sireniki, hunters noticed that construction on shore did not frighten belugas, and belugas in the Anadyr River did not avoid construction, large vessels, or normal activities. They did state that the belugas are not hunted in the Anadyr River (Huntington and Mymrin 1996).

Harvest Practices . Beluga stocks that winter in the Bering Sea are hunted throughout their summer range. The Beaufort Sea stock is of particular importance to activities conducted near Barrow because they pass Point Barrow on their way to their summer range in the eastern Beaufort Sea. This stock is mostly harvested on the Alaska coast at Kivalina and Point Hope where they come relatively close to land. They typically pass Barrow farther offshore, but some are taken by hunters from Beaufort Sea communities. The Inuvialuit of Mackenzie River delta and Amundsen Gulf regions of the eastern Beaufort Sea also conduct an annual subsistence harvest of beluga whales in the Mackenzie River estuary. According to Fisheries and Oceans Canada (DFO 2000), the annual landed Canadian harvest of beluga from the Beaufort Sea stock between 1990-1999 averaged 111 belugas. This harvest is extremely important to the residents of the Mackenzie River delta communities, supplying a significant portion of their annual nutrition and an important cultural/traditional activity. The Department of Fisheries and

Oceans Canada estimates the annual take of this stock by both Alaska and Canada at 186 animals (DFO 2000).

Bowhead Whale

Distribution. An estimated 50,000 bowhead whales once ranged over Arctic seas in two main stocks (Fraker 1984): the eastern and western Arctic stocks, with more than 30,000 in the eastern stock. Commercial whaling reduced the eastern Arctic stock to fewer than 1,000 whales between the 1600's and the 1800's. The western Arctic may have had two stocks of bowheads: those summering in the Bering and Chukchi seas, and those summering in the eastern Beaufort Sea.

The Bering Sea and Chukchi Sea stock, which once numbered about 18,000 whales, was greatly reduced during the late 1800's and early 1900's (Carroll 1994, Fraker 1984), and is likely extinct because bowheads no longer summer in the Bering and Chukchi seas. The current stock, the western Arctic stock (Hill and DeMaster 1999), summers in the eastern Beaufort Sea and winters in the Bering Sea, and has a minimum population of about 7,738 whales (figure 11). The western Arctic stock of bowhead whales is increasing, and increased at an estimated rate of 3.2 percent annually during a 1978-1993 survey period.

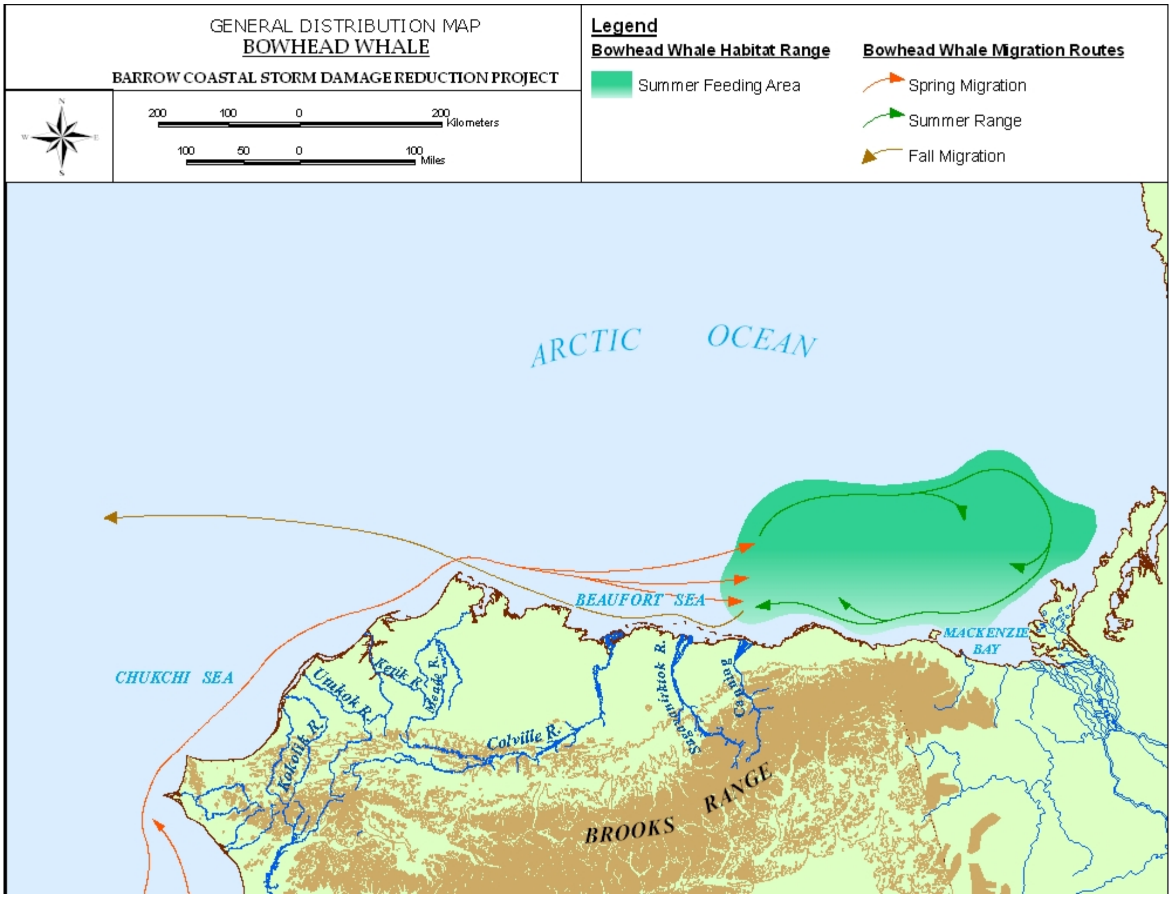

Figure 11. Seasonal movements of Bowhead whales through Bering Strait into the east Chukchi Sea and west Beaufort Sea

Bowhead whales winter in the Bering Sea south of Saint Lawrence Island and in the Gulf of Anadyr, and begin to migrate north through the Bering Strait along leads in early spring. The majority of the population migrates off shore along the coast of the southeastern Chukchi Sea, but some bowheads follow leads that form along the edge of the shorefast ice. At Point Hope bowheads come relatively close to land, and continue northward along the coast until they arrive on their summer feeding grounds in the Beaufort Sea after rounding Point Barrow. In September, bowheads migrate west from the Beaufort Sea along the 60-foot depth contour and across the northern Chukchi Sea from Point Barrow toward Wrangel Island (Fraker 1984). Approaching Siberia they then turn south along the western Chukchi Sea coast toward the Bering Straits and the Bering Sea. The timing of return to wintering grounds in the Bering Sea is not well known, but probably takes place from November to January

Life History. Bowhead whales can grow to a maximum of about 60 feet (18.3 meters) long and weigh more than 60 tons (54 tonnes) (Carroll 1994). Calves are about 14 feet (4.3 meters) long and 2,000 pounds (747 kg) at birth and grow rapidly to about 26 feet long during their first year. Growth slows after weaning. Female bowheads are sexually mature at about 41 to 46 feet and probably about 15 years old. The age of bowheads is hard to determine but several recent findings of ancient stone and ivory harpoon heads in subsistence-harvested whales point to ages of 150 years or more (AP 2000). Segregation by sex and age is evident during certain phases of their migration (ACS 1996).

Bowheads make a variety of complex sounds, many of which are loud. The sounds produced can be described as a moan, growl, roar, scream, or purr. Other physically produced sounds include “tail and flipper” slapping, breaching, and expelling air from the blowhole. All sounds produced by bowheads probably serve in transmitting some kind of information to other bowheads. Based on the hearing ability of species that can be tested, it is assumed that bowheads can hear or detect sounds above ambient noise levels in the frequencies that they produce. Unlike belugas, bowheads do not have echolocation abilities.

Predators of bowhead whales are primarily orca whales and humans. Other sources of mortality can include disease, collisions with vessels, and perhaps in rare circumstances, suffocation under the ice if breathing holes cannot be found or made. Entanglement of whales in fishing gear and lines is also becoming more common.

Bowheads strain small fish, copepods, euphausiids (krill), and other small invertebrates from the water through baleen plates by swimming with their mouths open. They feed only in summer in the Beaufort Sea and at all depths from the surface to the bottom using a variety of feeding strategies. Little is known about how baleen whales actually find food, but because baleen whales do not echolocate like toothed whales, they may depend on hearing to locate swarms of krill and other prey by the sound the prey makes.

Major Environmental Influences. Most behavioral research on the effect of noise on bowhead whales involves the development and operation of oil facilities in the bowhead’s summer feeding grounds in the Beaufort Sea. Noise generating industrial activity in the feeding grounds includes drilling, dredging, seismic exploration, vessel and aircraft traffic, ice breaking, and the construction of artificial islands. These activities have given scientists an opportunity to record observations on the reaction of bowheads to industrial activity since the early 1970's (Fraker 1984).

Observations of bowhead reaction to shore-based stations in the Beaufort Sea, such as artificial island drilling platforms, are inconclusive. The natural dispersal of bowheads on the feeding grounds in the Beaufort Sea appears to be highly variable from year to year. In some years bowheads are abundant near industrial activities while in others they are scarce. These observed variances may be related to annual variances in food availability rather than the industrial activity itself. In some instances, the availability of food resources may require bowhead whales to increase their tolerance of industrial activity.

Anthroprogenic noise is predominantly low frequency below 1 Khz and can reach sound pressure levels of over 200 dB. Whales produce and perceive low frequency sounds. Reaction thresholds tend to be lower for continuous noises than for pulses and lower for moving or erratic signals than for stationary ones. Studies have found that most bowhead whales avoid drillship or dredging noise with broad-band (20-1000Hz) received levels around 115db re 1uPa, levels that could occur 3-11 km from typical drilling and dredging vessels (Perry 1998). At low frequencies (5 to 500 Hz), commercial shipping is the major contributor to noise in the world's oceans (Richardson et al. 1995)).

Gray Whale

Distribution. Gray whales are coastal baleen whales that migrate along the Pacific Coast between Arctic seas and wintering areas in more temperate waters. At one time there were three gray whale populations: a north Atlantic population, now extinct; a Korean or western north Pacific stock, now very depleted; and the eastern north Pacific population, the largest surviving population. The eastern Pacific Ocean population of gray whales makes one of the longest of all mammalian migrations, averaging 10,000 to 14,000 miles (16,000-22,530 km) round trip. The whales begin to leave their feeding grounds in the Bering and Chukchi seas in October and head south for their mating and calving lagoons in Baja California, Mexico (figure 12). The southward journey takes 2 to 3 months. The whales remain in the lagoons for 2 to 3 months, allowing the calves to build up a thick layer of blubber. The return trip north takes another 2 to 3 months. Mothers and calves travel very near shore on the northbound migration. Some individual gray whales are found year round in the Straits of Juan de Fuca between the State of Washington and Vancouver Island, Canada, and possibly off the central California coast.

Hunted to the edge of extinction in the 1850's after the discovery of the calving lagoons, and again in the early 1900's with the introduction of floating factories, gray whales were given partial protection in 1937 and full protection in 1947 by the International Whaling Commission (IWC). Since that time the eastern north Pacific gray whale population has recovered. The population size has been increasing over the last several decades and the abundance estimate from the 1997/1998 censuses was 26,635 whales.

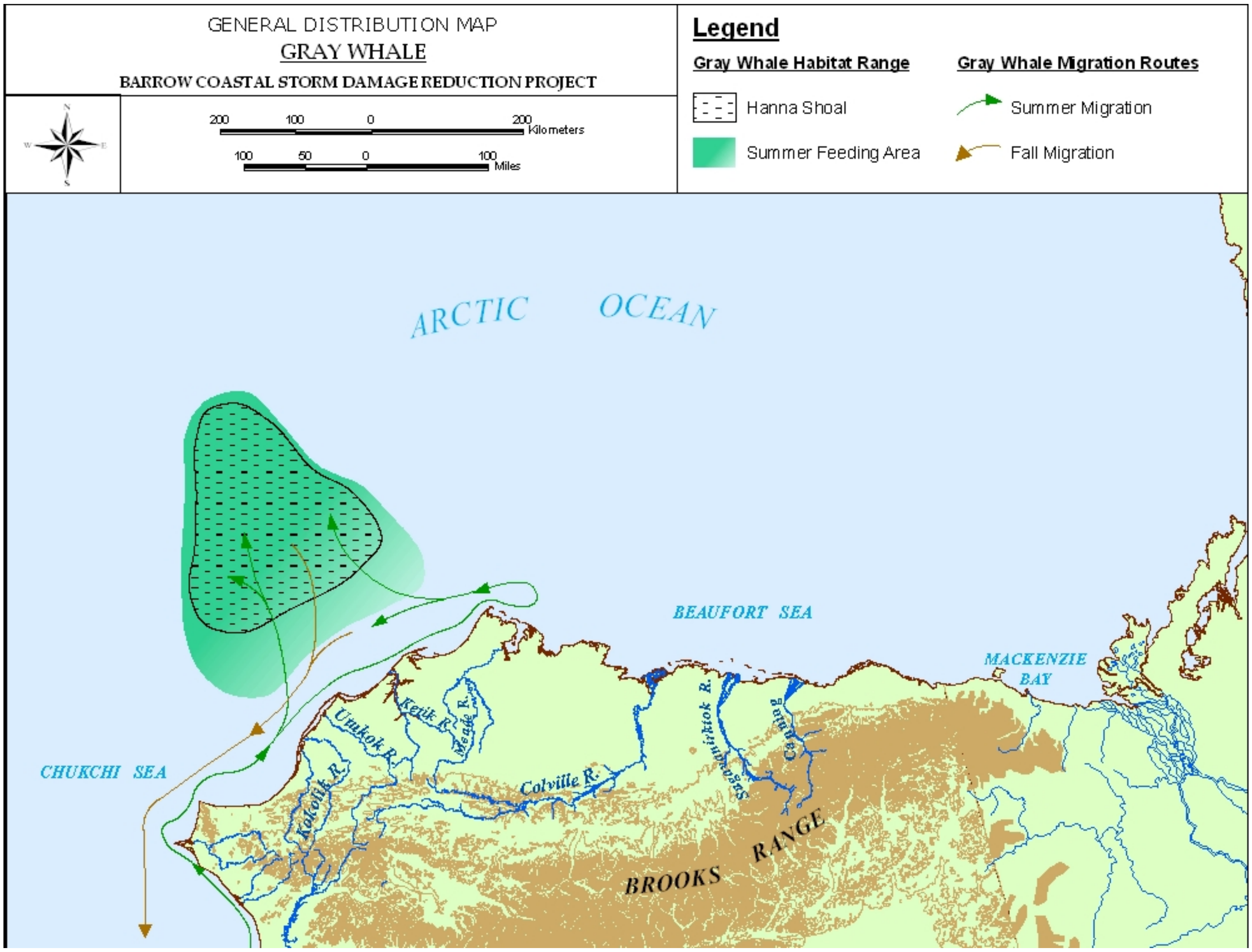

Figure 12. Seasonal movements of gray whales through Bering Strait into the east Chukchi Sea and west Beaufort Sea.

Members of the eastern north Pacific stock seasonally inhabit waters in near-shore areas of Kotzebue Sound and coastal waters of the Chukchi Sea north of 69° north latitude including waters near Barrow (USEPA 1984). The southward migration appears to be along the western Chukchi Sea coast of Russia.

Life History. The gray whale's shape is streamlined with a narrow, tapered head. The whale received its name from the gray patches and white mottling on its dark skin. Adult males measure 45 to 46 feet (13.7 to14 meters) and adult females measure slightly more. Both sexes weigh 30 to 40 tons (27 to 46 tonnes) at maturity. Causes of mortality in gray whales include orcas, collisions with boats, entanglement with fishing gear, entrapment in ice, stranding, disease, starvation, the Siberian harvest by Russian hunters, and occasional harvest by North American Native hunters.

Gray whales reach sexual maturity between 5 and 11 years of age or when they reach 36 to 39 feet in length. Courtship and mating behavior are complex, and frequently involve three or more whales of mixed sexes. Mating and calving both occur primarily in the lagoons of Baja California, Mexico, although both have been observed during the migration. Females bear a single calf at intervals of 2 or more years. Gestation is 12 to 13 months. Newborn calves are dark gray to black, although some may have distinctive white markings. Calves weigh from 1,100 to 1,500 pounds (411 to 560 kg), are about 15 feet long at birth, and nurse from 7 to 8 months.

Gray whales emit low frequency moans, and the portions of the brain that is dedicated to hearing suggest they have well developed hearing, especially in the lower frequency ranges. Like other whales, they have small external ear openings on each side of their head that lead to a narrow auditory canal. The effectiveness of sound reception and hearing through the ear canal is unknown, but the middle and inner ear follow the basic mammalian ear structure. Gray whales have adaptations for vision in low-light conditions and are nearsighted in air.

Gray whales feed on the rich bottom substrate where there are abundant shrimp, amphipods, and worms. These are the same clam-rich feeding areas of walrus (figure 8). Amphipods are believed to be the principal food of gray whales (Nelson et al. 1994). They feed primarily during the summer months of long daylight hours in the cold Arctic waters. To feed, a whale dives to the bottom, rolls on its side and draws bottom sediments and waters into its mouth. As it closes its mouth, water and sediments are expelled through the baleen plates, which trap the food on the inside near the tongue to be swallowed.

Nelson et al. (1994) reported that gray whales disturb hundreds of square miles of sea floor during feeding by excavating pits from 11 to 54 square feet in area and up to a foot deep. Whale feeding results in excavation and resuspension of 112 million metric tons (tonnes) of sediment each year, equivalent to about two times the yearly sediment load of the Yukon River. This is dwarfed by walrus feeding that disturbs a minimum (2.5 percent) of 4,500 km^2 of sea floor or resuspends 560 million tons to a possible maximum disturbance (24 percent) of 43,300 km2 or 6.19 billion tons of resuspended sediment injected into the water column each feeding season. A large proportion (4.5 million tons of fine mud resuspended by whales near the coast is transported out of the Chukchi Sea to the Beaufort Sea each year by the strong northerly Alaska Coastal Current. In addition, sand is gradually transported northward and fills old feeding pits, and modern mud does not accumulate in the sea floor region under the Alaska Coastal Current.

The resuspended sediments increase turbidity and recycle nutrients that can be used by many marine invertebrates. Hanna shoals west of Point Barrow are very high in benthic invertebrate biomass (Dunton et al 2003, Goodall 2003) and are important feeding grounds for gray whales (Nelson et al. 1994).

Major Environmental Influences. Gray whales are not normally threatened by ice-related environmental conditions as are bowhead and beluga whales, but late fall migrants are occasionally trapped by ice and perish. Starting in about 1998 hundreds of emaciated gray whale carcasses washed onshore along the migration route from Baja California to the Arctic. The cause of mortality is little understood, but starvation resulting from an overpopulation of whales may be the cause (ASG-UAF 2002, Moore et al. 2003).

Harbor Porpoise. The harbor porpoise is the smallest species of cetacean in Alaska waters, reaching a length of 5 feet. Harbor porpoises range from Point Barrow in Alaska, south to Point Conception in California. Relatively high densities of porpoises are found in the more temperate parts of their range, while fewer are found in Arctic waters. Harbor porpoises are occasionally seen at Point Barrow.

Three stocks are recognized in Alaska waters: Bering Sea, Southeast, and Gulf of Alaska. A partial-range survey of the Bering Sea stock in 1991 estimated about 11,000 porpoises (Ferrero et al. 2000). There are likely more porpoises in the Bering Sea stock because only the southern part of their range was surveyed. A likely migration path based on the range, distribution, and timing of the Bering Sea stock (Ferrero et al. 2000) is shown in figure 13.

Harbor porpoises are sometimes seen around the mouths of rivers and shallow near-shore areas along the eastern Chukchi Sea coast north to Point Barrow during summer. Commercial trawl fisheries are the principal source of human-induced mortality. Orca whales are the principal natural predator of harbor porpoises. A few porpoises are occasionally entangled in subsistence nets along shore, but subsistence hunters do not target this species (Ferrero et al. 2000). A subsistence gillnet fishery near Point Barrow in 1991 resulted in the capture of six harbor porpoises (Suydam and George 1992).

<u>Major Environmental Influences</u>. Major environmental influences that might affect harbor porpoises near Point Barrow would include seasonal and temporary climatic shifts that would affect ice conditions and water temperature, indirectly affecting food resources that might attract harbor porpoises to the Point Barrow area.

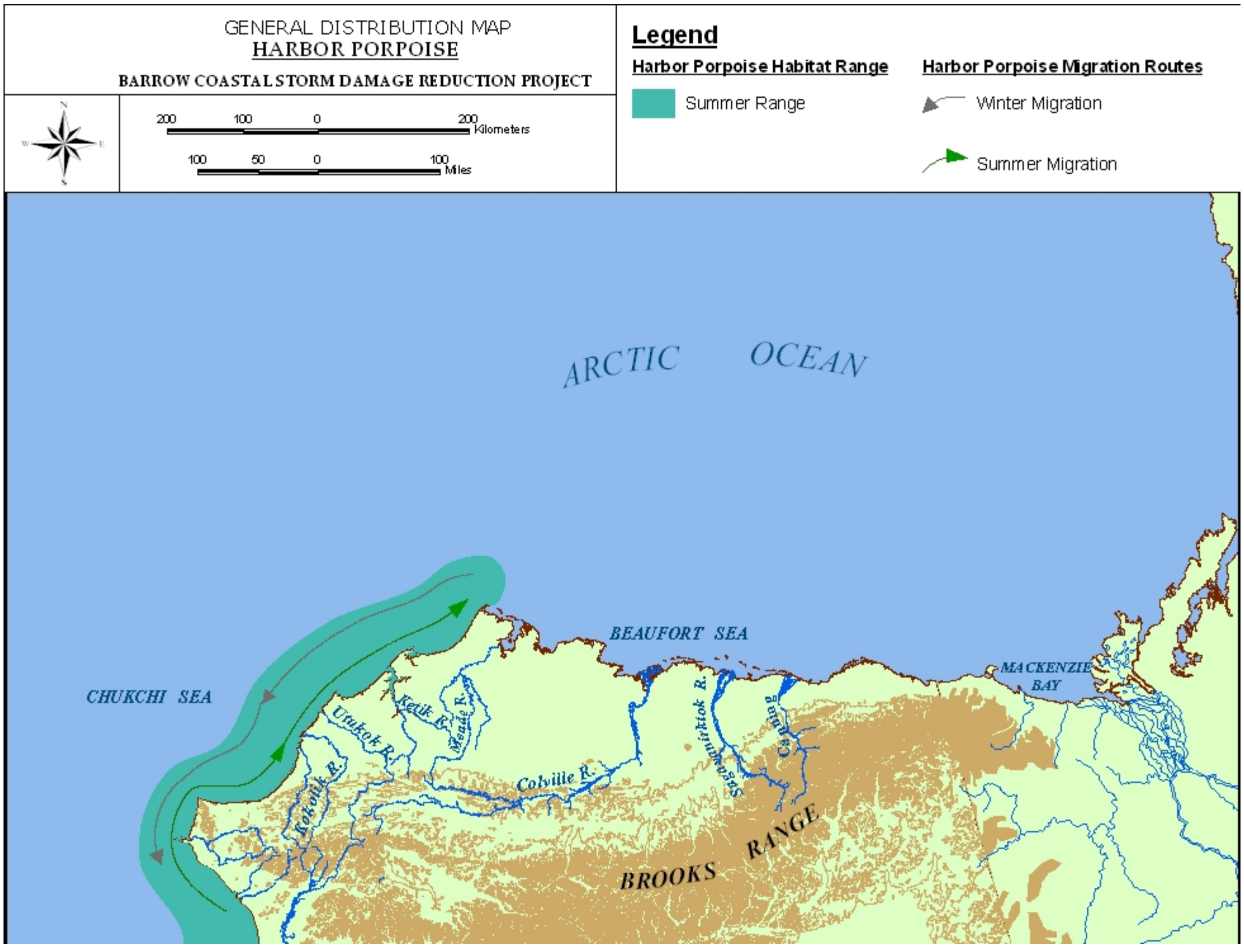

Figure 13. Seasonal movements of harbor porpoise through Bering Strait into the east Chukchi Sea and west Beaufort Sea.

Polar Bear

Distribution. Polar bears are circumpolar in distribution and consist of several stocks. Alaska has two stocks of polar bears: the Beaufort Sea stock (figure 14) and the Chukchi Sea stock (figure 15). The ranges of these two stocks overlap in the northeastern Chukchi Sea between Point Hope and Point Barrow (Ferrero et al 2000, Kalxdorff 1997). Polar bears near Barrow could be of either stock.

Polar bears are more abundant near coastlines and the southern edges of sea ice than on the central Arctic ice pack. Most bears of the Chukchi stock migrate only as far south as Saint Mathew Island (Kalxdorff 1997). Some polar bears also winter along coastal areas farther north in the Chukchi Sea where there are concentrations of seals and marine mammal carcasses (Kalxdorff 1998). In the spring most polar bears that winter in the northern Bering Sea follow the ringed seals and receding ice north through the Bering Strait and Chukchi Sea.

Polar bears of the Chukchi stock normally live along the edge of the polar ice pack north of about latitude 72° during the summer months (Kalxdorff 1997). Some of the Chukchi stock moves near Wrangel Island when walrus are present, and many of the pregnant females den on Wrangel Island for the winter and give birth. Most polar bears that den on land in Alaska are from the Beaufort Sea stock and den east of Point Barrow, but some of the Chukchi stock den between Point Hope and Point Barrow where they intermix with the Beaufort Sea stock (USGS 2001). Polar bears of both stocks den on the ice pack north of Point Barrow.

Polar bears are common to Point Barrow and are known to gather in relatively large groups to feed on the remains of bowhead whales left on the beach by subsistence hunters from the community of Barrow. The ringed seal is a principal prey species of the polar bear near Barrow during winter. Most polar bears that feed on ringed seals near Barrow during winter follow the receding ice and ringed seals north during summer.

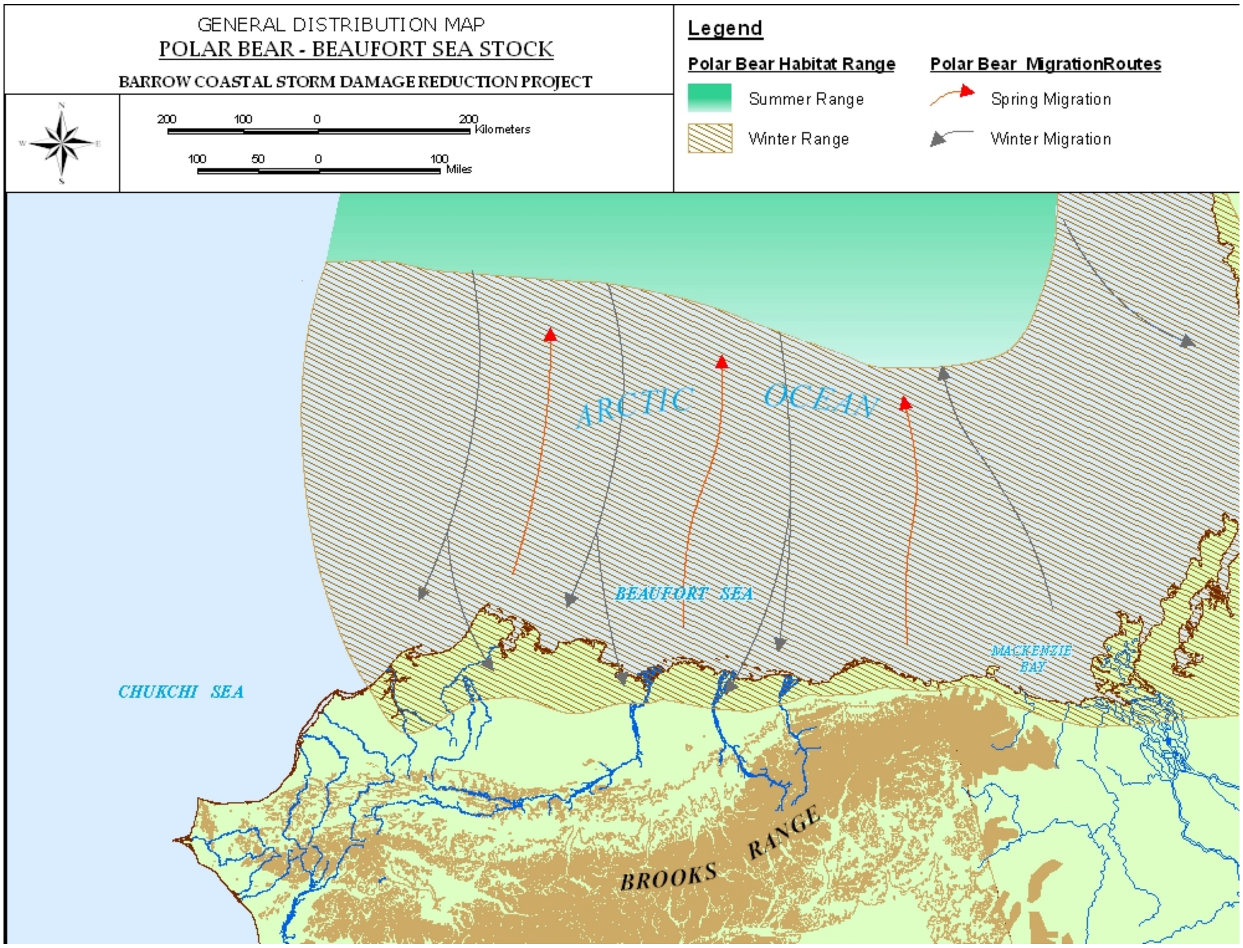

Figure 14. Seasonal movements of Beaufort Sea stock polar bears through the northern Bering Sea and Chukchi Sea.

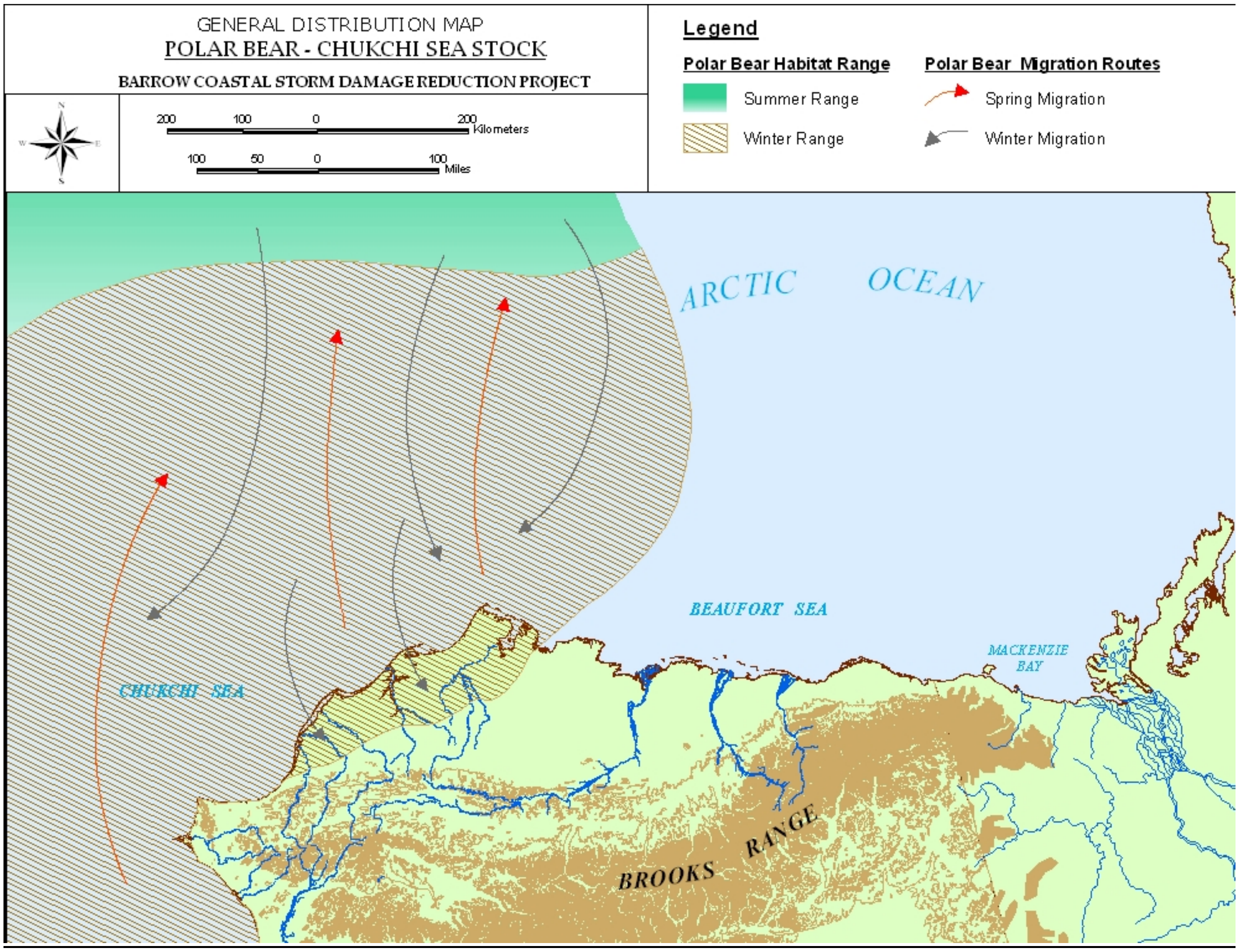

Figure 15. Seasonal movements of Chukchi Sea stock polar bears through the northern Bering Sea and Chukchi Sea.

<u>Life History.</u> The polar bear is the largest land carnivore on Earth. Newborn polar bears weigh about 1.5 pounds at birth. By the time they reach adulthood, male polar bears weigh from 800 to 1,500 pounds and may stand almost 10 feet tall, while adult females normally weigh from 330 to 550 pounds and are up to 8 feet tall. Female polar bears reach sexual maturity when they are about 4 years old, while males reach sexual maturity at about 6 years old. Males, however, do not successfully mate until they are about 8 years old. Cubs are born every 3 years in some populations and every 2 years in others. Adult females can gain as much as 440 pounds between conception and denning. Polar bears can live as long as 20 to 30 years in the wild, but few are thought to live past 18 years.

Predators of the polar bear are humans and other polar bears, particularly the larger, cannibalistic males that prey on cubs and smaller juveniles. Other sources of mortality include disease, parasitism, starvation, and accidents.

Ringed and bearded seals are the principal prey of the polar bears, although other species of seals, young walrus, and even beluga whales are sometimes taken (Kalxdorff 1997, Kalxdorff 1998; Lowery et al. 1987). Carrion such as dead whales, walrus, and seals also are eaten, as are occasionally caribou, fish, and seabirds and their eggs when other foods are not available.

Major Environmental Influences. Major environmental influences affecting polar bears include changes in prey abundance and thinning ice conditions that can make capture of prey more difficult. Climatic changes that might have an affect on terrestrial denning might also affect the population of the Beaufort Sea stock.

Terrestrial Mammals. The Alaska Department of Fish and Game manages terrestrial mammals on the Arctic Slope, including in the Barrow area. They also post wildlife management reports for the principal species on the Wildlife Conservation publication website. The State of Alaska is divided into management units and sub-units for management purposes, and Barrow is included in unit 26A.

Caribou. Caribou in northwestern Alaska, known as the Western Arctic Caribou Herd (WACH), range over 140,000 square miles (Dau 2001). The Barrow area is in the herd's peripheral range. Patterns of habitat use shift from season to season and vary from year to year. The well-being of caribou depends on freedom of movement to areas of favorable snow conditions, vegetative types, and insect relief. Caribou provide critical food, hides, sinew, and other resources for most residents of the borough. Many cows in the WACH calve at the headwaters of the Utukok, Meade, Ketick, and Colville rivers. The WACH winters primarily south of the Brooks Range or the North Slope south of Barrow.

A smaller herd, the Teshekpuk Lake herd, shares range with the WACH. This herd was estimated by the Alaska Department of Fish and Game in 2002 at 45,166 animals (ADF&G 2003). The overlapping range of these herds relative to Barrow is shown in figure 16.

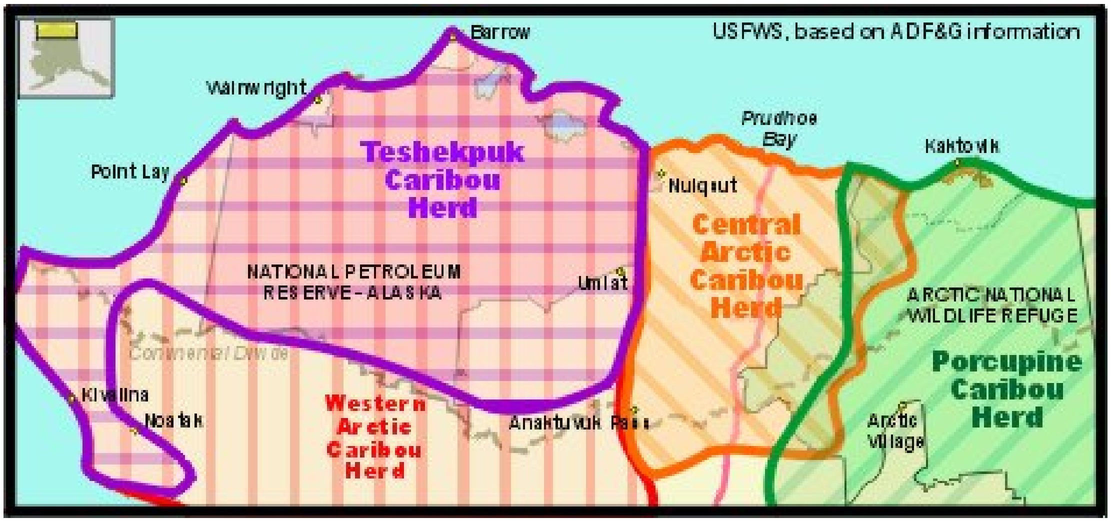

Figure 16. The range of Arctic Slope caribou herds in Arctic Alaska (Source: USFWS).

Moose. Moose are generally distributed along water courses in the Barrow area, and their principal predator, the gray wolf, is found throughout the North Slope. By late winter, most moose can be found in the riparian corridors, primarily on the Colville River drainage south of Barrow (Carroll 2004a). In late April, when snow cover begins to disappear in the foothills, moose begin to move away from the riparian corridors. In late May and early June, most pregnant cows move away from the river bottoms to calve. Bull moose disperse widely during the summer months, ranging from the northern foothills of the Brooks Range to the Arctic coast including near Barrow. Most cow moose move out of the river bottoms, but stay near riparian habitat during summer months, while some range onto the coastal plain. During the fall, as snow cover accumulates, moose move back into the riparian corridors of the large river systems. During summer, wolves prey on moose, caribou, sheep, ground squirrels, small rodents and birds. In winter wolves tend to congregate in areas and prey on wintering moose and caribou.

Brown Bears. Brown bears usually do not range onto the coastal plain, but are sometimes found on the Barrow Peninsula. The Alaska Department of Fish and Game estimates there are from 500 to 720 brown bears in Game Unit 26A east, which includes the Barrow Peninsula. Bear densities appear to be at high levels relative to the carrying capacity of the habitat (Carroll 2003).

Musk Ox. The musk ox population declined or disappeared from Alaska before the arrival of firearms, but firearms were an important factor in the final disappearance of musk ox from Alaska (Lenart 2005). The Alaska Department of Fish and game reintroduced musk ox to Barter Island and the Kavik River, east of Barrow, in 1969 and 1970. The number of musk ox increased steadily through the 1970's and 1980's and expanded their range eastward into Canada and by 2005 west to the Colville River. The Arctic Slope musk ox population has declined in recent years, but may be stabilizing. Natural mortality events and increased predation by brown bears may have contributed to the decline in some areas.

Gray Wolf. Management reports for wolves posted on the Alaska Department of Wildlife Conservation publication web page (ADF&G 2007) are dated by about 10 years. The abundance of gray wolves in Game Management Unit 26A (Western Arctic Slope) apparently peaked at about 4.1 wolves per 1,000 km^2 in 1994, but declined to an unknown density by 1998 (Carroll 2000). A reduction in the prey base, primarily moose, is believed the cause of the decline.

Furbearers. The status of furbearers near Barrow is reported in management reports posted by the Alaska Department of Fish and Game (Carroll 2004b). Red fox, Arctic fox, and wolverine are the only furbearer species commonly found in Unit 26A.Because of limited habitat, boreal forest species such as marten and coyote are rare and found only in the southern portion of the unit. Lynx expanded their range into Unit 26A during the late1990s.

No quantitative population information is available for lynx, red foxes, Arctic foxes, or coyotes in Unit 26A. Lynx were at low, but increasing density in Unit 26A. Red foxes were fairly abundant in interior regions of Unit 26A. Arctic foxes were abundant along the coastal plain in Unit 26A. Coyotes were occasionally seen along the southern border of Unit 26A. Hunters have reported that wolverines seem more numerous in Unit 26A in recent years, but there have been no recent population surveys. Magoun (1984) estimated a fall population size of 821 wolverines for Unit 26A, assuming an overall density of 1 wolverine/54 mi^2 for the entire unit.

Arctic fox move seasonally between summer breeding habitat in tundra and winter habitats along northern Alaska coast and onto the sea ice. Productivity of foxes is related to abundance of microtines (small rodents).

Small Mammals. Arctic ground squirrels are found in colonies restricted to well-drained soils free of permafrost. Ground squirrels hibernate from late September through May. Ground squirrels are important to the diet of snowy owls, rough-legged hawks, Arctic fox, and wolves. Other rodents found in the area include collared lemming, brown lemming, and tundra vole. Brown lemming is the leading herbivore along the coast. Their impact on the vegetation is cyclic and corresponds to the 3 to 5 year population cycle. Lemmings and voles are active all year, grazing frozen plant material and breeding under the snow. Shallow snow depths result in low temperatures under the snow, creating an energy stress that can reduce winter reproductive success.

2.10.2 Marine Resources (intertidal and shallow subtidal habitats)

Invertebrates. When compared with the Bering Sea, there are relatively few species of near-shore marine invertebrates in most areas of the northeast Chukchi Sea and west Beaufort Sea. For the most part, the shallows of the Beaufort Sea have a mud and silt bottom where attachment potential for some invertebrate species is limited. The one known exception is just east of Prudhoe Bay in the shallows of Stefansson Sound where there are several boulder patches between the shore and Cross Island and Narwhal Islands (Norton 1979). These isolated patches of invertebrate richness and diversity are apparently unique to the Stefansson Sound area in the Beaufort Sea. Similar boulder fields are not now known to exist offshore of Point Barrow, but may have been present in the past because MacGinitie (1955) reported isolated boulders in a "rubble zone" off Point Barrow while studying the ecology of marine invertebrates.

Infaunal benthic community composition is mainly determined by the grain size of sediments and the productivity of the overlying water masses (Grebmeier and Barry 1991). Perhaps the most detailed study of invertebrates at Point Barrow is that done by MacGinitie (1955), who described the substrate at Point Barrow as gravel on the beaches and out to about 6 meters (20 feet) deep, where it is replaced by extremely fine-grained and sticky blue clay, and chunks of tundra. The blue clay and tundra zone extended out to about 12 meters (40 feet) deep and 70 meters (75 yards) from shore during his study. Beyond the zone of blue clay and tundra, MacGinitie reported the bottom was composed of material ranging from small pebbles to boulders weighing tons. Beyond the zone containing boulders, the bottom consisted of finer gravel and shell beds. Contributing to a general lack of diversity and abundance of near-shore marine invertebrates in the Barrow area is likely the extent of near-shore shallow water, depth of freezing, ice gouging during winter, wave action during summer, and a general lack of suitable substrate shallower than about 12 meters deep. MacGinitie wrote detailed accounts of changing shoreline and bottom types at Barrow. Shoreline erosion was estimated to average 2.1

meters (7 feet) annually and rubble habitat studied by MacGinitie was covered by mud during a violent storm in October 1949.

MacGinitie (1955) grouped marine invertebrates at Point Barrow according to their feeding habits. He grouped free-swimming invertebrates as plankton feeders, bottom dwelling (infaunal and epifaunal) invertebrates as detritus and debris feeders, and animals that eat other animals as predators. Plankton feeders included jellyfish, ctenophores (comb jellies), and some amphipods. Detritus feeders included most marine worm, clams, bryozoans (colonial moss animals), and foraminifera (single-celled protests). Debris feeders, or scavengers, included sea urchins, some crabs, hermit crabs, and some snails. Predators included jellyfish, ctenophores, chaetognaths (a mostly planktonic predator of zooplankton), starfish, flatworms, anemones, certain isopods, amphipods, crabs, and some predatory snails. MacGinitie (1955) provides complete and detailed lists of marine invertebrates found in the respective habitat types at Point Barrow.

The diversity of species in offshore areas near Point Barrow tends to be low, but the abundance of individuals can be extremely high (MacGinitie 1955). The abundance and diversity of infauna (marine worms and clams) in near-shore water of the northeast Chukchi Sea and west Beaufort Sea in less than about 2 meters tends to be low during summer because of freezing of the shorefast ice to the bottom during winter (Broad et al 1981). High-energy wave action during summer storms and drifting ice cakes grounding against the shore (MacGinitie 1955) may also inhibit infaunal colonization of near-shore substrate. MacGinitie (1955) found that tunicates and bryozoans dominated the near-shore gravel zone.

Infaunal biomass and diversity tends to increase with depth out to the shear zone 15 to 25 meters (50 to 80 feet) deep, where ice gouging can destroy infaunal organisms (Conlan and Kvitek 2005). According to MacGinitie (1955), icebergs of “glacial origin” sometimes grounded and gouged the bottom to depths of at least 30 meters (100 feet) at Point Barrow up to at least the 1950’s. The abundance and diversity of infaunal organisms increases offshore of the shear zone where ice gouging is not likely to disturb the sea bottom. Near-shore ice processes and continual recolonization of infaunal invertebrate communities likely account for the low abundance and diversity typical of marine habitat in the immediate project area.

The abundance and diversity of epifaunal invertebrates, including amphipods, mysiids, and isopods, in water shallower than about 2 meters tends to be higher in summer than winter because mobile invertebrates from deeper water can rapidly recolonize near-shore waters during summer. Some species also find winter refuge in holes deeper than about 2 meters under shorefast ice where the ice does not freeze to the bottom.

Planktonic invertebrates in the Chukchi Sea and Beaufort Sea at Barrow are plentiful, but cyclical in abundance (MacGinitie 1955). These mostly microscopic invertebrates include copepods, amphipods, chaetognaths, and a diverse complement of veligers (mollusk larvae) and other invertebrate larvae. Planktonic invertebrates are an important component of the Arctic food web that sustains a diverse assemblage of marine mammals including the bowhead whale, fish, and seabirds.

Invertebrate biomass in the Bering Sea, Chukchi Sea, and Beaufort Sea is relatively well known (Dunton et al. 2003, Goodall et al. 2003). Clearly, the benthic biomass population in the Beaufort Sea is distinct from that of adjacent Arctic seas with relatively shallow continental shelves. The mean benthic biomass concentration in the Beaufort Sea is relatively low at 33 gm-2 when compared with the mean benthic biomass concentrations in the Chukchi Sea (167 gm-2), East Siberian Sea (225 gm-2), and the Bering Sea (370 gm-2). Dunton et al. (2003) suspects that higher areas of benthic biomass are the result of high rates of primary production or an abundance of advected carbon settling directly to the seafloor. Benthic biomass immediately east of Point Barrow is relatively low compared with the benthic biomass west of Point Barrow where a high area of biomass concentration (360 gm-2) is found on Hanna Shoal. Benthic biomass decreases immediately east of Point Barrow, but increases to 200 gm-2 off the mouth of the Colville River where large amounts of carbon may be introduced to warmer near-shore waters.

Benthic invertebrate surveys were conducted near Barrow, Alaska, from 11 through 16 August 2004 (Hoffman 2004). Surveys were also conducted near a potential gravel source at Cooper Island, approximately 25 miles northeast of Barrow. These surveys were intended to determine the abundance and local distribution of crabs and infaunal invertebrates that might be present in areas where gravel would potentially be mined (Cooper Island) and deposited (Barrow shoreline) to assess the potential impacts of erosion control measures along the Barrow coastline.

Five sites were sampled along the Barrow coastline and six locations were sampled near Cooper Island (figure 17). Crab pots baited with Pacific herring were soaked for approximately 72 hours at Barrow and for 24 hours near Cooper Island. Attempts to obtain benthic grab samples using a 1 m^3 dredge were taken at all stations, but valid (i.e. full load in the dredge) could not be obtained because a compacted silt/clay layer on the surface was nearly impenetrable to the dredge.

No crabs or invertebrates were caught offshore from Barrow or at Cooper Island.

Marine Algae. Two general types of marine algae are in Arctic waters: attached and floating microscopic algae and diatoms, and attached macroscopic marine kelp. Probably no other feature of the marine biota of the Point Barrow area is more striking than the absence of a macroscopic benthic algal component (Mohr et al. 1957). Although marine kelp is relatively rare in the Northeast Chukchi Sea and Beaufort Sea because of its association with rocky substrate, there are a few areas in the Beaufort Sea where marine algae grow in abundance (Dunton 1990, Dunton et al. 1982). One such area rich in attached marine macro algae is the boulder patch in Stefansson Sound near Prudhoe Bay. Here, boulder patches dominated by several species of brown and red kelp are apparently not subject to seafloor sedimentation or ice gouging. Closer to Barrow, laminarioid marine kelp was found on rocky bottom 80 km (50 miles) southwest of Point Barrow in

1954 (Mohr et al 1957) and approximately 225 km (140 miles) east of Point Barrow off the mouth of the Colville River. According to MacGinitie (1955) and Mohr et al. (1957), there is almost a total lack of marine kelp in the immediate Barrow region, and marine kelp will not be discussed further in this draft EIS.

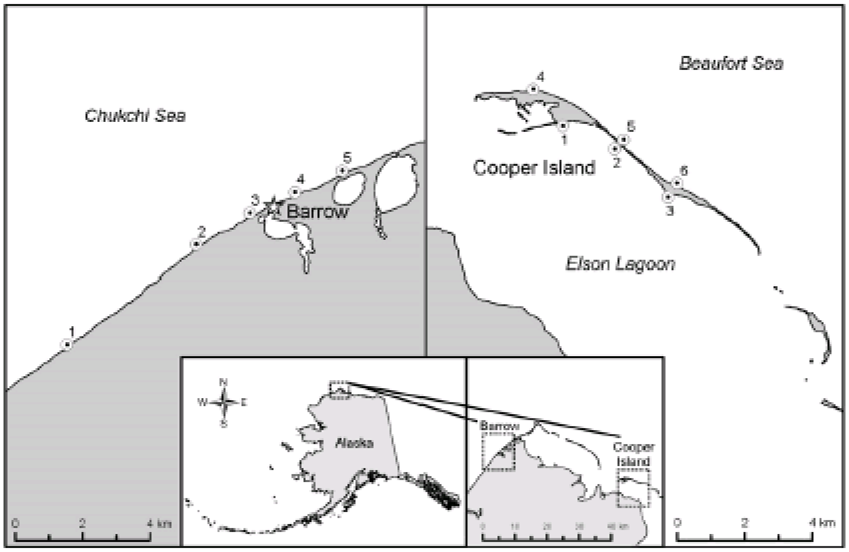

Figure 17. Benthic invertebrate sampling locations near Barrow and Cooper Island, in 2004.

More than 100 species of phytoplankton, mostly diatoms, dinoflagellates, and flagellates are identified from the Beaufort Sea (MMS 1987). Pelagic phytoplankton, epifaunal plankton, and epontic plankton will be discussed in more detail because of their role as primary producers in Arctic seas.

Dramatic plankton blooms that are typical of more temperate near-Arctic waters are not typical in Arctic waters. Rather, there is a gradual, moderate increase in phytoplankton biomass that begins in late spring with ice break-up, peaks in mid-summer when sunlight is most intense, and decreases in late summer when the days shorten. Plankton communities that live on the under surface of ice (epontic communities) and that are attached to the bottom substrate as benthic microalgae, consist mostly of diatoms. The biomass of these epontic diatom communities increases rapidly on the undersurface of ice in early spring. Available light limits the growth of Arctic phyto and epontic plankton where ice and snow cover and Arctic darkness limit light penetration during the winter. Sediments frozen into the ice can also affect light penetration in local near-shore areas where sediments stirred into suspension by late fall storms did not have time to settle out before ice formation (MacGinitie 1955).

Compared with more temperate seas, primary productivity in the Beaufort Sea is relatively low at <150 gC/m^2-yr (NOAA et al. 2003). Dunton et al. (2003) integrated chlorophyll *a* data from the Chukchi Sea and Beaufort Sea to examine linkages between water column productivity and benthic biomass. Chlorophyll *a* concentrations were as high as 150 µgL^{-1} at Hanna Shoals west of Point Barrow and decreased east of Point Barrow. Dunton et al. (2003) concluded that compared with other mapped regions, chlorophyll *a* concentrations are generally lower in the Beaufort Sea with the exception of waters surrounding Barter Island, approximately 500 km (310 miles) east of Point Barrow where chlorophyll concentrations reach 80µgL^{-1}. Schell and Homer (1981) estimate that epontic algae contribute 5 percent of the annual total primary production in near-shore Beaufort Sea coastal waters.

2.10.3 Birds

Ducks, Geese, Swans, and Mergansers. Point Barrow is bordered east, south, and west by the National Petroleum Reserve-Alaska (NPR-A) (figure 18). NPR-A, including Point Barrow, is important to many waterfowl species including tundra swan, Canada goose, northern pintail, old squaw duck, greenwing teal, black scoter, common goldeneye, red-breasted merganser, common eider, king eider, Steller's eider, and spectacled eider. Many of theses species nest in the mosaic of habitats on the NPR-A tundra. The threatened Steller's eider nests near Barrow.

Most waterfowl eggs have hatched by mid-July, but young ducks and geese cannot fly until August. Some species, such as Canada geese, black brant, and snow geese, congregate in coastal areas and graze on vegetation in saline and brackish meadows, laying on fat for energy to carry them south during the fall migration. Snow geese congregate in large colonies that can include thousands of geese. There are three colonies of snow geese on the north slope of Alaska (Suydam 1997), but none are in the immediate vicinity of Point Barrow. Up to 32,000 Pacific black brant (25 percent of the world population) and 30,000 individuals of other goose species molt annually on Teshekpuk Lake Special Area (TLSA) on the National Petroleum Reserve in Alaska (Derksen 1978, King 1984).

By late August and early September, flocks of waterfowl migrate along the coast or over the tundra. Waterfowl leave northern Alaska by several routes. Brant fly west along the Beaufort coast and then southward, ultimately ending up in Baja California. Snow geese and white fronted geese fly eastward to the Mackenzie River Valley and then turn southward toward destinations in the southern United States and Mexico.

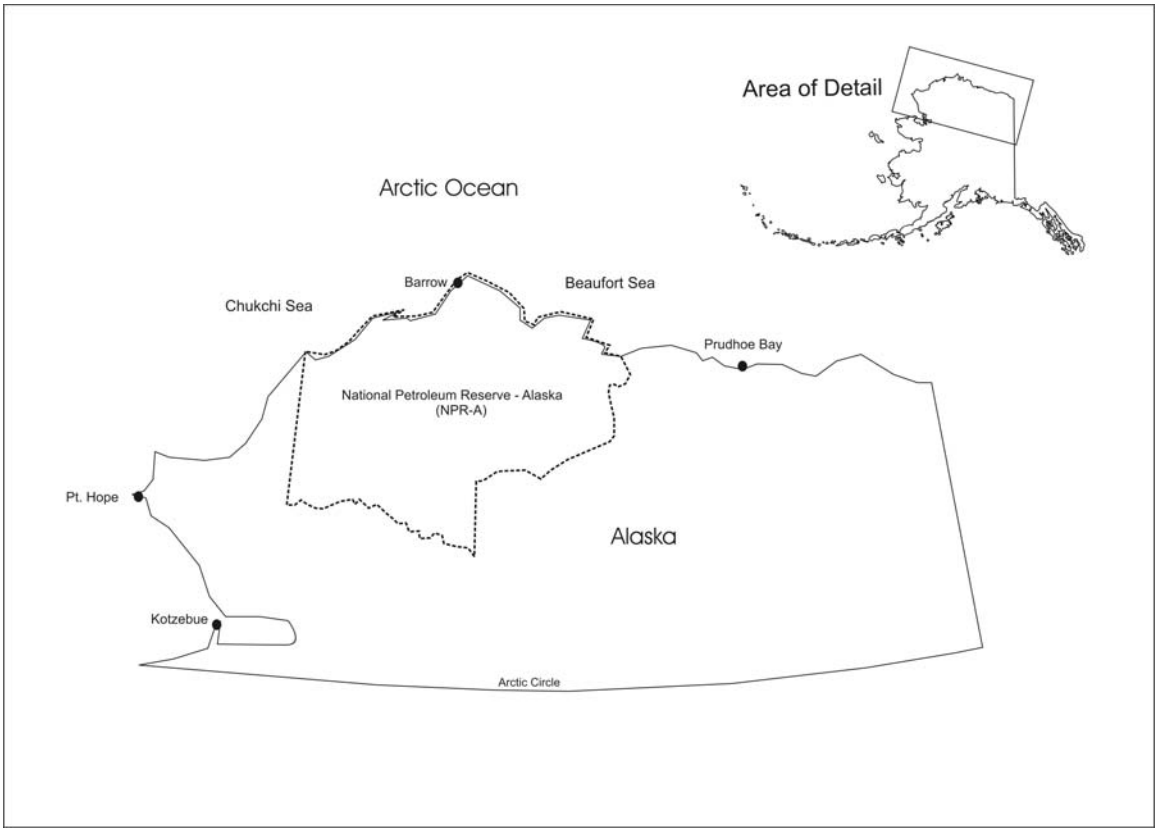

Figure 18. Arctic Alaska and the National Petroleum Reserve, Alaska (NPR-A).

All birds molt at least once each year. Waterfowl including ducks, geese, and swans lose their flight feathers at one time, rendering them flightless and vulnerable to predators. Many waterfowl move to protected areas where food is abundant and they are safe from predation. For example, oldsquaw move to sheltered lagoons along the Beaufort Sea coast and eiders move to marine molting areas offshore. Offshore molting areas for Steller's and spectacled eiders are designated as critical habitat for these species (FWS 2004).

Eiders are among the most important sea ducks in the Barrow area. Four species—common, king, spectacled and Steller's—are found at Barrow. The number of king eiders migrating past Point Barrow has declined in recent years. Previous migration counts estimated that 800,000 to 1 million eiders passed Barrow, but only an estimated 300,000 to 400,000 king eiders migrated past Barrow in the spring of 1996 (Suydam et al 2000 in MMS 2004). Aerial surveys by the USFWS reveal that some of the highest concentration areas for nesting king eiders on the North Slope occur just southeast of Teshekpuk Lake (Suydam 1997).

A remnant population of threatened Steller's eiders estimated at about 1,000 birds nests on the central Arctic coastal plain between Wainwright and Prudhoe Bay and primarily

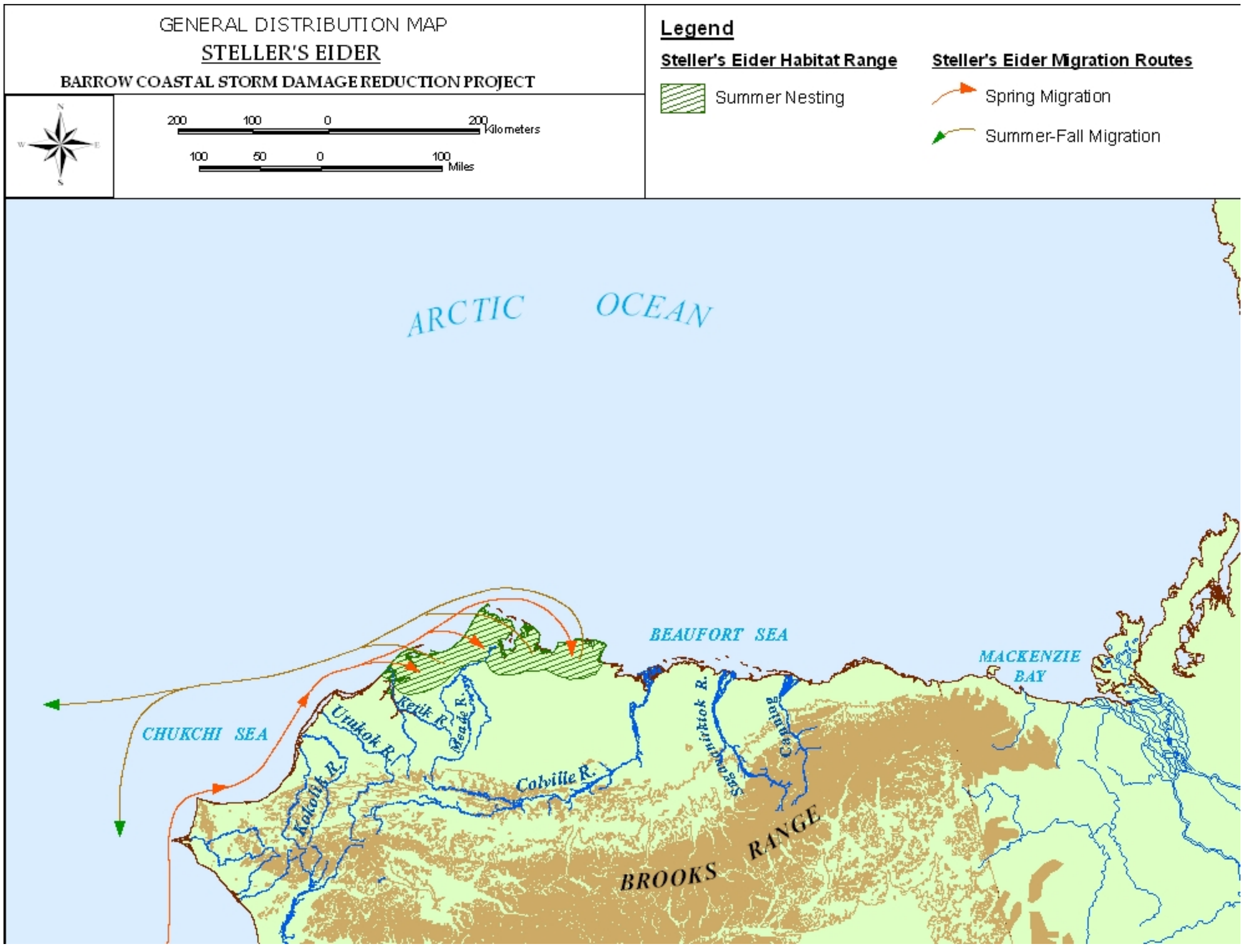

Figure 19. Steller's eider migration and nesting range.

near Barrow (FWS 2004) (figure 19). An estimated 7,000 pairs of spectacled eiders nest on the Arctic Slope from about Wainwright east to Prudhoe Bay (FWS 1998) (figure 20).

During the 1990's about 72,600 common eiders migrated past Point Barrow in May and June and again from August through October (Suydam et al. 2000). Data on how common eiders use Beaufort Sea waters is fragmentary except during the brood rearing period when successfully nesting hens and ducklings are found near barrier islands. Staging areas for these nesting eiders are not well documented. Spectacled eider migration and nesting patterns are shown on figure 20.

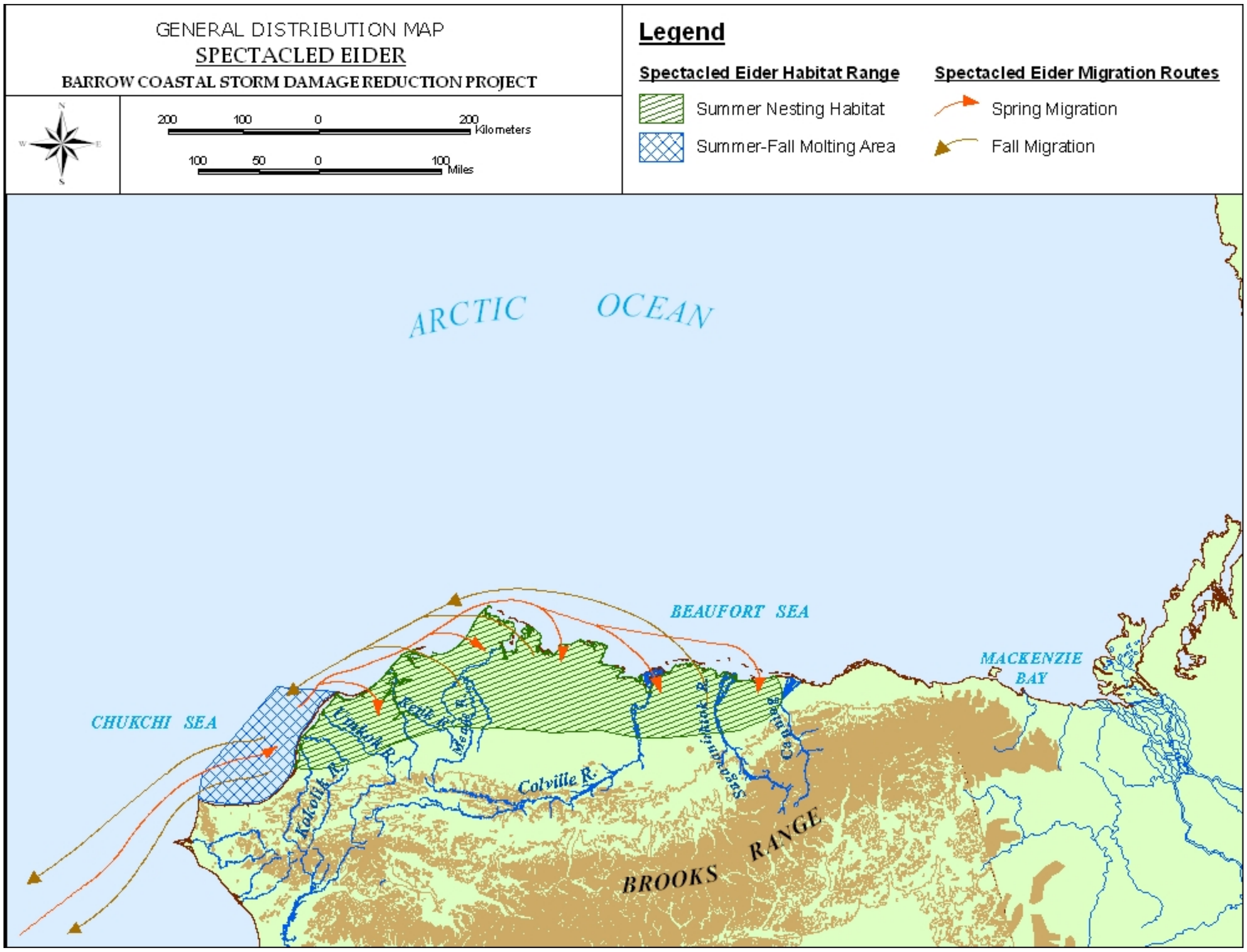

Figure 20. Spectacled eider migration route and nesting range.

Cranes. One species of crane, the sandhill crane, is a summer visitor to the NPR-A, including Point Barrow. This large crane nests in solitary pairs on the tundra, but forms large flocks similar to geese during migrations. Sandhills are omnivorous. In the Arctic they eat mostly tundra berries, plant roots, small rodents, and the young of ground-nesting birds.

Seabirds, Gulls, Terns, Loons, and Phalaropes. Many non-breeding seabirds occupy marine waters of the Chukchi and Beaufort seas offshore of Point Barrow during summer, but some species including gulls and loons nest on inland tundra ponds. Some common marine seabirds found near Barrow include black guillemots, common and thick-billed murres, horned puffins, and fulmars. A colony of up to 200 black guillemots nests on Cooper Island, a barrier island 40 km (25 miles) east of Point Barrow (Friends of Cooper Island 2004). The Kittlitz's murrelet has been listed as a Candidate species under the Endangered Species Act. Figure 21 indicates its range in the Barrow area.

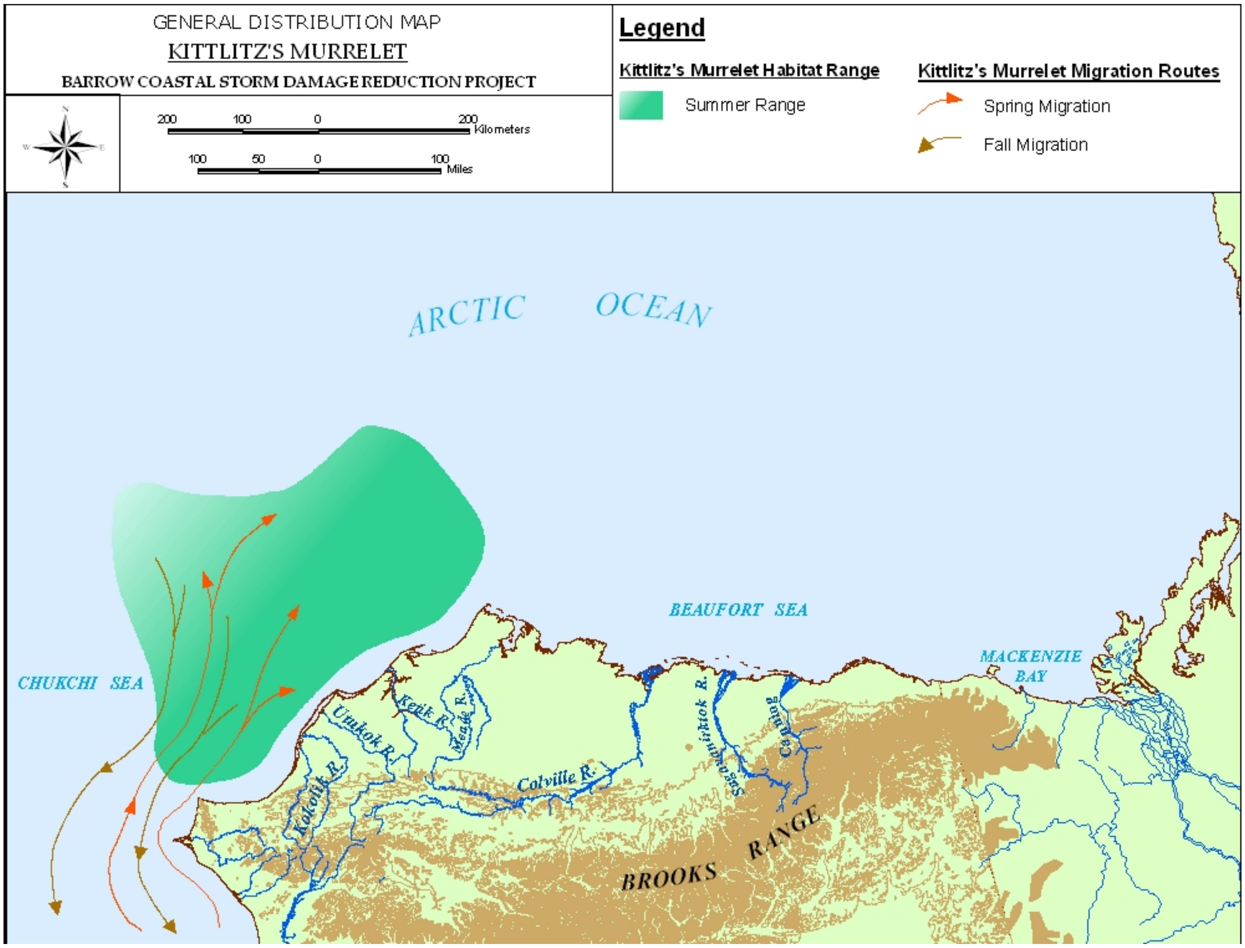

Figure 21. Range of Kittlitz's murrelet in the Chukchi Sea.

Several species of gulls are common in the Point Barrow area. These gulls include the mew gull, black-footed kittiwake, glaucous gull, and Sabine's gull. The similar appearing Bonaparte's gull might be less common in the Barrow area. The Arctic tern is also a common summer visitor to the Barrow area.

Four species of loons are found near Barrow. These loons include the common loon, yellow-billed loon, Arctic loon, and red-throated loon. Non-breeding birds can be found in marine waters, but breeding birds mostly nest on tundra lakes and ponds that support fish.

Phalaropes are small sandpiper-like birds of which two species occupy offshore marine waters much of the year. Both these pelagic species, the red and northern phalarope, are found in marine and inland waters in the Point Barrow area.

Shorebirds. Shorebirds include three species of plovers and numerous species of sandpipers. Plovers common in the Point Barrow area include the golden, black-bellied, and semipalmated plovers. Sandpipers include whimbrel, bar-tailed godwit, spotted sandpiper, long-billed dowitcher, ruddy turnstone, black turnstone, rock sandpiper, pectoral sandpiper, knot, dunlin, Barid’s sandpiper, semipalmated sandpiper, and possibly the western sandpiper. Although not a shorebird, the common snipe is also a regular summer visitor to Point Barrow. Most all these species nest on the tundra of the NPR-A, including Point Barrow, and non-breeders of many species might be present near the project area.

Tundra surveys (Hoffman 2005) were done to assess habitat use by breeding shorebirds near a potential gravel source on the south side of Emaiksoun Lake (figure 22). These surveys were conducted to verify local conditions with known breeding habitat associations of various species of shorebirds. The Barrow Spit was surveyed in August to determine use by post-breeding shorebirds and waterfowl (figure 23).

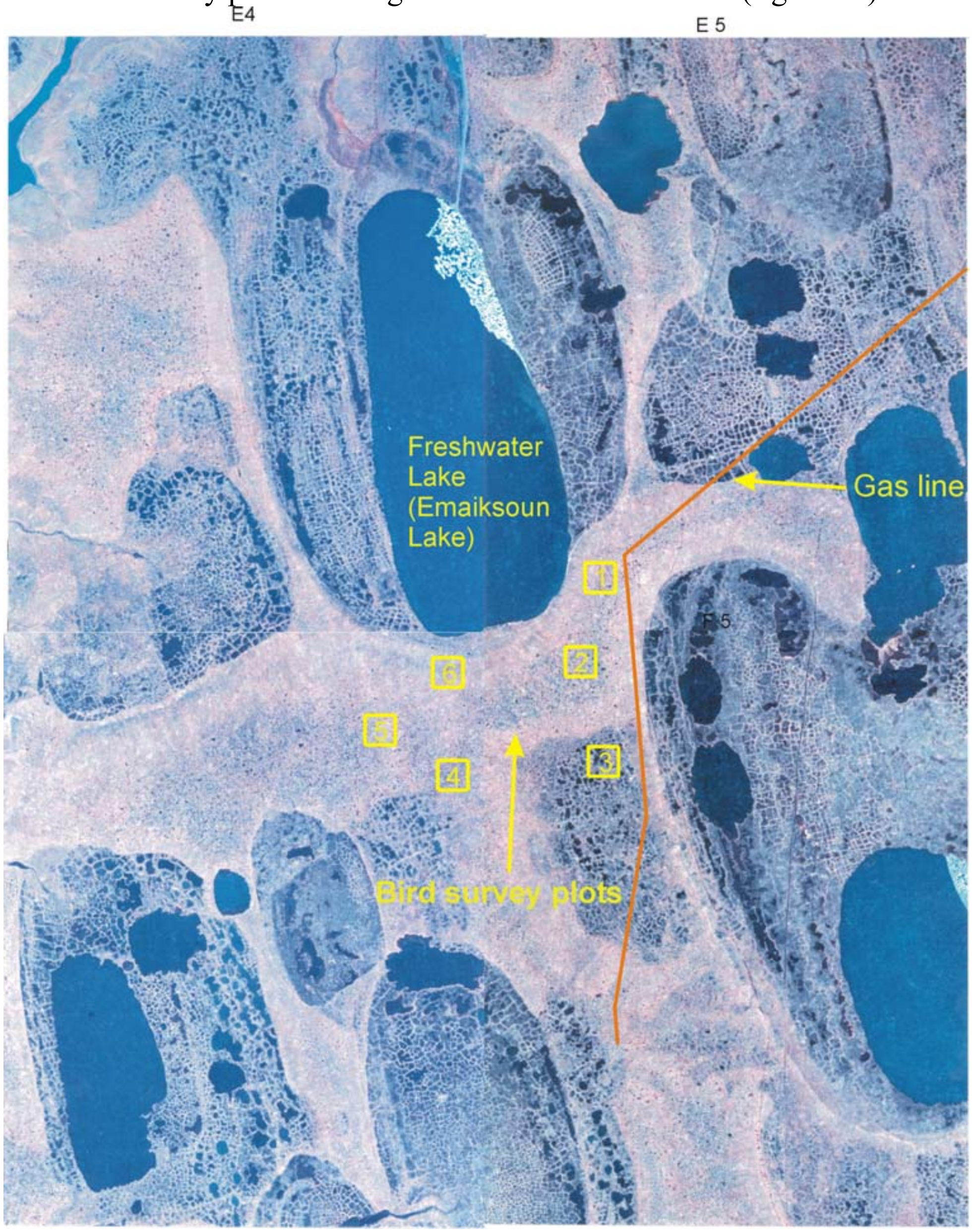

Figure 22. Breeding shorebird survey locations on the tundra south of Emaiksoun Lake.

Birds seen on the tundra surveys are in table 18. Species alpha codes used for this survey are those published in the American Ornithological Union (AOU) Check-list of North American Birds, Seventh Edition (AOU 1998) and include the changes made by the 47th supplement to the check list (Banks et al. 2006).

Lapland longspurs (LALO) were the most common bird and were observed in almost every plot. Plot locations are shown in figure 23. Pectoral sandpipers (PESA) were the

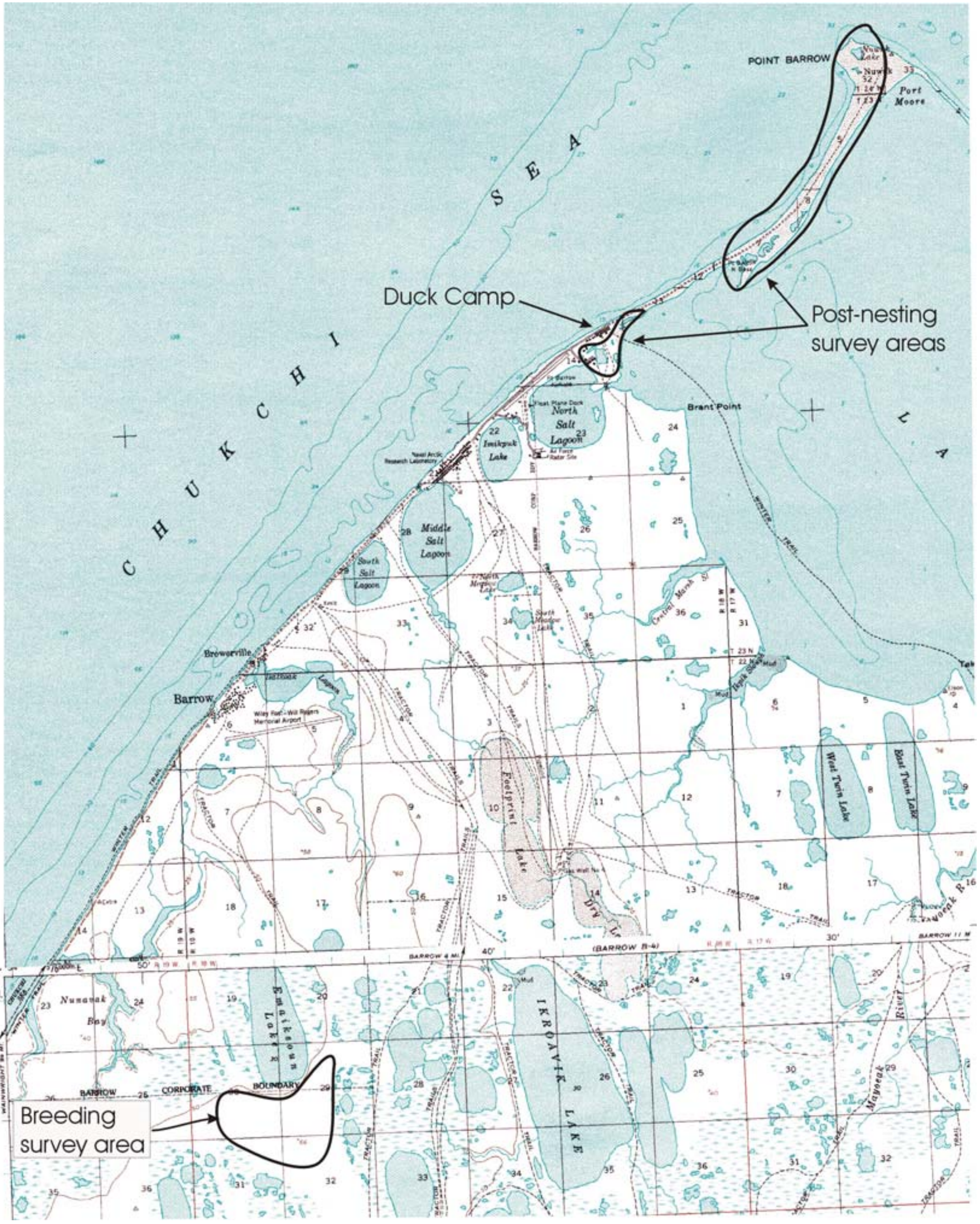

Figure 23. Barrow June and August 2005 shorebird surveys location map.

next most abundant bird, but were observed in fewer sectors. Nesting birds were not encountered in the survey plots, but detailed nest plot surveys were not conducted.

Of the six survey plots on the tundra, only one (plot 3) was on wet tundra with shallow ponds; all others were on dry tundra. The tundra plot surveys provide an indication of the bird species that might be impacted by development of a gravel pit south of Emaiksoun Lake. Since there is typically within-year variability in abundance, it is difficult to determine the number of birds that would be impacted by a gravel pit at this location.

Table 19. Tundra Shorebird surveys, June 2005.

Date:	Observers:			Order of Sectors Surveyed:			
19-Jun-05	Hoffman			Start Time: 1420			End Time:1506
Wind Speed:	Direction:			Min.Temp (°C):		Max Temp (°C):	
15 G20 mph	East			-1		1	
Time Begin:	1420	1451					Weather: snow and fog
Time End:	1435	1506					
Sector #	**1**	**2**	**3**	**4**	**5**	**6**	
LASO	2	3	Not surveyed this day.				
DUNL	1						
PESA		3					

19-Jun-05	Hoffman			Start Time: 1420			End Time:1506
Wind Speed:	Direction:			Min.Temp (°C):		Max Temp (°C):	
15 G20 mph	East			2		4	
Time Begin:	1420	1451					Weather: snow and fog
Time End:	1435	1506					
Sector #	**1**	**2**	**3**	**4**	**5**	**6**	
LALO	2	3	Not surveyed this day.				
DUNL	1						
PESA		3					

Date:	Observers:			Order of Sectors Surveyed: 1-6			
20-Jun-05	Hoffman			Start Time: 1330			End Time:1624
Wind Speed:	Direction:			Min.Temp (°C):		Max Temp (°C):	
calm	variable			0		2	
Time Begin:	1330	1350	1417	1501	1541	1609	
Time End:	1345	1405	1432	1516	1556	1624	Weather: p/c
Sector #	**1**	**2**	**3**	**4**	**5**	**6**	
LALO	1	4	2		4	2	
PESA		2	8	1			
GWFG			4				
REPH		3					
WESA				2			

Observations during the post-breeding survey on the spit are included in figures 24 and 25. A mud plume on the day of the survey due to northeast winds may have affected bird distribution near the tip of the spit. On this day, sea ducks were foraging near the edge of a mud plume in the lee of the spit. Shorebirds were not encountered during the survey, but use of the spit by post-breeding shorebirds is generally limited to mid-August to early September. Their presence near ponds in these locations often varies depending on the time of day.

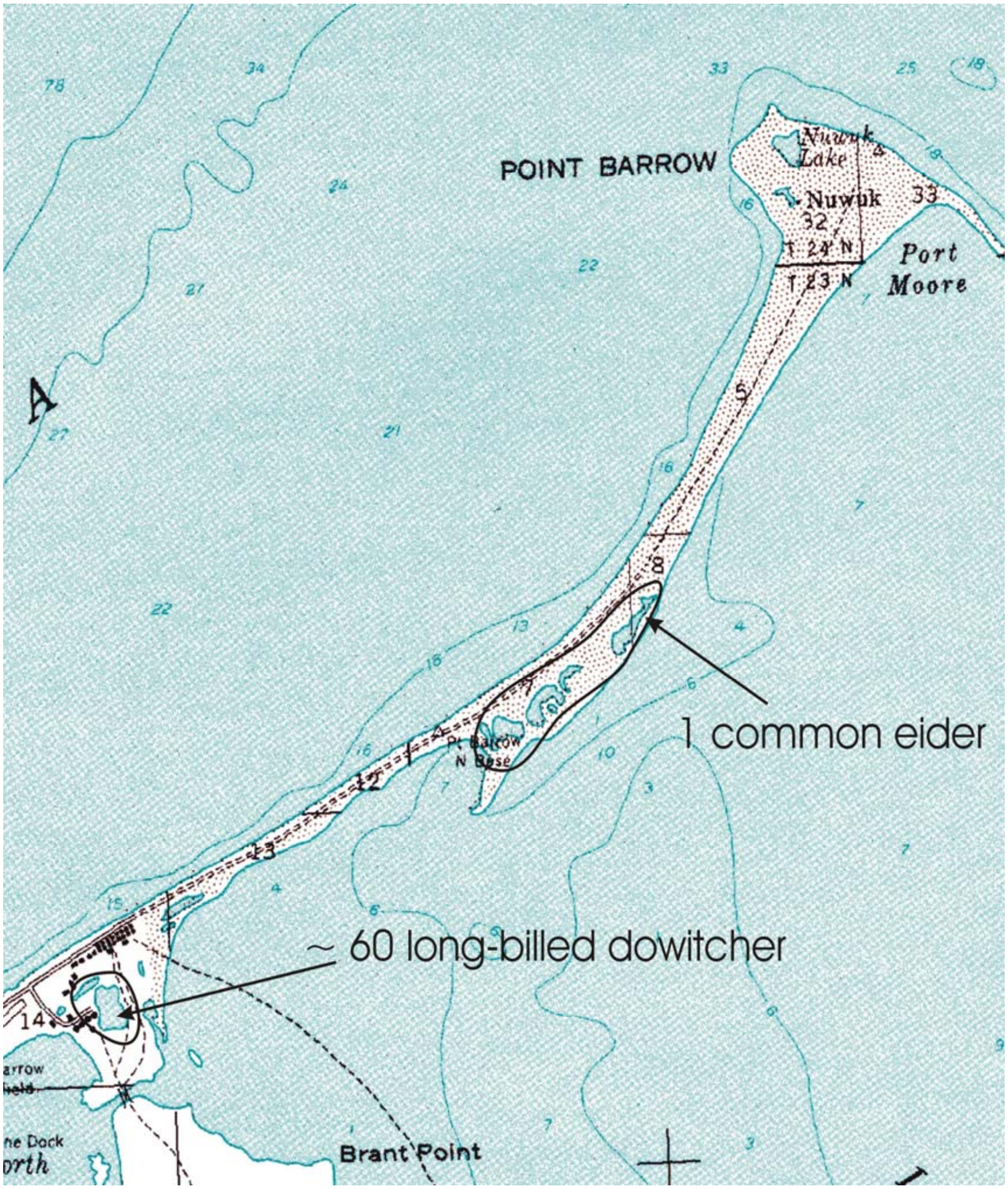

Figure 24. Bird observations near the base of the spit.

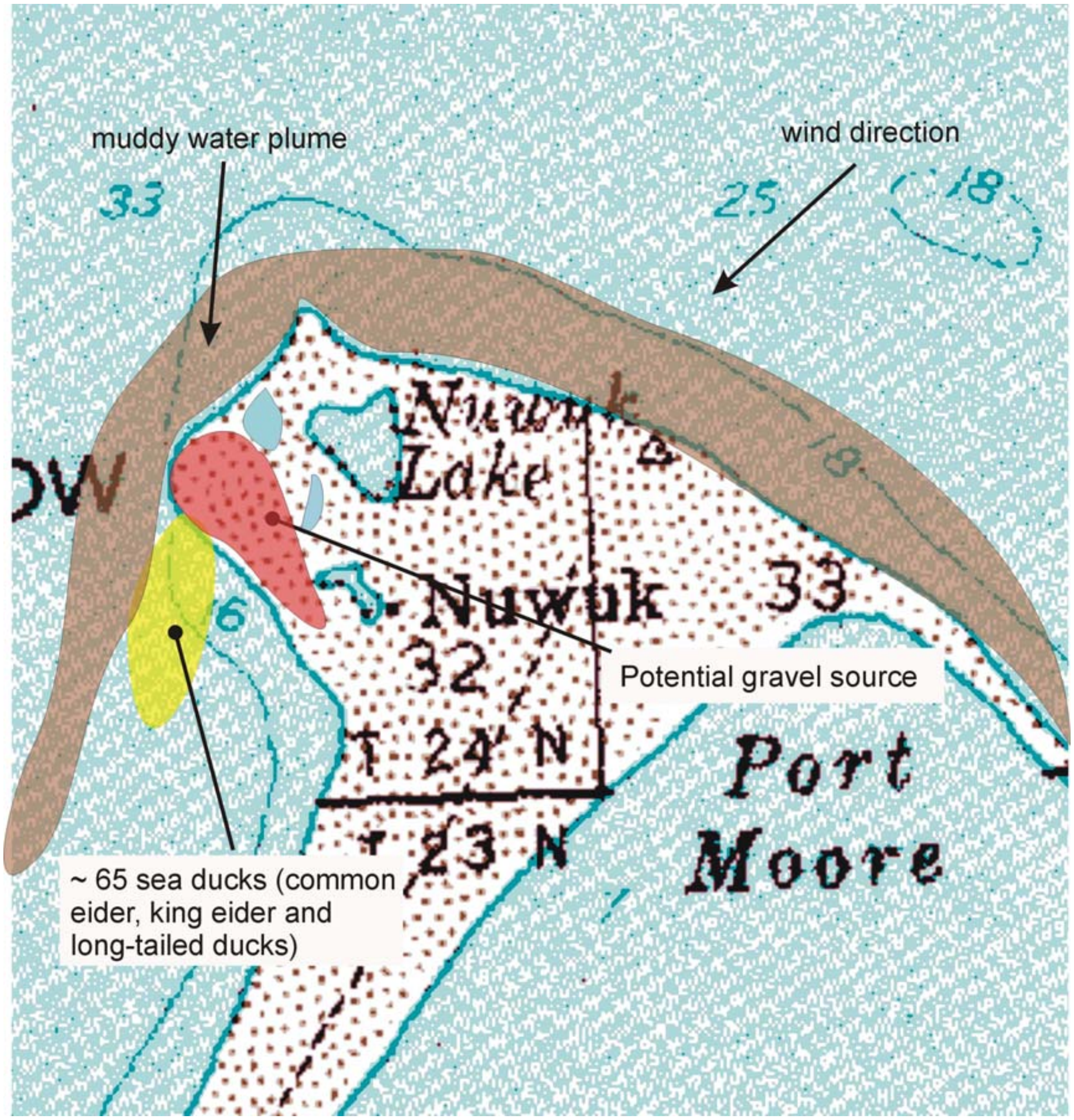

Figure 25. Bird observations near the tip of the spit.

Habitat on and near the spit is used for foraging by post-breeding shorebirds and as resting and foraging habitat for some sea ducks. For shorebirds, the food resources provide an important source of energy after the energetic demands of the breeding season and in preparation for fall migration. Waterfowl are not known to nest on the spit (common eiders often nest on barrier islands in the region) and the degree of disturbance from ATVs and tour vehicles in the summer make this area unlikely nesting habitat for most bird species. It seems negative impacts to birds from gravel extraction on the spit could be minimized if the gravel source was the accretion area on Point Barrow, and the existing ponds that provide habitat for shorebirds was not removed. If the ponds were not impacted, timing windows during parts of August and September could reduce most impacts to birds.

Seasonal habitat use within shorebird groups is variable, but there is a marked general post breeding movement by many species from tundra habitat occupied by nesting birds to marine littoral zones, salt march, and barrier island habitats for staging in late summer (early August) and migration into early September (MMS 1998).

Jaegers. Three species of this predatory, gull-like bird are found at Point Barrow. These species include the parasitic, pomarine, and long-tailed jaeger. The smaller, long-tailed jaeger is perhaps the most numerous of the jaegers. These predatory birds often prey on small rodents and the young of other birds.

Hawks, Falcons, Owls, and Eagles. Several owls are summer visitors to Point Barrow, and one species, the snowy owl can be found in the Barrow area much of the year. Summer visitors to the Arctic tundra include the short-eared owl, and possibly the great horned owl, great gray owl, boreal owl, and hawk owl.

Hawks that visit the Arctic tundra during summer include the rough-legged hawk and Northern harrier. The sharp-shinned hawk, gyrfalcon, peregrine falcon, and pigeon hawk are also found on Arctic tundra and could occasionally be seen near Barrow.

Golden and bald eagles may also visit the Barrow area on occasion.

Hawks, falcons, and owls primarily feed on rodents, snowshoe hairs, and smaller birds. Snowy owls are common in Barrow and their presence is more common during years with high populations of lemmings.

Terrestrial Birds. Terrestrial birds include numerous species represented mostly by sparrows, swallows, thrushes, warblers, redpolls, finches, buntings, the horned lark, the common raven, the ruby kinglet, the water pipit, white and yellow wagtail, northern shrike, and willow and rock ptarmigan. The common raven and bank swallow are attracted to man-made structures as nesting habitat, and are sometimes found in Arctic villages as a result.

2.10.4 Vegetation, Wetlands, and Associated Wildlife Uses

The diversity of plant and animal species is more limited in the Arctic than in more temperate regions. As a result of the cooling influence of the Arctic Ocean on the summer climate, the number of plant species in coastal areas, such as Barrow, is further reduced relative to the interior of the Arctic Coastal Plain.

Brown et al. (1980) report 124 species of vascular plants (sedges, grasses, rushes, and a limited number of low-stature shrubs), 177 species of mosses, and 49 species of hepatics (liverworts) identified in the Barrow area. Lichens are also indigenous to the coastal tundra. All these plant species are particularly adapted to the arctic climate and tundra terrain of the region, and the niches within which many flourish are highly specific. Two factors that control the local distribution of plants are the moisture content and pH characteristics of the soils. These factors, particularly moisture content, can vary considerably over small distances. Gersper et al. (1980) described meadows, ice-wedge polygon troughs, rims and basins of low-centered polygons, and centers of high-centered polygons as five micro topographic units of the coastal tundra. Soil-moisture content often differs considerably among these units. As a result, the vegetation patterns in areas of ice wedge polygons often vary substantially over short distances (Brown et al. 1980).

North Slope vegetation has been classified by the Circumpolar Arctic Vegetation Mapping Team (2003) in geobotanical areas based on bioclimate subzones, topography, substrate chemistry, and plant biomass. Barrow is within bioclimate subzones B and C characterized by the presence of a wetland complex dominated by sedges, grasses, and mosses. The elevation only ranges from sea level to 5 meters along the northern shores of Elson Lagoon, rising to a little more than 10 meters southwestward across the peninsula (Brown et al. 1980).

Typical landscape ranges from floodplains and gently sloping stream banks to highly polygonized relief, drained lake basins and shallow oriented lakes and ponds. Most landform variations are observed at meso- and micro-scales. Polygons are found in poorly drained areas displaying a wide range of micro-topographic units from almost xeric conditions on tops of high centered polygons and rims of low-centered polygons to waterlogged conditions and standing water in low-centered polygon basins and troughs. Microtopography variations cause changes in soil moisture usually within a few meters of distance. This is reflected in a mosaic of vegetation communities and habitat types within small distances (Webber et al. 1980).

Where the microrelief is exposed to thin snow cover, winds or sandy soils are present above the water table (creek banks, low-centered polygons rims and high-centered polygon tops), vegetation is exposed to extreme and unusually drier conditions. Typical vegetation communities at these sites include Luzula heaths, least willow heaths, and watersedge/arctic bluegrass communities. Luzula heaths' dominant species include northern woodrush (*Luzula confusa*), arctic cinquefoil (*potentilla hypartica*), and witch's hair lichen (*Alectoria nigricans*) among others. Least willow heaths are dominated by least willow (*Salix rotundifolia*), graminoids such as tall arctic grass (*Arctagrostis latifolia*), heart-leaved Saxifrage (*saxifraga nelsoniana*), and coral lichen (*Sphaerophorus globosus*), whereas watersedge/arctic bluegrass communities are dominated by watersedge (*Carex aquatilis*), arctic bluegrass (*Poa arctica*), and arctic woodrush (*Luzula arctica*). Watershed/arctic bluegrass communities are found extensively in the Barrow site vicinity, not only on polygon rims and tops, but also on dry, relatively undeveloped polygon sites (Brown et al., 1980).

As the moisture level increases, vegetation changes into watersedge/ Wahlenberg's oncophorus moss (*Oncophorus wahlenbergii)* communities in moist, flat sites and drained polygon troughs and marshgrass/tall cottongrass (*Dupontia fisheri/ Eriophorum angustifolium*) meadows in wet, flat sites and troughs. In areas where standing water is present during the growing season or during the wettest years (basin of low-centered polygons, ponds and stream margins), only species adapted to waterlogging are able to thrive. In such areas, watersedge/red cottongrass (*Eriophorum russeolum*) meadows and polar grass (*Arctophila fulva*) meadows are predominant. Other species forming part of such communities include leafysteam saxifrage (*Saxifraga foliolosa*), Gmelin's buttercup, (*Ranunculus gmelinii*), and several species of mosses and lichens.

Barrow's shoreline is predominantly a gravelly beach ranging from 40 feet to 250 feet wide and exposed to high winds, storm surges, salinity, and the grounding effects of shore ice. Few plant species can withstand such extreme conditions; therefore, less than 10 percent of the area is covered by vegetation. Plant species adapted to such harsh environment include oyster leaf *(Mertensia maritima*), scurvy grass (*Cochlearia officinalis*), alumroot (*Honckenya peploides*), arctic poppy (*Pappaver Hultenii),* and beach ryegrass (*Leymus arenarius).* Vegetation cover along the Barrow shoreline is also constrained by the extensive use the community exerts on it during the summer season.

A vegetation survey was conducted in concert with the invertebrate/fish survey in August 2004 on Cooper Island, which is one of the alternative gravel borrow areas (figure 26). Cooper Island is an elongated barren island composed predominantly of unconsolidated sand, gravel, stones, and cobbles. This island extends for about 7 to 8 miles east-west, with a width of about 300 to 500 feet, but widens toward the west to reach about 2,700 feet wide in some sections. These are estimated measurements as the island shoreline changes over time. A few shallow ponds have been formed to the west of the island and probably contain a mixture of water from snowmelt and storm events.

A continuous grass cover surrounds the borders of some of the ponds, providing a complementary foraging habitat to Arctic terns and several species of shorebirds and waterfowl during the summer. Dominant grasses in these salt marsh communities are creeping arrowgrass (*Puccinellia phryganodes*) and a few individuals of *Dupontia fisheri*; both species are known to provide forage to waterfowl. Heavy grazing was observed in some of these communities, probably from shorebirds. Creeping arrowgrass is a small grass that propagates mainly by stolons, which allows it to overcome effects of grazing. This grass is also known for its high nutrient content per unit mass, for nitrogen, magnesium, calcium, and sodium.

Besides the rather small belts of creeping arrowgrass found along the lagoon shorelines, vegetation is sparse on the rest of the island. A few plant species have adapted to extreme temperatures, winds, and saline/brackish water conditions and have patchy distribution on the island. Among the plants are Arctic poppy (*Papaver lapponicum*), tufted saxifrage (*Saxifraga caespitosa*), beachrye (Elymus arenarius), scurvy grass (*Cochlearia officinalis*), *Festuca brachyphylla,* and oysterleaf (*Mertensia maritima*) (photograph 4). Some of these species are found following subtle micro-relief patterns, becoming established at the windward side of small gravelly mounds perpendicular to wind direction. No grazing was observed on these plant species.

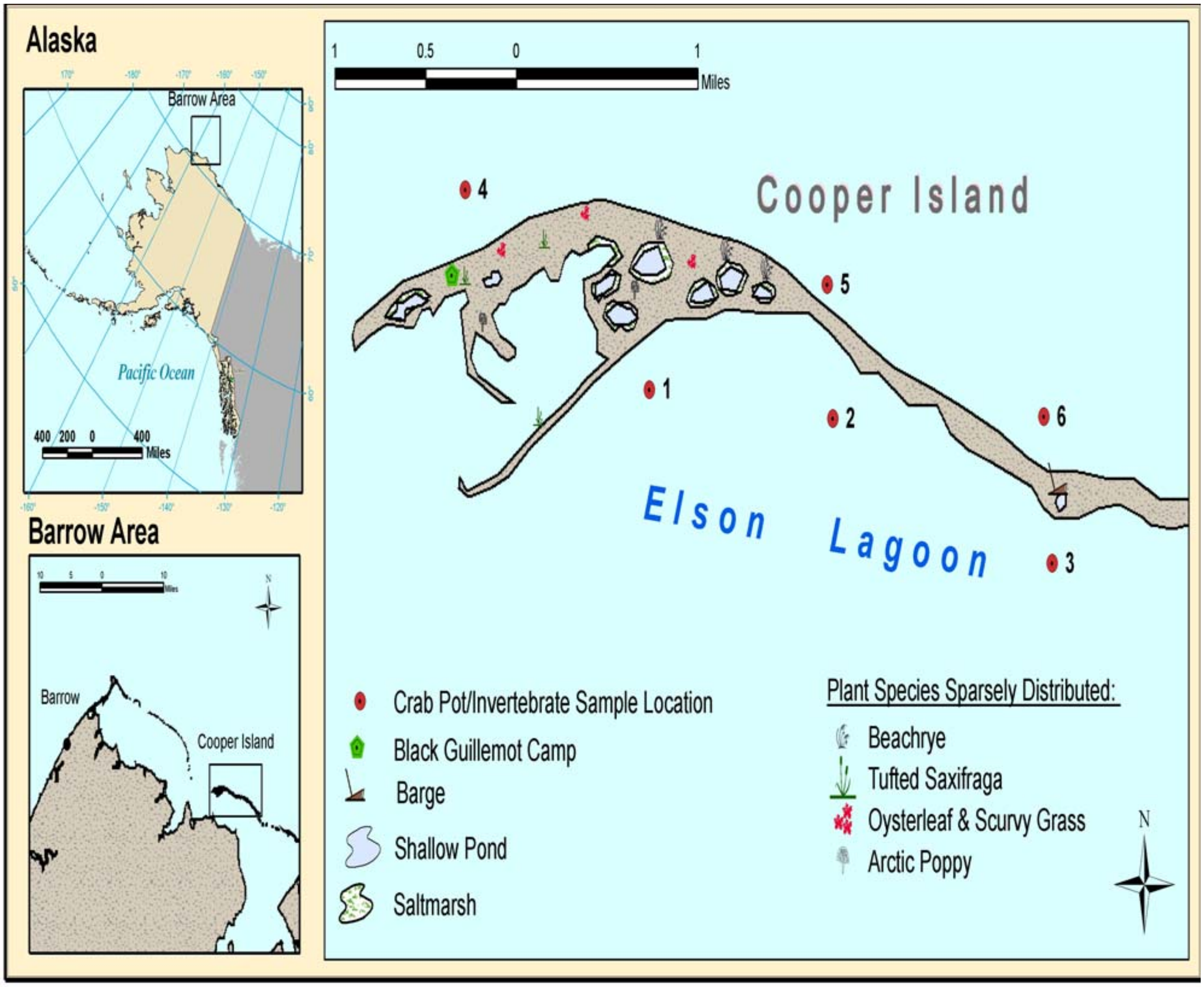

Figure 26. Cooper Island invertebrate sampling locations and vegetation map.

2.10.5 Threatened and Endangered Species

The Endangered Species Act of 1973 provides broad protection for species of fish, wildlife, and plants that are listed by the U.S. Government as threatened or endangered. Endangered means that a species is in danger of extinction throughout all or a significant portion of its range. Threatened means that a species is likely to become endangered in the foreseeable future. The Lacey Act of 1900, the Bass Act of 1926, the Migratory Bird Act of 1918, the Endangered Species Preservation Act of 1966, and the Endangered Species Conservation Act of 1969 preceded the ESA of 1973. Amendments to the 1973 ESA were made in 1978, 1979, 1982, and 1988.

Two sections of the ESA, section 7 and section 9 are central to the ESA. Section 7 requires federal agencies to ensure that their actions (including permitting) are not likely to jeopardize the continued existence of a listed species or result in the destruction or modification of critical habitat. Section 9 makes it unlawful for anyone to take a listed species. Take includes significantly modifying its habitat. Both sections 7 and 9 allow "incidental" takes, but only with a permit. The U.S. Fish and Wildlife Service (FWS) and the NMFS enforce the ESA.

The Endangered Species Act of 1973, as amended, protects three listed species found in the project vicinity. These species are the bowhead whale, Steller's eider, and spectacled eider. The U.S. Fish and Wildlife Service listed the polar bear as a threatened species in May 2008. The Kittlitz's murrelet, a small seabird, is a Candidate species for possible listing under the Act.

Bowhead Whale. The bowhead whale is a large, slow moving baleen whale that was hunted almost to extinction by commercial whaling from the late 1700's through the early 1900's (Fraker 1984). Only the western Arctic stock remains viable today. This stock of 9,472 to 10,545 whales is experiencing about from 3.5 to 4.9 percent growth annually even though on average 38.4 bowhead whales are taken annually by Alaska Natives for subsistence (Angliss and Outlaw 2006).

Bowhead whales are migratory and pass the project site in spring and fall (figure 11). In April and May, the spring migration rounds Point Barrow through leads in the ice. The fall migration, August and September, is westward along the 60-foot depth contour offshore of Point Barrow. The springtime destination of these migrating bowheads is the summer feeding grounds in the Beaufort Sea from about 300 to 600 miles east of Point Barrow. The fall destination is wintering grounds in the northeast Bering Sea. More detailed information on the migration of bowhead whales is presented in section 6.4.1.

Steller's Eider. The world's population of about 220,000 Steller's eiders is found in the North Pacific and Atlantic oceans in winter and in Arctic waters in summer (USFWS fact Sheet). Those found in the North Pacific Ocean during winter and in the East Siberian, Bering, Chukchi, and Beaufort seas during summer are predominantly a Siberian sea duck, most of which winter along the Alaska Peninsula and the Aleutian Islands. Ninety-six percent of Steller's eiders nest in Siberia and are not listed as threatened, but 4 percent of the population nests in Arctic Alaska and was listed as threatened in June 1997 (Federal Register June 11, 1997). It is impossible to distinguish between Alaska and Siberian Steller's eiders by appearance, so all Steller's eiders are considered threatened when in Alaska.

The FWS estimates that roughly 1,000 pairs of Steller's eider nest on the Arctic plain of Alaska (FWS 1998). Most of these nesting pairs are believed to nest in the vicinity of Barrow. Steller's eiders arrive at Barrow in May. Pairs seek nest sites near inland tundra ponds and non-breeders stay in coastal marine waters. Most breeding Steller's eiders return to the same nesting site throughout their lives. Males and females whose nests have failed leave inland nesting sites in July prior to molting and stage on coastal marine waters with non-breeders. Females with successful broods follow in September when their broods are fledged. Large flocks of Steller's eider gather in traditional areas along the coast to molt before migrating to their winter range. Steller's eiders stage and migrate from their winter range to their summer range in large flocks. Migration to the molting areas in fall is over a longer period and individually or in smaller flocks separated by gender or age. In 2001, the FWS designated about 7,330 km2 (2,830 mi^2) in five areas of Alaska as critical habitat for nesting and molting Steller's eiders (Federal Register March 13, 2000). No critical habitat for Steller's eiders was designated near the project site.

Steller's eiders are gregarious and gather in flocks to feed. When in marine waters, they feed near shore in water up to about 5 meters (30 feet) deep; but they sometimes rest over deeper waters or on tidal flats in large flocks. Food items consist of amphipods and small mollusks when available. Amphipods are likely prey in the project area. Additional information on Steller's eiders is presented the Final Fish and Wildlife Coordination Act report produced for the Barrow Storm Damage Reduction Study.

Spectacled Eider. Spectacled eiders were listed as threatened in May 1993 (Federal Register May 10, 1993). Spectacled eiders are a large sea duck that winters in very large flocks in Bering Sea polynyas south of Saint Lawrence Island. Most of the world's population of 363,000 spectacled eiders (Petersen et al. 1999) winters in this area of the Bering Sea. This area of the Bering Sea is particularly rich in benthic biomass (Grebmeier and Dunton 2000). Their food consists of clams and other mollusks that are in abundance 40 to 60 meters (130-200 feet) deep on the sea floor under the polynyas (Petersen et al. 1995). Spectacled eiders have undergone a little understood, but dramatic decrease in population during the past several decades. Lead contamination on nesting grounds and nest failure due to predation might be principal reasons for the decline (Dunkel 1997).

Spectacled Eiders migrate from this wintering area to nest and summer. Most spectacled eiders summer in Siberia while about 5,000 pairs nests on the Yukon-Kuskokwim Delta (Y-K Delta) in western Alaska, and about 6,000 to 9,000 pairs nest on the Arctic plain of Alaska.

Spectacled eiders arrive on the NPR-A near Barrow shortly after breakup where breeding pairs establish nests near shallow ponds or lakes, usually within 3 meters (10 feet) of water. During this season they feed by diving and dabbling in ponds and wetlands, eating aquatic insects, crustaceans, and vegetation. Soon after eggs are laid and usually by the end of June, males leave the nesting grounds for offshore molting areas. Females whose nests failed leave the nesting area to molt at sea by mid-August. Breeding females and their young remain on the nesting grounds until early September. Molting flocks gather in relatively shallow coastal water, usually less than 36 meters (120 feet) deep. While moving between nesting and molting areas, spectacled eiders travel along the coast up to 50 km (31 miles) offshore.

Several marine areas in Alaska are designated as critical habitat for spectacled eiders, but a proposal to include the project area was deleted from the final ruling (FWS 2001). Additional information on spectacled eiders is in section 6.4.3.

2.10.6 Fish

Many of the modern studies on Arctic fish were conducted in association with petroleum development east of Point Barrow and proposed development of the National Petroleum Reserve-Alaska (NPR-A) adjacent to and south of Barrow (BLM 1998). Consequently, much of what is said about fish in this technical report applies to areas associated with petroleum development proposed for the NPR-A and existing development east of Point Barrow.

Accounts of species diversity in the Beaufort Sea vary from about 101 species (UBC 2004) to about 62 species (Becker 1987), and it is generally accepted that there are at least 62 marine species in the Barrow area (MMS 1997). Thirty-seven of these species are found in the warmer near-shore brackish waters, and about 40 species are found in the colder marine waters farther offshore. Some species use both habitats.

Many species are anadromous or seasonally inhabit brackish water in lagoons or near-shore coastal areas. Others are considered to live in freshwater, but can tolerate and live in brackish water for extended periods of time. Anadromous species and species that can tolerate brackish water include chum salmon, pink salmon, Dolly Varden, whitefish, cisco, rainbow and pond smelt, Arctic lamprey, stickleback, and starry flounder. The range of Chinook salmon and coho salmon does not extend to Barrow, but they are known to stray in the Beaufort Sea east to Prudhoe Bay (Mecklenburg et al. 2002).

Freshwater species live in many rivers and lakes on the Arctic slope. Generally, freshwater deeper than about 2 meters (6½ feet) can support fish over winter if sufficient oxygen is present. At least 20 species of freshwater and anadromous fish are found in or near the Colville drainage system that enters the Beaufort Sea 150 km (93 miles) east of Barrow (BLM 1998). Teshekpuk Lake, 120 km east of Barrow (75 miles), is the most diverse of the lake environments on the Arctic Slope, with 11 species present (BLM 1998). Most of the same freshwater species in these drainages might be present in suitable freshwater habitats inland from the project area. Freshwater species that live on the Arctic Slope might include Arctic char, lake trout, Arctic grayling, burbot, slimy sculpin, longnose sucker, northern pike, and Alaska blackfish (Mecklenburg et al 2002).

Offshore marine species near Point Barrow are more diverse than freshwater species, but not as diverse as species compositions farther south in the Chukchi Sea and Bering Sea. More common near-shore species include the anadromous and brackish water species mentioned above in addition to capelin, Arctic and saffron cod, several marine sculpin, snailfish, Bering wolfish, Alaska plaice, Arctic flounder, Bering flounder, longhead dab, yellowfin sole, eel blennies, eelpouts, and Arctic alligator fish. Mecklenburg et al. (2002) lists additional marine species that are not as common, but may occasionally be found near Barrow.

The marine environment consists of inlets, lagoons, bars, and numerous mudflats. During the open-water period, a band of relatively warm, brackish water extends across the entire Beaufort Sea coast and dominates the near-shore areas (BLM 1998). The summer distribution and abundance of coastal fish (marine and migratory species) are strongly affected by this band of brackish water, which typically extends from 1.6 to 9.6 km (1 to 6 miles) offshore with the plumes off river mouths sometimes extending 24 km (15 miles) offshore. During the summer, migratory fish tend to concentrate in the near-shore area, which also is used by marine fish and occasionally by freshwater fish. The areas of greatest species diversity in the near-shore zone are the Colville and Ikpikpuk river deltas (Bendock, 1997). The amount of freshwater entering the near-shore zone decreases as the summer progresses and near-shore waters become colder and more saline. From late summer to fall, migratory fish move back into rivers and lakes to over winter and, if sexually mature, to spawn. In winter, near-shore waters less than 1.8 meters (6 feet) deep freeze to the bottom. Marine fish continue to use the near-shore area under the ice, but eventually move into deeper offshore waters when the ice freezes to the bottom (Craig, 1984).

Near-Shore Fish Surveys. Near-shore marine waters at Barrow and Cooper Island were sampled with a beach seine for species diversity and abundance over a 3-year period during August (Johnson and Thedinga 2004-2006). Cooper Island waters were sampled because Cooper Island is being investigated as a possible source of gravel for the proposed project. In 2005 Point Barrow and Skull Cliff were explored for gravel and rock sources, respectively. Sampling locations are shown in figure 27.

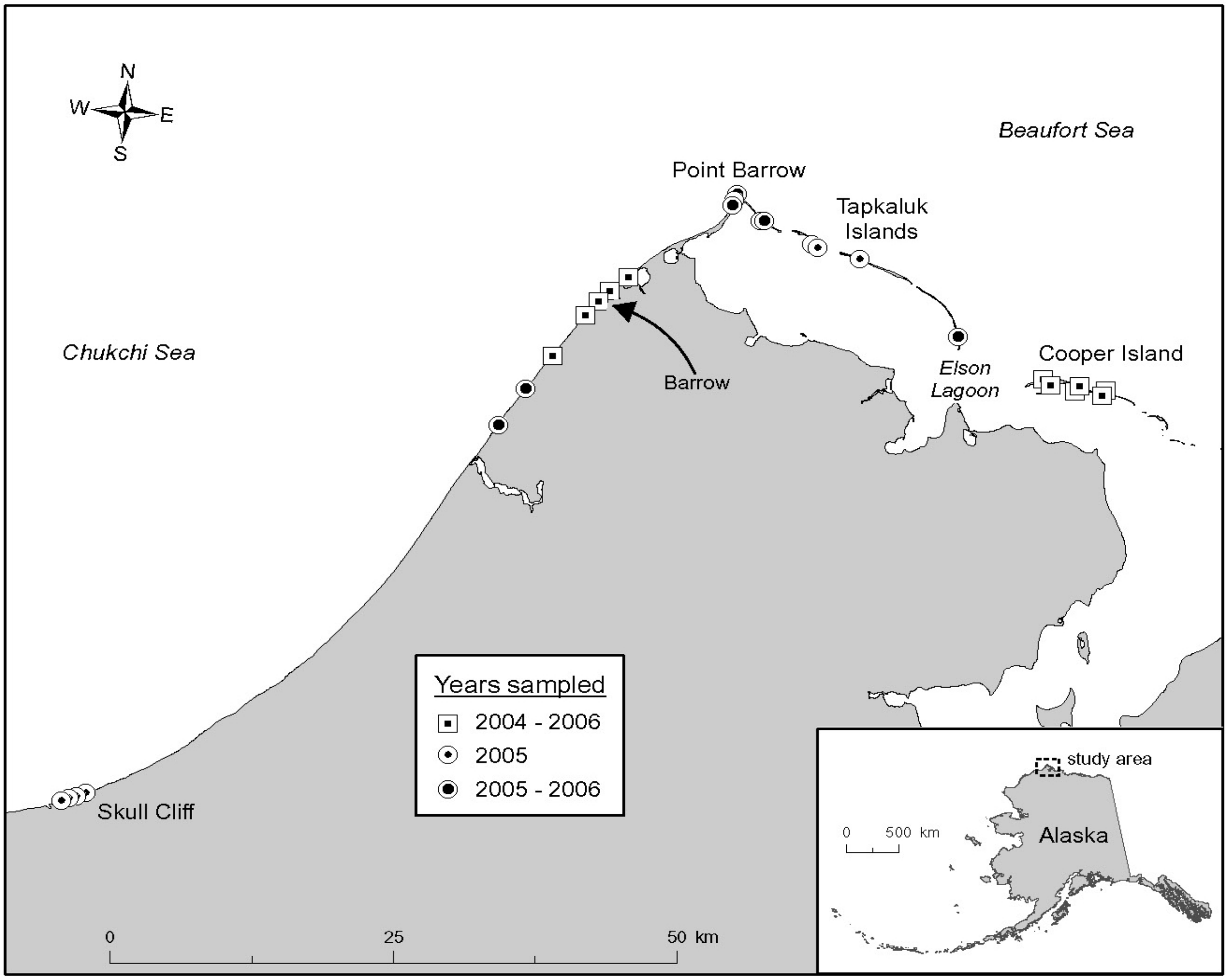

Figure 27. Sites sampled with a beach seine for fish assemblages near Barrow, Alaska. Eleven sites were sampled in 2004, 26 sites in 2005, and 18 sites in 2006.

2004 Fish Survey. Species diversity at Cooper Island and Barrow was low, but abundance of a few species at both sites was relatively high. Capelin and juvenile Arctic cod were most numerous at the Barrow site, where 85 percent of the catch was capelin and 14 percent Arctic cod. More than 2,000 fish were caught at the Barrow sites. Seine hauls at Cooper Island were made on the Beaufort Sea side and on the Elson Lagoon side of the barrier island. Fish on the Beaufort Sea side were significantly more numerous, with 1,180 fish caught in three hauls, while only 33 fish were caught in three hauls on the Elson Lagoon side of the island. Capelin and Arctic cod were the most abundant species on the Beaufort Sea side of Cooper Island, while least cisco and juvenile sculpin were more abundant on the lagoon side of the island. Three species—capelin, Arctic cod, and least cisco—caught in the survey at Barrow and Cooper Island are biologically significant to the Arctic food web.

2005 Fish Survey. Juvenile gadids (cod) dominated the overall catch in 2005, comprising 51 percent of the total catch. Mean FL of gadids was 17.4 mm (range = 11-27 mm).

Young-of-the-year Pacific sand lance *(Ammodytes hexapterus)* were the next most abundant fish, accounting for 10 percent of the total catch.

At Skull Cliff, 80.4 km (50 miles) west of Barrow, capelin was the most abundant fish (43 percent of catch) captured . Of all capelin captured, 83 percent were from Skull Cliff. All capelin were adults (mean FL = 120 mm; range 115-160) and most were gravid. Yellowfin sole *(Limanda aspera)* (mean FL = 86 mm) and Arctic sculpin *(Myoxocephalus scorpioides)* (mean FL = 98 mm) were the next most abundant species captured, comprising 23 percent and 13 percent of the total catch, respectively. The largest Arctic cod (FL = 138) at any site was captured at Skull Cliff.

At the Barrow sites, juvenile gadids were the most abundant fish captured, accounting for 73 percent of the total catch. Barrow sites had the greatest mean catch per seine haul (60 fish). Of all Pacific sand lance captured, 68 percent were from the Barrow sites; mean FL of sand lance was 41 mm.

At Cooper Island, total catch was greater on the Beaufort Sea side of the island (54 fish) than in Elson Lagoon (18 fish). The most abundant fish captured at the Beaufort Sea sites were juvenile cottids (sculpin) and Pacific sand lance, comprising 72 percent of the catch. The most abundant fish captured in Elson Lagoon was the least cisco *(Coregonus sardinella),* comprising 78 percent of the catch (table 1). The Beaufort Sea side of the island was the only area that fourhorn sculpins *(Myoxcephalus quadricornis)* (mean FL = 169), and age-1 Arctic cod *(Boreogadus saida)* (mean FL = 80 mm) were captured. The Elson Lagoon sites had the lowest mean catch per seine haul (six fish), but had the largest fish (mean FL = 263 mm, range 41-322 mm). Mean FL of fish captured at Cooper Island was 19 mm (range 15-24 mm) for juvenile cottids, 50 mm (range 39-55 mm) for Pacific sand lance, and 291 mm (range 245-322 mm) for least cisco.

At Point Barrow, juvenile poachers (Agonidae) were the most abundant (59 percent of catch) fish captured. Mean FL of poachers was 22.6 mm. Arctic cod were the next most abundant fish (18 percent of catch).

At the Tapkaluk Islands, juvenile gadids were the most abundant fish (44 percent of catch) captured. Juvenile cottids were the next most abundant fish, comprising 25 percent of the catch. One Arctic cisco *(Coregonus autumnalis)* was captured on the Beaufort side of the Tapkaluk Islands.

Water temperature varied among all sites (7.0-11.0 °C). The coolest temperatures (mean = 7.4 °C) were at the Barrow and Point Barrow sites, and the warmest (mean = 10.6 °C) were at Skull Cliff. Salinity was similar at all¯sites, averaging about 35¯PSS¯.

In late summer, juvenile gadids, Pacific sand lance, juvenile cottids, and capelin were the dominant fish in the Chukchi and Beaufort seas near Barrow. Least cisco was the most abundant fish in Elson Lagoon. Capelin is an important forage species in the diet of marine mammals, seabirds, and other fish species (Craig et al. 1982, Alaska Sea Grant 1993). Least cisco have some importance as a sport fish, but are more valued in rural subsistence fisheries (Griffiths et al. 1992, Alaska Department of Fish and Game 2004). Arctic cod, a dominant species in the 2004 seine catches, comprised only 2 percent of the total 2005 catch. Based on 2004 catches near Barrow, the 2005 juvenile gadids were probably Artic cod, in which case the contribution of Arctic cod to the total catch would increase to 52 percent, a greater proportion than in 2004. Similar species and catches have been reported in other near-shore studies in Arctic waters (Craig 1984, Bond and Erickson 1989).

The differences in salinity between the Elson Lagoon and Beaufort and Chukchi Sea sites in 2004 were not observed in 2005. A storm that produced strong southwesterly winds may have caused the intrusion of high saline waters from the Beaufort Sea into Elson Lagoon, resulting in similar salinities at all sites in 2005. A usual band of brackish water (10-25 PSS) adjacent to the Beaufort Sea shoreline in summer provides important feeding habitat for many species like least cisco and Arctic cisco (Craig 1984). Marine species such as Arctic cod, however, will enter near-shore waters in late summer when salinities increase (Craig 1984). Differences in number of species and total catch of Arctic fishes between seaward and more protected shoreline areas have also been reported by Bond and Erickson (1989).

Catches were much less in 2005 than in 2004. In 2004, total catch was less than 3,200 fish (11 hauls) compared with only 718 fish in 2005 (26 hauls) (table 19). Mean catch per seine haul was more than 10 times greater in 2004 than in 2005. Annual variation in seine catches was also reported by Thedinga et al. (in press); they attributed the variation to year-class strength of walleye pollock *(Theragra chalcogramma).* Near-shore waters near Barrow from Skull Cliff to Cooper Island appear to be important rearing areas in summer, especially for capelin and young-of-the-year Arctic cod. Anecdotal information also suggests that capelin may spawn on beaches near Barrow in mid-July.

Table 20. Number of fish captured with a beach seine at 26 sites near Barrow, Alaska, August 5-11, 2005. A blank represents the absence of a species from a site.

		Skull Cliff	Barrow	Point Barrow	Tapkaluk Islands Elson Lagoon	Beaufort! Sea	Cooper Island Elson Lagoon	Beaufort Sea
Juvenile gadids	Gadidae		307	7	6	39		5
Pacific sand lance	*Ammodytes hexapterus*	*1*	50		3	4		16
Juvenile cottids	Cottidae	2	6		13	13		23
Capelin	*Mallotus villosus*	34	4			1		2
Arctic sculpin	*Myoxocephalus scorpioides*	*18*	*10*		2	5	1	1
Unidentified poacher	Agonidae	1	4	26	1	1		
Unidentified larvae			19	1		1		
Juvenile stichaeids	Stichaeidae		10			6		
Least cisco	*Coregonus sardinella*					*1*	14	
Arctic cod	*Boreogadus saida*	*1*	2	*8*				2
Yellowfin sole	*Limanda aspera*	*11*	*1*			*1*		
Longhead dab	*Limanda proboscidea*	2	6	1				3
Ninespine stickleback	*Pungitius pungitius*	6	1				1	
Juvenile snailfish	Liparidae	2	1	1	2			
Arctic cisco	*Coregonus autumnalis*					*1*	2	
Plain sculpin	*Myoxocephalus jaok*	*1*						
Fourhorn sculpin	*Myoxocephalus quadricornis*							2
Number of sites		4	7	3	2	4	3	3
Total catch		79	421	44	29	73	*18*	54
Mean catch per seine haul		20	60	15	15	*18*	6	*18*

This was the final year (2006) of a 3-year study to inventory fish assemblages in shallow marine waters near Barrow, Alaska (table 20). Fish were sampled with a beach seine at 18 sites near Barrow from August 13–14, 2006 to identify fish assemblage; 11 of the sites had been previously sampled in 2004 and 2005. All seine sites were low gradient beaches with substrata predominantly composed of sand and gravel. Total catch at all sites was 2,564 fish. Mean catch per seine haul was greatest at Point Barrow (903 fish, n = 2) and least at Cooper Island (<3 fish, n = 6). The most abundant species captured at the Chukchi Sea sites (Barrow and Point Barrow) were juvenile cottids and juvenile gadids, whereas the most abundant species captured at the Beaufort Sea sites (Tapkaluk Islands and Cooper Island) were capelin (*Mallotus villosus*) and Pacific sand lance (*Ammodytes hexapterus*). Overall, the most abundant fish captured were juvenile cottids comprising 68 percent of the total catch. Mean size of most species captured was less than 87 mm fork length.

Catch and species composition varied among years (2004-2006). Mean catch per seine haul was 292 fish (n = 11) in 2004, 28 fish (n = 26) in 2005, and 142 fish (n = 18) in 2006. The most abundant species were capelin and Arctic cod (*Boreogadus saida*) in 2004, juvenile gadids and Pacific sand lance in 2005, and juvenile cottids and gadids in 2006. Subsistence and forage fish that were consistently captured (not always in large numbers) each year were least cisco (*Coregonus sardinella*), capelin, and Pacific sand lance. Capelin and sand lance are important in the diet of larger fishes, seabirds, and marine mammals. Shallow waters near Barrow provide habitat for at least 17 fish species; most fish caught were juveniles.

Water temperature and salinity varied among sites. The coolest temperature (0.5EC) was on the Beaufort Sea side of Cooper Island, and the warmest temperature (6.0EC) was on the Elson Lagoon side of the Tapkaluk Islands. The lowest salinity (10 PSS) was on the Elson Lagoon side of Cooper Island, and the highest salinities (30 PSS) were at most sites directly exposed to the Beaufort and Chukchi seas.

Annual variation in catch and species composition is not unusual in near-shore environments. The aggregating behavior of some species, especially for juvenile life stages, can account for patchy distribution and abundance patterns. For example, the schooling behavior of sand lance probably accounts for the “hit or miss” catches of this species in near-shore waters (Johnson and Thedinga 2005). In our study, one seine haul catch of mostly juvenile cottids accounted for 62 percent of the total overall catch in 2006. Annual variation in beach seine catches was also reported by Thedinga et al. (2006); they attributed the variation to year-class strength of walleye pollock (*Theragra chalcogramma*). The wide variability in fish catch reinforces the need for multi-year sampling to adequately assess fish use of near-shore habitats.

Shallow marine waters near Barrow appear to provide juvenile habitat in summer, especially for capelin and sand lance. Anecdotal information also suggests that capelin may spawn on beaches near Barrow in mid-July. The extent and duration of time that these and other species spend in shallow waters near Barrow is unknown. Seasonal and sometimes large catches of sand lance have been reported elsewhere in Alaska (Murphy et al. 2000, Johnson and Thedinga 2005). Future studies should consider sampling at other times of the year to better understand fish use of near-shore habitats.

Ocean conditions were noticeably different in 2006 compared with earlier years. Floating ice and icebergs stranded ashore were common, especially in the Beaufort Sea (e.g., Tapkaluk Islands and Cooper Island). Water temperatures were several degrees cooler in 2006 (0.5EC to 6.0EC) than in 2004 and 2005 (7.0EC to 11.0EC) (Johnson and Thedinga 2004, Thedinga and Johnson 2006), and may have contributed to the low numbers of fish captured in the Beaufort Sea. Similarly, differences in salinity likely attributed to the presence or absence of some species in our catches. For example, least cisco were captured only in the more protected brackish waters of Elson Lagoon (10 PSS) and not on the seaward side of Cooper Island or near Barrow where salinity was about 30 PSS. A band of brackish water (10-25 PSS) adjacent to the Beaufort Sea shoreline in summer provides important feeding habitat for many species like least cisco (Craig 1984). Differences in number of species and total catch of Arctic fishes between seaward and more protected shoreline areas have also been reported by Bond and Erickson (1989).

This study provides only a “snapshot,” temporally and spatially, of fish distribution and habitat near Barrow. At least 17 fish species use shallow waters near Barrow in summer including capelin and sand lance. Both of these species are important in the diet of larger fishes, sea birds, and marine mammals.

Table 21. Total fish catch by species and year in shallow, marine waters near Barrow, Alaska. Fish were captured with a beach seine in August 2004, 2005, and 2006; one seine haul per site. Fish are listed in decreasing order of abundance based on total catch among all years.

Common name	2004 (11 sites)	2005 (26 sites)	2006 (18 sites)
Juvenile cottids	16	57	1,753
Capelin	797	41	200
Juvenile gadids		364	388
Arctic cod	354	13	
Pacific sand lance	9	74	171
Unidentified larvae	12	21	27
Least cisco	14	15	10
Arctic sculpin		37	
Juvenile poachers	1	33	2
Juvenile stichaeids		16	1
Yellowfin sole	1	13	
Juvenile snailfish		6	7
Longhead dab		12	
Ninespine stickleback	1	8	
Unidentified cisco[a]	1	3	2
Veteran poacher	5		
Fourhorn sculpin		2	
Kelp snailfish	2		
Threespine stickleback			2
Plain sculpin		1	
Shorthorn sculpin			1
Total catch	3213[b]	716	2,564
Catch per seine haul	292	28	142

[a] Either Arctic cisco or Bering cisco; difficult to separate species in the field.

[b] 2,000 fish added to total catch including one additional species (tubenose poacher*Pallasina barbata*); see Johnson and Thedinga (2004) for explanation.

The following sections discuss life histories of fish species found in the Barrow area.

Arctic Cod (*Boreogadus saida*). Arctic cod is circumpolar in distribution and is found in the Arctic Ocean to 84° 42' north latitude. In Alaska, its distribution extends from the northern Beaufort and Chukchi seas, south through the Bering Strait and into the Bering Sea (Mecklenburg et al. 2002). They are often found in brackish lagoons and near river mouths during summer, but have a strong affinity for ice cover during winter and summer.

They are slender fish growing to a maximum length of about 40 cm, but are usually less than 25 cm. Northern populations are larger in size than are southern populations. Arctic cod are similar in appearance to other codfishes.

Arctic cod are commonly found near the surface, but can also inhabit depths below 900 meters. They form large schools in ice-free waters, but when found under ice, they prefer a rough surface where they can hide in the cracks.

Males and females are sexually mature at about 20 cm long and at 3 years of age. Arctic cod spawn under the ice during winter (Craig and Haldorson 1981). Females produce from 9,000 to 21,000 eggs about 1.5 mm in diameter, and up to 10 percent of the male's body weight is gonads (FOC 2004). Eggs are buoyant. Little is known about its mating behavior.

Arctic cod favors temperatures below 4 °C and thrives in temperatures below 0 °C. Antifreeze proteins in its blood are one adaptation responsible for this ability.

Most other cods are demersal feeders, but Arctic cod eat mainly plankton in the upper water column. They start life eating larval copepods, but as they grow they graduate to adult copepods, marine worms, krill, and smaller Arctic cod. They are believed to be the most significant consumer of secondary production in the Beaufort Sea (Frost and Lowery 1983). Arctic cod live about 6 years.

Arctic cod is a key component of Arctic food webs and is a primary food source for belugas, ringed seals, seabirds, and predatory fish (Craig 1984). There is no commercial fishery for Arctic cod in the Beaufort Sea (BLM 1998), but they are harvested commercially by Russian fishermen in Russia (FOC 2004).

Capelin (*Mallotus villosus*). In number and biomass, capelin may be the most abundant species at Point Barrow. In August 2004, capelin comprised about 85 percent of seine catches adjacent to the project site where more than 2,000 fish were caught (Johnson and Thedinga 2004). Murdoch (1885) was the first to record capelin at Point Barrow and numerous specimens from Point Barrow are in the University of British Columbia collection (Mecklenburg et al. 2002).

Capelin is widespread in the oceans of the northern hemisphere. They are small pelagic shoaling fish about 21 cm long in North Pacific populations. Sexual dimorphism is apparent with females being larger than males.

Capelin primarily feed on zooplankton, but is itself an important part of the food web as forage for other mammals, seabirds, and fish. They are primarily filter feeders, consuming euphausiids, copepods, amphipods, and a variety of planktonic invertebrates. Competition between capelin and other zooplankton-feeding species, including Arctic cod, may result when these species overlap.

Feeding is seasonal. It intensifies during the pre-spawning period and declines as the spawning season approaches, then virtually stops during spawning. Several weeks after the spawning period, surviving capelin resume feeding and continue until cessation in early winter.

Adult capelin are normally pelagic fish. In many parts of their range, they inhabit waters to 150 meters deep during the day and move to shallower depths at night (FWIE 1996a).

Capelin exhibit reproductive seasonality. In many parts of its range, spawning takes place in late winter following migration from deeper water to shallows and beaches with characteristics suitable for spawning. In the Kodiak, Alaska area, they spawn in May and June; in Bristol Bay they spawn in late spring. In the Bering Sea, they spawn in summer, and in the Beaufort Sea near Point Barrow, they spawn in August and September. Spawning takes place in water from 4 to 7 °C when fish are 3 or 4 years of age. Males and most females die after spawning. Some female capelin may spawn more than once.

Most, but not all, populations of capelin spawn on beaches composed of coarse sand or fine gravel. Some populations are known to spawn at depths up to 80 meters. Substrate characteristics of capelin-spawning beaches can be specific among populations where the particle size of spawning substrate ranged from 1 to 15 mm (FWIE 1996a). Eggs are buried by wave action and where they are safe from exposure and from predation while development takes place.

Capelin eggs are spherical, demersal, and adhesive. They can be buried 15 cm or more beneath the surface of the beach where they attach to the substrate and develop. Capelin eggs range about 0.3 to 0.9 mm in average diameter. The number of eggs increases with size of the female. A large female can produce up to 50,000 eggs. The density of eggs in spawning gravel can be greater than 800/cm^2. High egg density sometimes results in mortality due to lack of oxygen and accumulation of excretory products. Development time to hatching is inversely related to incubation temperature. Eggs deposited higher on beaches where warmer temperatures might prevail can hatch several days before eggs deposited lower on beaches.

The emergence of capelin larvae from the beach gravel, and the onset of larval drift, is episodic and closely correlated with sharp temperature increases caused, in some localities, by the occurrence of warm onshore winds. Larvae exist on yolk-sac reserves while in the gravel, and time to complete yolk sac absorption varies from 3 to 8 days depending on gravel temperature (FWIE 1996a). When beach-residence times exceed time to yolk-sac absorption, larval condition declines rapidly and survival is poor. Capelin are reported to spawn in warm, brackish water in the Canadian Arctic (FWIE 1996a) and warmer less saline coastal waters in the Alaskan Arctic may enhance the survival of capelin larvae as well.

Dispersal of the larvae is initially passive, but is later moderated by vertical migrations that bring the larvae in contact with different current regimes (FWIE 1996a). Larval dispersal, followed by the wanderings of juveniles in search of food, forms the migratory pattern of this species in early life, bringing them inshore and near the surface in early summer and offshore into deeper waters in autumn. Capelin larvae have been found over a wide range of salinities from 4.8 to 32.6 parts per thousand.

The majority of capelin does not live longer than 5 years, but the growth rate is slower in colder regions such as Greenland where 7-year-old fish are known. The west Beaufort Sea is characterized by warmer near-shore water during summer (BLM 1998) that may result in growth rates more typical for this species.

Capelin is extremely important to the Arctic food web. Predators in the Chukchi and Beaufort seas include seals, baleen whales, beluga, seabirds, fish, and humans.

Another survey conducted in the Barrow area provides additional insight on the local occurrence of marine and anadromous fishes (George et al. 1997). George et al. (1997) surveyed the western end of Elson Lagoon with fyke nets from July 18 through August 21, 1993 to determine the presence and relative abundance of species and other population structure parameters. Fourhorn sculpin, a near-shore Arctic species, dominated these catches (66 percent) with least cisco second in abundance (26 percent). Other species caught in relatively small numbers included saffron cod, Arctic flounder, Arctic cisco, stickleback, rainbow smelt, pink salmon, Pacific herring, Dolly Varden, capelin, and broad whitefish. A brief summary of four horn sculpin and least cisco follows because of the abundance of these species in these survey catches.

Four Horn Sculpin (*Myoxocephalus quadricornis*). Four horn sculpin is another fish with circumpolar Arctic distribution that is very tolerant of fresh and brackish water of the near-shore zone. Freshwater and marine forms of this fish exist. Marine adult four horn sculpin range from 28 to 36 cm (11 to 14 inches) in length. Mature females are slightly larger than males. In Alaska, they inhabit near-shore coastal waters and the delta areas of coastal rivers throughout the Arctic and south to Norton Sound in the Bering Sea (Mecklenburg et al. 2002). The marine form of this species eats marine worms, small invertebrates, small fish, and fish eggs.

This species is not considered as important to the Arctic food web as are the Arctic cod and least cisco, but is still important to the diet of predatory fish, seabirds, and marine mammals. Four horn sculpin made up 10.7 percent of the ringed seal diet in a Point Hope study (Johnson et al 1966). Four horn sculpin are also fed as alternate prey to black guillemots chicks on Cooper Island. The species was previously seldom fed to guillemot chicks on Cooper Island and recent use as alternate prey is attributed to environmental changes in the Beaufort Sea that is affecting the catchability of Arctic cod by black guillemots (FOCI 2003).

Morrow (1980) describes the life history of the four horn sculpin in detail. Spawning is during December over soft bottoms at depths of 15 to 20 meters in water 1.5 to 2 °C. The male guards the eggs and hatching requires 97 days at 1.5 °C. Growth of juveniles is slow with fish 1-year-old 4.0 to 5.5 cm long. Sexual maturity is reached in 3 to 5 years with most fish maturing by age 6.

Least Cisco (*Coregonus sardinella*). Least cisco was also figurative in the catch of Johnson and Thedinga (2004) on the Elson Lagoon side of Cooper Island. Consequently, this species deserves a summarization of its life history (excerpted from FWIE 1996b).

Least cisco is primarily a freshwater fish, but anadromous populations that inhabit brackish water part of the year exist. It is a resident of many inland waters throughout Interior Alaska and is anadromous in streams and rivers draining into the Bering, Chukchi, and Beaufort seas. Least cisco is present in most streams and lakes north of the Alaska Range and in the near-shore zone of the marine coastal environment. Anadromous least cisco inhabit brackish waters throughout the summer. In fall, least cisco migrate back into freshwater rivers and lakes to spawn and over winter. Least cisco inhabit a wide variety of habitats: shallow, slow-moving lakes and sloughs; large, deep, fast-moving rivers; and shallow tributary streams. Migratory forms of least cisco spend the winter in freshwater rivers and river deltas and the summer and early fall in coastal regions immediately adjacent to the shoreline. Least cisco have been found abundant in the near-shore brackish-water zone

Least cisco and other anadromous fishes have apparently adapted to tolerate the near-shore band of relatively warm and brackish water that flows along the Beaufort Sea coast during summer. The habits of feeding during summer in the sea and moving upriver and into lakes for the winter might be an Arctic adaptation to escape the low winter temperatures in sea water yet also take advantage of higher food abundance in coastal waters during the short Arctic summer.

Least cisco are primarily planktonic feeders, utilizing the mid-water column in lakes, sloughs, and coastal marine waters. They consume a wide variety of the secondary producers (invertebrates) in both marine and freshwater environments. Composition of food items is largely dependent upon the specific location at which least cisco species are sampled. Primary food items recorded are various species of copepods, cladocerans, mysiids, amphipods, and isopods; some fish (four horn sculpin and nine-spine stickleback); and some surface-dwelling aquatic insects.

They appear to be fairly tolerant of wide fluctuations in water quality. For example, least cisco is one of the most abundant species in near-shore Beaufort Sea waters where wind-generated turbidity results in day-to-day fluctuations in turbidity from 1 to 146 NTU 80 meters from shore (FWIE 1996b). Least cisco were also abundant in Simpson Lagoon west of Prudhoe Bay where dissolved oxygen ranges from 7 to 12 ppt.

Least cisco are apparently tolerant of a wide range of salinity. Anadromous least cisco inhabits brackish waters throughout the summer, at which time they make extensive migrations of at least 161 km (100 miles) along the coast where salinity during the open water period ranges from nearly fresh to saline. For example, in late June and early July melting ice and river flooding results in salinities from 1 to10 ppt in lagoons. Between mid July and September brackish conditions from 18 to 25 ppt might be normal. In fall, least cisco migrates into freshwater rivers and lakes to spawn and over winter. In winter their coastal environment may become uninhabitable because of thick near-shore ice and hypersaline conditions.

Least cisco are apparently also tolerant of a wide range of temperatures. For example, they tolerate July temperatures of 12 to 13 °C and winter and spring temperatures from 0 to 6 °C.

Age at sexual maturity apparently varies among different geographically isolated populations of least cisco, as well as among different life history types of least cisco whose ranges overlap. Age at maturity can be as high as 8 years in some anadromous populations (FWIE 1996b).

2.10.7 Essential Fish Habitat

As directed in 50 CFR Part 600, the Magnuson-Stevens Act Provisions: Essential Fish Habitat (EFH), Federal agencies consult with the National Marine Fisheries Service (NMFS) on all actions or proposed actions, authorized, funded, or undertaken by the agency that may adversely affect EFH.

Essential fish habitat is designated for commercial species of fish and shellfish, or for forage species that are an important forage resource for commercial fish and shellfish species or marine mammals. Essential Fish habitat means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of essential fish habitat: "waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; "substrate" includes sediment, hard bottoms, structures underlying the waters, and associated biological communities; "necessary" means the habitat required to support a sustainable fishery and a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle.

The NMFS has developed a website for mapping EFH in Alaska (NOAA 2004). The Alaska District consulted the NOAA web site for designated EFH at and near the project site at Barrow. Inner shelf marine waters and freshwaters in the vicinity of Point Barrow are designated EFH for Pacific salmon. Essential fish habitat has been designated in areas of the Chukchi Sea and Bering Sea for sculpin and several species of forage fish present near Barrow but not at Barrow. A brief discussion of fish species with EFH at the project site or that have EFH along the west coast of Alaska but not at the project site follows.

Sculpin. Sculpin are a large family of bottom fish inhabiting a wide range of habitats from tide pools to water 1,000 meters deep. Most sculpin spawn in the winter. All species lay eggs, but in some genera, fertilization is internal. Eggs are generally laid among rocks and are guarded by the males. The larval stage is found across broad areas of the shelf and slope. Smaller sculpin generally eat small invertebrates, but larger species eat small fish and crustaceans. The dominant sculpin in the project vicinity is the four horn sculpin. (*M. quadricornis*). This small sculpin has no commercial value, but can be significant to the diet of important Arctic species including ringed seals and sea birds.

Forage Fish Species. The principal use of fish species referred to as forage fish is food for numerous species of fish and shellfish including commercially important species, marine mammals, and seabirds. Forage fish are not considered to have a significant commercial value, but some fish species present at the project site have forage value in addition to commercial value in other parts of

Alaska or subsistence value near the project site. These species include Pacific herring and Arctic cod. Pacific herring are not designated as forage fish by NMFS and are a species with significant commercial value where found in great abundance. Arctic cod also have significant forage and subsistence value but no commercial value.

Most marine waters in Alaska are designated EFH for forage fish that includes smelts, capelin, eulachon, and sand lance (NOAA 2004). Forage species found at the project site in probable order of descending abundance are capelin, Arctic cod, sand lance, rainbow smelt, and Pacific herring. Marine waters at the project site are not designated as EFH for forage species even though they are present in varying degrees of abundance.

Pacific Salmon. At least six species of North American Pacific salmon (genus *Oncorhynchus)*, one species of Asian salmon (*O. masou*), and one species of Atlantic salmon (Salmo salar) are found in Alaskan marine waters (Mecklenburg et al. 2002). Two of the Alaskan species, pink salmon (*O. gorbuscha*) and chum salmon (*O. keta*) are relatively common in marine waters at Point Barrow, and two others, coho salmon (*O. kisutch*) and Chinook salmon (*O. tshawytscha*) are less common. Pink and chum salmon spawn in some coastal rivers of the west Beaufort Sea. Near-shore marine waters and rivers where Pacific salmon spawn are designated EFH.

3.0 Archaeological and Historical Resources

The earliest known archaeological sites in the Barrow area date as early as 4,250 years before present. These early coastal sites in northwest Alaska are interpreted to represent sealing camps, but it is known that the same people also traveled inland to fish and hunt caribou (Anderson 1984; Dumond 1998a). Around 3,000 years ago, people still lived along the coast and began to focus on hunting seal at their breathing holes, although they did not ignore caribou, whales, or fish (Gerlach 1998a). Walakpa (BAR-00013), about 13 miles south of Barrow, and the Coffin site a mile east of Walakpa, were occupied by both cultures (Stanford 1976).

Around 2,500 years before present, subsistence and settlement patterns began to change. The number of coastal settlements increased and there was a corresponding increase of focus on coastal resources (Anderson 1984; Dumond 1998b). Beginning around 1,550 years before present, the climate slowly warmed and the amount of offshore ice decreased. This required the development of new sea mammal hunting techniques adapted to the open sea. During this time, whale hunting increased at some coastal sites (McClenahan 1993). A similar culture was also developing in northern and western Alaska that included the earliest appearance (around 2,100 years before present) of technology for hunting seal, walrus, and whale from the ice and open leads (Ackerman 1998). Archaeological sites attributed to these people have been found at Kugusugaruk, Walakpa, Utqiagvik, Birnirk, and Nunagiak on Peard Bay (Anderson 1998; Gerlach and Mason 1992).

By about 1,000 years before present, the people inhabiting the coast of northern Alaska were “easily recognizable” as the “direct ancestors” of contact-period Eskimo people (McClenahan 1993). Material culture items known from ethnographic records have been recovered at sites dating to this period. In addition, technology developed for winter ice-hunting and hunting with kayak and umiaq on the open sea, along with a subsistence focus on whale hunting, continued use of some land-based resources, dog traction, and settlement in large communities (Anderson 1984; McClenahan 1993;

Morrison 1998). Sites occupied by people at this time have been reported at several sites including Walakpa, Nuvuk, Utqiagvik, and Birnirk.

Waldo Bodfish, a Barrow elder who recently passed away, recalled stories told to him relating where people lived in the Barrow area in the time before non-Natives arrived. He stated that Piġniq and Nuvuk were the first areas to be populated. Mr. Bodfish further stated that as more people began to settle in Barrow at the end of the 18th century, most people lived at Nuvuk. When commercial whalers appeared in the Barrow area in the 19th century, they brought with them "the people of the coast along here, the-people-of-Utuqqaq, the people-of-the-river, the-people-of-Point-Hope," and that "slowly mixing together they began to populate it (Barrow), together with the inland people."

The earliest reports from traders, explorers, and commercial whalers state there were a dozen houses with drying racks and scaffolds for storing goods and supplies around modern day Barrow (Gal 1991). In 1826, Nuvuk (at Point Barrow) was described only as an "extensive Native village" (Hall 1990). A more detailed description of at least 20 semi-subterranean houses was provided by a Russian-American Company ship in 1838. From 1852 to 1854, Dr. John Simpson stayed at Point Barrow and noted that Nuvuk had 309 people living in 54 semi-subterranean houses. He also noted that influenza and related difficulties were dramatically affecting the people of Nuvuk (Hall 1990; Murdoch 1988).

The first whaling ship passed Point Barrow in 1848, but none is believed to have stopped at any Barrow vicinity communities until 1854 (Hall 1990). Over the next 30 years, commercial whaling vessels stopped in ever increasing numbers (Hall 1990). In 1880, Nuvuk had about 30 occupied semi-subterranean houses, storage racks, and summer tents. This decreasing population has been attributed by some (Murdoch 1988) to the reduction of whales, an important source of food and nutrition, due to over harvesting by commercial whalers.

In 1881, the International Polar Expedition, led by John Murdoch, built their station at "Ooglaamie," also known as Utqiagvik in what is now Browerville, at the Isatkoak Lagoon. At that time, there were about 150 people living at Nuvuk in 26 houses. At Utqiagvik, they reported there were at least 61 semi-subterranean houses, burials, and miscellaneous features.

> That the ancestors of those people have made it their home for ages is conclusively shown by the ruins of ancient villages and winter huts along the sea-shore and in the interior. On the point where the station was established were mounds marking the site of three huts dating back to the time when they had no iron and men "talked like dogs" (Murdoch 1988).

Expedition members also noted that some families both Utqiagvik and Nuvuk pitched tents at Perigniak, a place between the two settlements where the eider ducks fly over. They would spend the summer hunting ducks with slings and guns and catching whitefish with gill-nets made from sinew (Murdoch 1988). The Expedition left Barrow in 1882.

The International Polar Expedition station building was then sold in 1883 to the Pacific Steam Whaling Company. It was the first shore-based whaling station in northern Alaska. Shore-based whaling required using spring-time leads and was a technique introduced by Iñupiaq whalers. The following year, the station was taken over by Charles Brower. In 1888, Brower added a trading post to the station and sold the facility back to the Pacific Steam Whaling Company. He then opened the Cape Smythe Whaling and Trading Company of Barrow in what is now known as Browerville (Murdoch 1988).

Between the turn of the century and 1930, Nuvuk had at least 100 residents (Gal 1991). In 1913, Stefansson noted that epidemics had reduced the population of the original inhabitants of Nuvuk and Barrow but that the overall population was maintained as other people moved in from the surrounding areas (Hall 1990). By 1930, however, most families moved from Nuvuk to Browerville. Thomas Brower stated that one family continued living at Nuvuk until the start of World War II.

The Naval Petroleum Reserve No. 4 was established through an Executive Order by President Harding in 1923 after petroleum was reported on the North Slope in 1917. Geological surveys soon followed through 1926, but until World War II, little was done on the North Slope because of the difficulty of transporting petroleum to the lower 48 states (Reed and Ronhovde 1971).

During World War II (1941-1948), petroleum became a priority and oil exploration on the North Slope was begun in 1944 within Naval Petroleum Reserve No. 4 (PET 4). The Arctic Research Laboratory in Barrow was established to support this exploration (Reed and Ronhovde 1971). The Arctic Research Laboratory facilities were built in August 1947 at the supply camp for the oil exploration. Scientists initially lived and worked in Quonset Number 259, then Building Number 260 was built and the first Quonset became the laboratory. The scientific laboratory competed for space in Quonset Number 259 with the exploration operations and after many delays, the Laboratory Building Number 250 was finished (Reed and Ronhovde 1971). During the war, a runway, hangars, warehouses, and other buildings were constructed at Barrow (Denfeld 1994).

The Distant Early Warning Line (DEW Line) extended across Canada, northern Alaska, and into the Aleutian Chain. It was designed to provide advance warning for the interception of attack from the Soviet Union so a counterattack could be planned. The existing Naval Arctic Research Laboratory facilities made Point Barrow ideal as a control center for construction of the DEW Line. By 1957, the DEW Line system was operational. The DEW Line went through a variety of technological changes and in 1985 it was renamed the North Warning System (Denfeld 1994). The Navy and the University of Alaska ended their work at the Naval Arctic Research Laboratory in 1980. The facilities were given to Ukpeagvik Iñupiat Corporation and today some buildings are leased to the North Slope Borough Department of Wildlife Management, Ilisagvik College, and provide housing, research support, and work space for scientists from around the world working on various projects.

3.1 Summary of Sites in the Barrow and Cooper Island Areas

Browerville (BAR-00007) includes the area northeast of Barrow. This historic district is in the process of being evaluated for the National Register of Historic Places by the Ukpeagvik Inupiat Corporation and the North Slope Borough. This district includes the Point Barrow Whaling Station (BAR-00012), which is the oldest frame building in the Arctic and listed on the National Register of Historic Places.

Isutkwa (or Esatkuat, BAR-00009) is an archaeological site in the project area that has not been evaluated for the National Register of Historic Places. Further consultation would be required to determine the eligibility of this site for the National Register of Historic Places, and the effects of the proposed alternative would be assessed, as required under Section 106 of the National Historic Preservation Act (36 CFR 800).

The Utqiagvik Village Site (BAR-00002) is known to contain a great deal of well-preserved archaeological information about the pre-contact through contact periods. Active erosion along the bluff, however, has been exposing and washing away portions of the site. Utqiagvik is eligible for the National Register of Historic Places. A sod house (BAR-00015) built around 1880, is currently being evaluated by the North Slope Borough for eligibility for the National Register. It is adjacent to the dike and would be visually affected by this alternative.

3.1.1 Emaiksoun Lake Area

Based on an archaeological survey (Corps of Engineers 2004, trip report attached), there are two sites of reburied human remains (BAR-42, BAR-43), and cranium fragments present at the north end of the gravel source area.

Additional archeological surveys were conducted at the potential gravel source areas near Emaiksoun Lake (BIA) and Cooper Island. The surveys were conducted by a contract (BTS Professional Services 2005), report attached. No additional cultural material was found at the BIA site. Cultural materials such as pot sherds were found in the Cooper Island survey. The site was recommended for eligibility for the National Register of Historic Places under the criteria. The bird research station run by bird biologist George Divorky may also be eligible.

Supplemental Reports

Fish Assemblages near Barrow, Alaska
August 2004-2006

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SUMMARY

This was the final year (2006) of a three year study to inventory fish assemblages in shallow, marine waters near Barrow, Alaska. The beach adjacent to Barrow is eroding at a rapid rate, and several locations in the vicinity of Barrow have been proposed as possible sources of replacement sediment. To identify fish assemblages that may be disturbed by the addition or removal of beach sediments, we sampled fish with a beach seine at 18 sites near Barrow from August 13–14, 2006; 11 of the sites had been previously sampled in 2004 and 2005. All seine sites were low gradient beaches with substrata predominantly comprised of sand and gravel. Total catch at all sites was 2,564 fish. Mean catch per seine haul was greatest at Point Barrow (903 fish, n = 2) and least at Cooper Island (<3 fish, n = 6). The most abundant species captured at the Chukchi Sea sites (Barrow and Point Barrow) were juvenile cottids (Cottidae) and juvenile gadids (Gadidae), whereas the most abundant species captured at the Beaufort Sea sites (Tapkaluk Islands and Cooper Island) were capelin (*Mallotus villosus*) and Pacific sand lance (*Ammodytes hexapterus*). Overall, the most abundant fish captured were juvenile cottids comprising 68% of the total catch. Mean size of most species captured was less than 87 mm fork length.

Catch and species composition varied among years (2004-2006). Mean catch per seine haul was 292 fish (n = 11) in 2004, 28 fish (n = 26) in 2005, and 142 fish (n = 18) in 2006. The most abundant species were capelin and Arctic cod (*Boreogadus saida*) in 2004, juvenile gadids and Pacific sand lance in 2005, and juvenile cottids and gadids in 2006. Subsistence and forage fish that were consistently captured (not always in large numbers) each year were least cisco (*Coregonus sardinella*), capelin, and Pacific sand lance. Capelin and sand lance are important in the diet of larger fishes, sea birds, and marine mammals. Shallow waters near Barrow provide habitat for at least 17 fish species; most fish that we caught were juveniles. Our study provides only a “snapshot”,

temporally and spatially, of fish distribution and habitat near Barrow. Future studies should be expanded to other seasons and nearshore areas (deeper waters) to obtain a full perspective on the role of the nearshore environment as fish habitat.

INTRODUCTION

This was the final year (2006) of a three year study to inventory fish assemblages in shallow (<6 meters deep), marine waters near Barrow, Alaska. Several locations, including Cooper Island (Fig. 1) have been identified as potential sources for three million cubic meters of sand and gravel needed to replenish the rapidly eroding coastline near the village of Barrow (Friends of Cooper Island 2003). The low shoreline near Barrow is subject to coastal erosion from strong northwesterly winds in summer and sea ice in winter. Several sites near Barrow and on Cooper Island were sampled with a beach seine in August 2004 to identify fish assemblages (Johnson and Thedinga 2004). In 2005, the survey area was expanded to include Point Barrow, Skull Cliff, and the Tapkaluk Islands (other possible sources of replacement sediment); a total of 26 sites were sampled (Thedinga and Johnson 2006). In 2006, 18 of the 26 sites sampled in 2005 were sampled again. Three years of sampling were needed to better understand the annual variability in distribution and relative abundance of fishes inhabiting shallow marine waters near Barrow.

METHODS

A total of 18 sites were sampled from August 13–14, 2006 (Fig. 1); 11 of the sites (5 near Barrow and 6 on Cooper Island) were sampled in August 2004 and 2005. The other 7 sites sampled in 2006 were sampled in August 2005 but not in August 2004 (Fig. 1). Cooper Island and the Tapkaluk Islands are located in the Beaufort Sea–sample sites are located on either the Beaufort Sea (exposed side) or Elson Lagoon (protected side). All sites from Point Barrow and westward are in the Chukchi Sea. One seine haul was made at each site. Each year all sites were sampled during daylight. Based on visual observations, all sites were low gradient beaches with substrata predominantly comprised of sand and gravel. Water temperature and salinity were measured at each site. Water temperature was measured at the surface with a thermometer, and salinity (practical salinity scale, PSS) was measured with a hand-held refractometer at an approximate depth of 20-cm.

The same fish sampling methods were used each year. Fish were sampled with a 37-meter long variable-mesh beach seine that tapered from 5 meters wide at the center to 1meter wide at the ends. Outer panels were each 10 meters of 32-mm stretch mesh, intermediate panels were each 4 meters of 6-mm square mesh, and the bunt was 9 meters of 3.2-mm square mesh. We set the seine as a round haul by holding one end on the beach, backing around in a skiff with the other end to the beach about 18 meters from the start, and pulling the seine onto shore. The seine had a lead line and a float line so that the bottom contacted the substratum and the top floated on the surface. After retrieval of the net, the entire catch was sorted, identified to species, counted, and a subsample was measured for fork length (FL) to the nearest mm. Fork length was measured for up to 50 individuals of selected species, primarily subsistence and forage fish species (e.g., capelin, Pacific sand lance). Fish were anesthetized in a mixture of 1 part carbonated water to 2 parts seawater for identification and measurement. Smaller individuals (<30 mm FL) of some families of fish (e.g., Cottidae, Gadidae) that could not be easily identified to species in the field were grouped and recorded as juvenile cottids and gadids. Similarly, because of the difficulty of separating Arctic cisco (*Coregonus autumnalis*) from Bering cisco (*C. laurettae*) in the field, we grouped them as unidentified cisco. Catch data were standardized to catch per seine haul by dividing the total catch by the number of seine hauls at each site.

RESULTS

2006

A total of 2,564 fish representing at least 9 species were captured among all sites (Table 1). Four species dominated the total catch; juvenile cottids (68%), juvenile gadids (15%), capelin (8%), and Pacific sand lance (7%). Other species captured in low numbers included least cisco, juvenile snailfish (Liparidae), threespine stickleback (*Gasterosteus aculeatus*), juvenile poachers (Agonidae), juvenile stichaeids, and shorthorn sculpin (*Myoxocephalus scorpius*).

Mean catch per seine haul was extremely variable and ranged from <3 fish (n = 6 seine hauls) at Cooper Island (Beaufort Sea and Elson Lagoon sites) to 903 fish (n = 2 seine hauls) at Point Barrow (Table 1). The capture of 1,583 fish (mostly juvenile cottids) in one seine haul at Point Barrow accounted for 62% of the total overall catch. The dominate species captured by location were juvenile gadids at Barrow, juvenile cottids at Point Barrow, capelin and Pacific sand lance at the Tapkaluk Islands, and least cisco at Cooper Island (Table 1). All least cisco were captured on the Elson Lagoon side of Cooper Island.

With the exception of least cisco, most of the fish that we captured were juveniles. The unidentified cottids, gadids, snailfish, and stichaeids were young-of-the-year; mean size of all these species was less than 30 mm FL (Table 2). Similarly, mean size of capelin ranged from 45.3 mm FL to 67.8 mm FL, whereas mean size of sand lance ranged from 37.7 mm FL to 69.5 mm FL (Table 2). In the Chukchi Sea, mean size of sand lance was about 30 mm greater for fish at the Point Barrow sites than at the Barrow sites (Table 2). At the Tapkaluk Islands, mean size of capelin was about 10 mm greater for fish on the Beaufort Sea side of the island than on the Elson Lagoon side (Table 2).

Water temperature and salinity varied among sites. The coolest temperature (0.5EC) was on the Beaufort Sea side of Cooper Island and the warmest temperature (6.0EC) was on the Elson Lagoon side of the Tapkaluk Islands. The lowest salinity (10 PSS) was on the Elson Lagoon side of Cooper Island and the highest salinities (30 PSS) were at most sites directly exposed to the Beaufort and Chukchi Seas.

2004-2006

Catch and species composition varied among years (2004-2006; Table 3). Mean catch per seine haul was 292 fish (n = 11) in 2004, 28 fish (n = 26) in 2005, and 142 fish (n = 18) in 2006. The most abundant species were capelin and Arctic cod in 2004, juvenile gadids and Pacific sand lance in 2005, and juvenile cottids and gadids in 2006. Subsistence and forage fish that were consistently captured (not always in large numbers) each year were least cisco, capelin, and Pacific sand lance.

Most fish captured in all years were juveniles. Mean size of capelin, sand lance, Arctic cod, juvenile gadids, and juvenile cottids was usually less than 90 mm FL. We did capture some adult least cisco and unidentified ciscos, and some gravid capelin were captured near Skull Cliff in 2005.

DISCUSSION

Juvenile cottids, juvenile gadids, capelin, and Pacific sand lance were the dominant species present in shallow, marine waters near Barrow in August 2006. Capelin and sand lance are important forage species in the diet of marine mammals, sea birds, and other fish species (Craig et al. 1982, Alaska Sea Grant 1993, Robards et al. 1999). Although few fish were captured at Cooper Island, least cisco was the most abundant species in Elson Lagoon. Least cisco is not an important sport fish, but is valued in rural subsistence fisheries (Griffiths et al. 1992, Alaska Department of

Fish and Game 2004). Based on our catches in 2004 and 2005 (Johnson and Thedinga 2004, Thedinga and Johnson 2006), some of the juvenile gadids that we captured in 2006 were probably Arctic cod. Similar species and catches to ours have been reported in other nearshore studies in Arctic waters (Craig 1984, Bond and Erickson 1989).

Annual variation in catch and species composition is not unusual in nearshore environments. The aggregating behavior of some species, especially for juvenile life stages, can account for patchy distribution and abundance patterns. For example, the schooling behavior of sand lance probably accounts for the "hit or miss" catches of this species in nearshore waters (Johnson and Thedinga 2005). In our study, one seine haul catch of mostly juvenile cottids accounted for 62% of the total overall catch in 2006. Annual variation in beach seine catches was also reported by Thedinga et al. (2006); they attributed the variation to year-class strength of walleye pollock (*Theragra chalcogramma*). The wide variability in fish catch reinforces the need for multi-year sampling to adequately assess fish use of nearshore habitats.

Shallow marine waters near Barrow appear to provide juvenile habitat in summer, especially for capelin and sand lance. Anecdotal information also suggests that capelin may spawn on beaches near Barrow in mid-July. The extent and duration of time that these and other species spend in shallow waters near Barrow is unknown. Seasonal and sometimes large catches of sand lance have been reported elsewhere in Alaska (Murphy et al. 2000, Johnson and Thedinga 2005). Future studies should consider sampling at other times of the year to better understand fish use of nearshore habitats.

Ocean conditions were noticeably different in 2006 compared to earlier years. Floating ice and icebergs stranded ashore were common, especially in the Beaufort Sea (e.g., Tapkaluk Islands and Cooper Island). Water temperatures were several degrees cooler in 2006 (0.5EC to 6.0EC) than in 2004 and 2005 (7.0EC to 11.0EC) (Johnson and Thedinga 2004, Thedinga and Johnson 2006), and may have contributed to the low numbers of fish captured in the Beaufort Sea. Similarly, differences in salinity likely attributed to the presence or absence of some species in our catches. For example, least cisco were captured only in the more protected brackish waters of Elson Lagoon (10 PSS) and not on the seaward side of Cooper Island or near Barrow where salinity was about 30 PSS. A band of brackish water (10-25 PSS) adjacent to the Beaufort Sea shoreline in summer provides important feeding habitat for many species like least cisco (Craig 1984). Differences in number of species and total catch of Arctic fishes between seaward and more protected shoreline areas have also been reported by Bond and Erickson (1989).

Our study provides only a “snapshot”, temporally and spatially, of fish distribution and habitat near Barrow. At least 17 fish species use shallow waters near Barrow in summer including capelin and sand lance. Both of these species are important in the diet of larger fishes, sea birds, and marine mammals. Future studies should be expanded to other seasons and nearshore areas (deeper waters) to obtain a full perspective on the role of the nearshore environment as fish habitat.

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Table 1. Number of fish captured with a beach seine at 18 sites near Barrow, Alaska, August 13-14, 2006; one seine haul per site. See Figure 1 for site locations. A blank represents the absence of a species from a site. Fish are listed in decreasing order of abundance based on total catch among all sites.

		Chukchi Sea		Beaufort Sea			
				Tapkaluk Islands		Cooper Island	
Common name	Scientific name	Barrow	Pt. Barrow	Elson Lagoon	Beaufort Sea	Elson Lagoon	Beaufort Sea
Juvenile cottids	Cottidae	103	1642	1	7		
Juvenile gadids	Gadidae	285	77		24	2	
Capelin	*Mallotus villosus*	4	39	67	90		
Pacific sand lance	*Ammodytes hexapterus*	26	40	1	103		1
Unidentified larvae		19			6		2
Least cisco	*Coregonus sardinella*					10	
Juvenile snailfish	Liparidae		5		2		
Threespine stickleback	*Gasterosteus aculeatus*	2					
Juvenile poachers	Agonidae	1	1				
Unidentified cisco	Coregoninae					2	
Juvenile stichaeids	Stichaeidae		1				
Shorthorn sculpin	*Myoxocephalus scorpius*				1		
Number of sites		7	2	1	2	3	3
Number of species		6	7	3	5	2	1
Total catch		440	1805	69	233	14	3
Mean catch per seine haul		63	903	69	117	5	1

Table 2. Mean fork length (FL) of fish captured with a beach seine at 18 sites near Barrow, Alaska, 13-14 August, 2006. See Figure 1 for site locations and Table 1 for scientific names.

	Chukchi Sea		Beaufort Sea			
			Tapkaluk Islands		Cooper Island	
	Barrow	Pt. Barrow	Elson Lagoon	Beaufort Sea	Elson Lagoon	Beaufort Sea
Common name	FL (n)	FL (n)	FL (n)	FL (n)	FL (n)	FL (n)
Juvenile cottids	26.8 (51)	20.3 (3)	21.0 (1)	23.3 (7)		
Juvenile gadids	21.7 (62)	28.3 (31)		25.9 (10)		
Capelin	45.3 (4)	48.2 (18)	57.5 (40)	67.8 (50)		
Pacific sand lance	37.7 (15)	69.5 (31)		46.3 (24)		61.0 (1)
Unidentified larvae	21.7 (3)					
Least cisco					311.4 (10)	
Juvenile snailfish		24.5 (4)		23.0 (2)		
Juvenile stichaeids		29.0 (1)				
Threespine stickleback	86.0 (2)					
Unidentified cisco					337.0 (2)	
Shorthorn sculpin				80.0 (1)		

Table 3. Total fish catch by species and year in shallow, marine waters near Barrow, Alaska. Fish were captured with a beach seine in August 2004, 2005, and 2006; one seine haul per site. See Figure 1 for sites. Fish are listed in decreasing order of abundance based on total catch among all years.

Common name	2004 (11 sites)	2005 (26 sites)	2006 (18 sites)
Juvenile cottids	16	57	1753
Capelin	797	41	200
Juvenile gadids		364	388
Arctic cod	354	13	
Pacific sand lance	9	74	171
Unidentified larvae	12	21	27
Least cisco	14	15	10
Arctic sculpin		37	
Juvenile poachers	1	33	2
Juvenile stichaeids		16	1
Yellowfin sole	1	13	
Juvenile snailfish		6	7
Longhead dab		12	
Ninespine stickleback	1	8	
Unidentified cisco[a]	1	3	2
Veteran poacher	5		
Fourhorn sculpin		2	
Kelp snailfish	2		
Threespine stickleback			2
Plain sculpin		1	
Shorthorn sculpin			1
Total catch	3213[b]	716	2564
Catch per seine haul	292	28	142

[a] Either Arctic cisco or Bering cisco; difficult to separate species in the field.

[b] 2,000 fish added to total catch including one additional species (tubenose poacher *Pallasina barbata*); see Johnson and Thedinga (2004) for explanation.

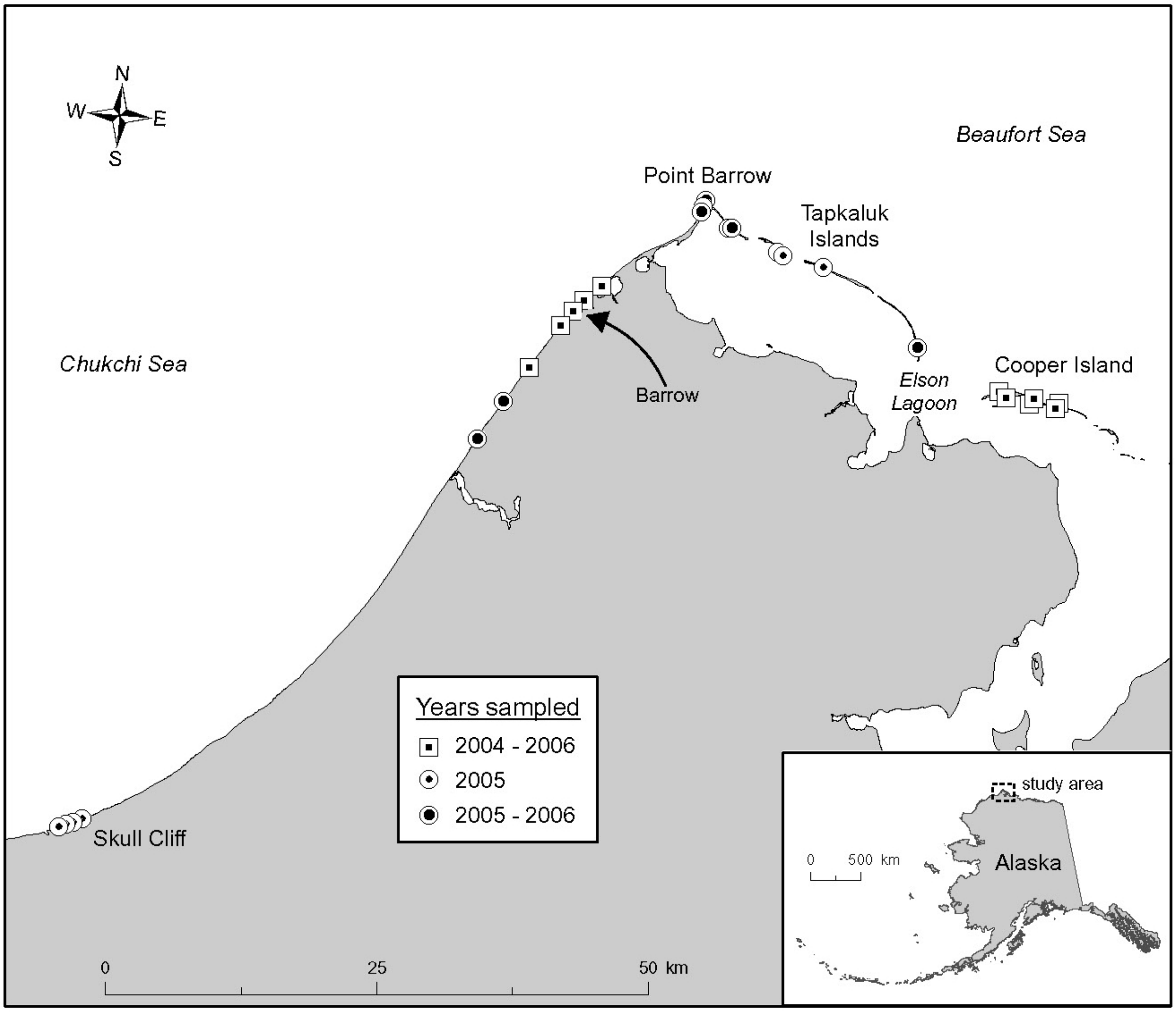

Figure 1. Sites sampled with a beach seine for fish assemblages near Barrow, Alaska. Eleven sites were sampled in 2004, 26 sites in 2005, and 18 sites in 2006.

Archaeological Pedestrian Survey near Barrow Alaska and Site Visit to Peard Bay

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Introduction

Margan Grover and Diane Hanson conducted a pedestrian survey south of Barrow August 22 – 24, 2003 (Figure 1). The purpose of the survey was to examine possible access routes and areas proposed by the geologist for boring holes to sample for gravels. A gravel source is being sought for a beach nourishment project designed to reduce storm damage in the towns of Barrow and Browerville.

A second trip took place by helicopter on September 4, 2003 to Peard Bay with Robert Glenn, Anne Jensen, Curt Thomas, Dee Ginter, Lizette Boyer, and Diane Hanson. The helicopter flew over the spit system west of the bay, along the Seahorse Islands. The island was composed of sand with some small gravel. The surface of the small island was wind and probably ice swept. Coal, apparently from a natural deposit nearby, had washed onto the beach with boat timbers, shell, and miscellaneous flotsam. The hydrologist and geologist concluded that this area was not suitable as a harvest source. This trip will not be discussed further in this report. No cultural resources were observed on the spit.

Barrow sits at the neck of a spit leading northward and is surrounded by low tundra and numerous lakes and ponds. It is within the Arctic Coastal Plain (Gallant et al. 1995) of low marshy areas filled with grasses, including cotton grass, bordering the lakes. The polygonal patterned ground is marsh surrounded by higher ice wedges and covered with grasses. Hills to the west of the survey area border the marshes and polygonal patterned ground. These hills are drier and covered primarily by lichens and mosses. Hummocks fringe the hills. In general, the topography within the survey is low, never rising above 66 feet above the mean high tide. Frozen ground was most frequently encountered at about 20 cm below the ground surface, although the depths varied from 16 cm in marshy areas, to 31cm and 37cm on the low hills. The top stratum nearly always consisted of peat, roots, and other organics, underlain by silty-clay sediment.

Brief Cultural History

The oldest coastal sites are Denbigh Flint complex, a complex within the Arctic Small Tool tradition. Walakpa on Walakpa Bay, 13 miles south of Barrow, has components dating to this time. The Denbigh Flint complex sites are associated with seasonal coastal camps of interior dwelling people (Dumond 1998a:207). The Choris culture follows the Denbigh Flint Complex at about 3000 years before present (B.P.) with ceramics in coastal sites and diagonally flaked bifaces (Gerlach 1998a:150). The people probably concentrated on hunting ringed seal at their breathing holes (Gerlach 1998a:

149), although they did not ignore caribou, beluga, or seal. Stanford (1976:16) has identified a Choris component in the Walakpa site (BAR-00013), south of Barrow. Stanford (1976:16) also stated that the Coffin site, approximately a mile east of Walakpa, had an assemblage from late Denbigh to Choris.

The Norton culture follows the Choris culture around 2450 B.P. Like Choris assemblages, Norton culture includes ceramics, although the designs are check and diamond stamped in addition to the linear stamped designs seen in Choris culture. Norton disappears north of Seward Peninsula before 1500 B.P. (Dumond 1998b:590). South of Point Lay, Norton is replaced or extends into the Ipiutak cultures. Ipiutak and Norton lithics are similar, and the assemblages are distinguished largely by an absence of ceramics in comparison to Norton and Choris (Gerlach 1998b: 393). “The character of Ipiutak outside Point Hope is often difficult to determine because of numerous resemblances between Ipiutak lithic artifacts and those of the Norton culture” (Gerlach 1998b: 392). Ipiutak coastal sites date from 1600 to 1200 B.P. (Gerlach and Mason 1992).

Punuk culture dates from roughly between 1300 and 800 B.P. and is contemporaneous with Birnirk. Most of the sites are in Siberia and on St. Lawrence Island, although there are sporadic occupations on the Northwest Alaska Coast, including Nunagiak on Peard Bay (Gerlach and Mason 1992). Punuk art styles reflect an Old Bering Sea/Okvik ancestry from St. Lawrence Island and Siberian cultures. Punuk culture bearing people used undecorated pottery, ground-stone knives, and plate armor (Ackerman 1998:694)

While the area to the south was dominated by the Ipiutak culture, the Birnirk culture occupied the area around Barrow (see Gerlach and Mason 1992:67), although Gerlach and Mason (1992:68) report that Bering Sea/Ipiutak style artifacts were recovered from burials at Utqiagvik in Barrow. The Birnirk culture is ancestral to Thule and Iñupiat cultures on the north coast. Birnirk assemblages have been found at Kugusugaruk, Walakpa, Utqiagvik, and Birnirk (Anderson 1998: 72; Gerlach and Mason 1992). Birnirk sites date between 1300 and 1000 B.P.

Thule culture developed from Birnirk culture, and in turn, is ancestral to the Iñupiat culture (Morrison 1998). Punuk fused with the Thule culture (Ackerman 1998), while the Ipiutak culture continued to exist in the Brooks Range well after the Thule occupation along the coast (Gerlach and Mason 1992:65). The Thule culture developed at approximately 1000 B.P. and spread from western Alaska eventually reaching Greenland.

There are several important coastal sites west of the survey area. Walakpa, at the mouth of Walakpa Bay, is southwest of the survey area and approximately 12 miles south-southwest of Barrow and 6 ½ miles southwest of the survey area. It has approximately 15 house remains on the surface and an extensive pre-contact sequence reputed to be the most complete in northwestern Alaska (AHRS Card). Walakpa is also the site of the Will Rogers-Wiley Post Memorial, marking the place their plane crashed in

1935. The memorial is listed on the National Register of Historic Places. BAR-095 and BAR-096 are on the sand spit south of Walakpa but are still on the north side of the mouth of Walakpa Bay. BAR-095 is a Norton culture site that included scrapers, pottery, bifaces, flakes, and fire cracked rock. South of this, BAR-096 had a stone artifact and items associated with a modern shooting blind (AHRS Card).

BAR-014 and BAR-091 are on the north side of Walakpa Bay, approximately ½ and ¾ of a mile southeast of the mouth. BAR-014, the Coffin site, is on a bluff on the west side of a small drainage. The site includes lithic assemblages of late Denbigh and Choris cultures. BAR-091, the Kahroak Site, is reported by Stanford (see AHRS card) to be a Paleoarctic period site on the east side of the drainage.

Between Walakpa and Nunavak bays is BAR-010, called Napawrax or Nunaktuau. It is an Iñupiaq camp reported to be near Walakpa Bay. The exact location of this camp is unknown (AHRS card). North of this is BAR-044, the Hollywood Reburial site. While there is no information about this site, it is presumably where human remains were reburied from elsewhere. There are also two paleontological sites on the bluffs between Walakpa Bay and Nunavak Bay (BAR-030 and 031).

North (BAR-037) and South Nunavak (BAR-038) are on their respective sides of Nunavak Bay. South Nunavak had several burials that were excavated by A.H. Hopson in 1929. The north side was also reported to have features (AHRS Card).

BAR-042 and BAR-043 are reburial sites south of the airport and north of Emaiksoun Lake. BAR-042 was encountered during the survey, and its location on the AHRS maps will need to be changed. BAR-043 is reported to be west of the survey area.

Methods

> The proposed test boring locations in the Emaiksoun Lake area were labeled TB1 through TB15. Margan Grover and Diane Hanson walked to the position of each borehole marked with a wooden survey stake by the geologist earlier, except TB4. The location of each survey stake was confirmed using a handheld GPS (Garmin GPS 12). The reference datum was NAD 27 Alaska. We tied additional flagging around the stakes and placed an orange snow stake, marked with reflective tape, beside each wooden survey stake. A shovel test was dug near the stake. The test pits averaged about 20cm deep before stopping at frozen ground. The soil from the pit was examined, a description of the sediments recorded in the field notebook, and the sediments and sod replaced. The location of the test pit was mapped relative to the survey stake using a Sylva compass. The declination of the compass was set at 0° then converted to true North after returning from the field. The surface around the proposed borehole was also examined.

We arrived in Barrow on the morning of August 22, 2003, and there was approximately 3 inches of snow on the ground. After getting the rental car, checking in at the hotel and getting lunch, the snow had melted and we started our survey at 2:30 p.m. The weather was cool and calm. The first four stakes were difficult to find because their locations had been changed from the original GPS coordinates. We called the geologist to get the new coordinates. The first three stakes, TB1, 2 and 3, were surveyed on August 22. The route of the survey is provided in figure 2.

August 23rd was also cool and calm. We walked from the north end of Emaiksoun Lake to the southern end along the high ground on the east side of the lake, examining the high ground along the way. TB 12, 11, 13, 15, 14, 10, and 8 were examined in that order on August 23 (Figure 2). We covered approximately 14 miles during the survey.

On August 24th we surveyed the western side of Emaiksoun Lake returning to the vehicle along the high ground on the east side. The weather was cold, windy, with snow squalls, and ice skimming over the puddles. TB 5, 6, and 7 were surveyed on August 24 (Figure 2). TB4 had been moved from the original coordinates and we intended to return to it at the end of the day. Unfortunately, we were unable to place a shovel test at TB4.

Results

Nunaruk Road area:

TB1 (N71° 16.38', W156° 47.98') is near Nunaruk Road and a storage yard. The area has scattered debris around it (Figure 3a). The shovel test pit was 5.75 meters at a bearing of 318° from the stake to the hole. The test pit profile was 0-4 cm peat/organic layer and 4-30 cm of mottled orange/grey silty-clay with rounded pebbles (Figure 3b). Organic pockets and some roots occurred within the silty-clay. Frozen ground terminated the testing. The surface vegetation included dwarf willow, mushrooms, grasses, and mosses (Figure 3)

A wooden grave marker sits 64.3 meters from TB1 at a bearing of 38° (GPS reading: N71° 16.409', W156° 47.915'). The grave marker is over a reburial site (BAR-0042). The grave marker is plain on the north side with a light brown or reddish-orange paint that is weathering off. On the south side of the grave marker is a brass plate with the inscription, “Here lie the Remains of, Iñupiat Ancestors found, here in July 1992, Reburied September 1992.” A wooden cross is above the brass plate (Figure 3c).

There are a number of can dumps or caribou butchering places between TB2 and TB1. Can dump 2 (N71° 16.065', W156° 48.165') included Spam cans with a key opener, and pop cans with the pull top indicating that it was about 30 years old or so. A small hillock with a small grave marker was 7.5 meters from Can Dump 2 at 357°. The grave marker was made of a small board and had “Spanky 1988-1997” written on it. There were owl pellets on the hill and caribou bones to the west of the feature. Cans, caribou bones, and antlers were down hill toward the north of the mound, near a creek bed leading to the north side of Nunavak Bay.

TB2 (N71° 15.91', W156° 47.78') test pit profile was 0-10 cm dark brown organic, and 10-17 cm medium brown peat and organic (Figure 4a). Ice was encountered 17cm below the ground surface. The entire profile was peat. The test pit was placed 3.3

meters, at a bearing of 112° from the stake. Vegetation cover included mosses, lichen, grass, and dwarf willow.

TB3 (N71 15.894', W156° 48.087') is on the side of a hill on the east side of a small drainage leading toward Nunavak Bay. The surface vegetation included mosses, lichen, grass, and dwarf willow. The soil profile, other than a thin layer of vegetation mat, included orange mottled brown and grey clayey silt/sand, rounded pebbles, with pockets of organic material (Figure 4b). Frozen ground began at 40 cm below the ground surface. The test pit was 90 cm away, at a bearing of 29° from the stake.

To the west of the stake over the bench, leading toward the drainage was a small can scatter (can dump 1; N71° 15.894', W 156° 48.149'; Figure 4c). The cans were single soldered seam cans with a rolled lip. They were opened with a hand can opener, probably similar to those found on pocketknives. The cans are of various sizes. Some may be from fruit cans.

Human skull fragments (N71° 15.835', W156° 48.322') were found west of TB3 and the can dump on the west side of the drainage. The location of the skull fragments was marked with a snow stake and reported to the Barrow Police, and to Anne Jensen an archaeologist with Ukpeaġvik Iñupiat Corporation (UIC). The bone fragments were weathered and there were rodent chewing marks along the edges.

West side of Emaiksoun Lake (Freshwater Lake):
TB 4 (N71° 15.34', W156° 48.1') was not visited. We visited the original location of TB4 then realized that there were new coordinates for the stake, which would have required that we backtrack so we continued on to TB 5 intending to pick up TB4 at the end of the day. By that time though, we had just enough time to repack our gear and check in at the airport.

TB5 (71° 14.25', W156° 48.685') was in a low wet marshy area near small ponds (Figure 5a). We walked along ice wedges uplifted on the patterned ground to get to the stakes. The test pit was 10.4 meters, and 56° from the stake to the pit. The soil profile was 0-9 cm peat/organic layer, 9-19 cm dark brown/black silty-clay (no pebbles), and at 19 cm the ground was frozen.

TB6 (N71° 13.87' W156° 50.026') was surrounded by low hummocky ground. The vegetation cover included lichen, moss, grasses, and dwarf willow. The matrix was peat and organics from the ground surface to 21 cm below the ground surface where the frozen ground began (Figure 5b). The test pit was placed 1.7 meters, and 32° from the stake.

TB7 (N71° 13.819', W156° 47.126') was on a small bench overlooking the south end of Emaiksoun Lake (Figure 5c). The predominant vegetation was dwarf willow, grasses, moss, and lichens. The soil profile: 0-8 cm peat/organic layer, 8-22 cm orange/brown, dark brown mottled clayey silt with occasional rounded pebbles, and 22cm frozen ground

(Figure 5d). The test pit was 3.9 meters, and 108°. Between TB7 and 8 there is a broken porcelain toilet laying on the ground.

South side of Emaiksoun Lake (Freshwater Lake):
TB8 (N71° 13.787' W156° 45.884') was in a gently sloping area near the southeast shore of Emaiksoun Lake (Figure 6a). The area to the south was hummocky. There were wood scraps and a wood pallet that had been placed there recently, but no other cultural materials were observed. We dug a test pit 4.77 meters, at a bearing of 105°, from the stake. The test pit had organic/peat at 0-7 cm, and mottled orange/grey clayey silt (no pebbles) at 7-31 cm (Figure 6b). Frozen ground ended the test at 31 cm.

TB9 (N71° 13.363', W156° 48.602') had a GPS reading different from the one we were originally given. The stake was on the top of hummocky ground overlooking low marshy land. The test pit was placed 3.7 meters at a bearing of 63° from the stake. The soils were 0-6 cm organic/peat, 6-37 cm orange/brown mottled clayey silt with rounded pebbles, and 37 cm frozen ground (Figure 6c). The vegetation on the ground was lichen, moss, lignon berries, salmon berries, and grasses.

TB10 (N71° 12.548' W° 156 50.943') had the usual vegetation cover nearby with grasses, moss, lichen, and some dwarf willow. The test pit was 3.66 meters from the stake at a bearing of 82° from the stake (Figure 7a). The soils were 0-13 cm organic/peat, 12-28 cm silty dark brown sediments with rounded pebbles, and some sand (Figure 7b). There were some pockets of organic material in the lower stratum. Frozen ground began 28 cm below the ground surface.

TB 11 (N71° 12.53', W56° 48.7') had a large red cone near the stake (Figure 7c). The stake was placed near low marshy land. The vegetation cover includes dwarf willow, mosses, lichens, and grasses. The soils were 0-8 cm organic/peat, and 8-18 cm silty-clay. The test pit ended at 18 cm with frozen ground. The pit was 1.25 meters from the stake at a bearing of 59° from the stake to the test.

TB 12 (N71° 12.74', W156° 46.995') sat in a low marshy area surrounded by ponds (Figure 7d). Water was oozing from the ground surface when we stepped on it. No test pit was excavated at TB 12.

TB 13 (N71° 11.74', W156° 48.64') had a ground cover of lignon berries, mosses, lichen, and grasses. The entire test pit from the surface to the frozen ground (20 cm below the ground surface) was organic/peat (Figure 8a). The test pit was 2.86 meters at a bearing of 91° from the stake to the pit.

TB 14 (N71° 10.78' W156° 49.47') was in a low marshy area beside a lake (Figure 8b). The vegetation was primarily grasses, but on the small hillocks there were mosses, lichen, and some grasses. The test pit was placed on higher ground 7.95 meters away at a bearing of 59°. The profile at 0-16 cm below the ground surface was peat and roots with frozen ground beginning at 16 cm below the ground surface.

TB 15 (N71° 10.738', W156° 47.8') was near the pipeline (Figure 8c). The pipeline ran along an angle of 90°/270° to and away from Barrow. The pipeline was 59.2 meters east of the stake at a bearing of 186°. The land was low and marshy with a ground cover of dwarf willow, mosses, grasses, and lichens. The sediments from 0-9 cm below the ground surface were organics/peat, 9-18 cm dark brown, silty-clay, with frozen ground beginning at 18 cm below the ground surface (Figure 8d). No gravels were observed in the tests.

Miscellaneous

A US Geodetic marker was found during the survey with several metal stakes around it. The marker had “1947 No. 2 TRAIL, Survey Azimuth Mark” stamped on the head. The GPS reading for the marker was N71° 12.787', W156° 50.427'.

Animal life

Not being our specialty, wild life observations were very general. Most of the animals seen in the survey area were waterfowl including swans, ducks, and geese both on the tundra and flying overhead. There was an Arctic loon in the north end of Emaiksoun Lake. An arctic fox was running toward the small valley forming the north terminus of Nunavak Bay. There was also a snowy owl near the road north of Emaiksoun Lake. There were voles on the tundra as well as rodent bones on small mounds where they were eaten by owls.

Discussion and Recommendations

TB 1, 3, 7, 9, and 10 had rounded pebbles near the ground surface in the silty-clay layer. While it is tempting to assume this indicates gravel sources, shallow as the archaeological test pits are, it may also be because these pits were all on the higher ground on the west side of the lake, rather than in the lower, marshy test areas.

No cultural materials were encountered in any of the test pits. There were broken snowmobiles, a porcelain toilet, metal cans, broken lumber, and a wooden pallet, scattered across the tundra, which were not recorded. Most had probably been deposited within the past 10 to 30 years. There is a coal bin approximately ¾ of a mile north of TB 10. We did not visit this feature, but the geologist noted it earlier. In general, there is a low probability of disturbing cultural materials in the area south and west of Emaiksoun Lake, and no archaeological monitor is needed to accompany the drilling crew during their work there.

There are three cultural features that will need to be avoided during drilling operations northwest of Emaiksoun Lake. There are two areas where human remains have been buried and at least one is marked by a grave marker. We assume the second is as well. Human remains were also found at the north end of the Nunavak Bay and this area needs to be avoided while accessing the boring areas.

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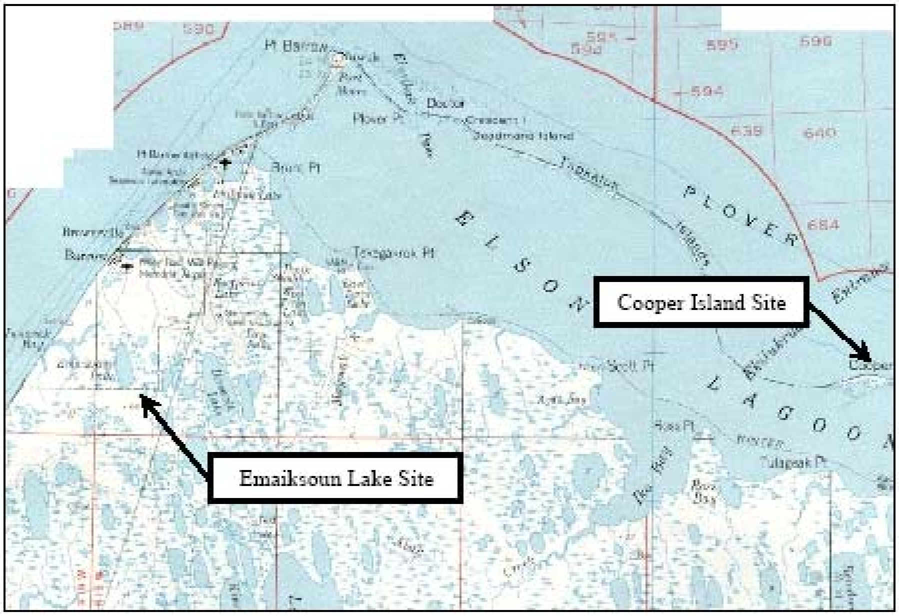
Final Report

Archaeological Survey of Gravel Sources near Barrow, Alaska

Contract Number W911KB-04-P-0135



Cooper Island Site

Emaiksoun Lake Site

Prepared For:
U.S. Army Corps of Engineers
Alaska District

Prepared By:
BTS Professional Services, LLC

December 30, 2004

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U.S. Army Corps
of Engineers
Alaska District

Barrow, Alaska

Coastal Storm Damage Reduction Technical Report

Appendix I – Background & Reference

July 2010

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Appendix I – Study Background and References

1.0 APPENDIX PURPOSE

The Background and Reference Appendix was added to the Barrow Technical Report (TR) to provide background information for better understanding of the Barrow, Alaska, area, the coastal storm damage problem, potential solutions, or reference materials that could be useful to local governments and others in evaluating future projects and proposals for Barrow and the North Slope Borough (NSB).

1.1 Prior Reports and Authorizations

1.1.1 Prior Corps Reports

The Corps of Engineers has conducted a number of studies considering water resources needs of northern Alaska, including Barrow. A major statewide, watershed-by-watershed study was conducted from 1947 to 1962 and produced 10 interim reports. Other studies covering Barrow include studies of beach erosion in 1969 and 1991 (under authority of Section 103 of the 1962 River and Harbor Act) and in 1999 (under Section 14 of the 1946 Flood Control Act); and studies of small boat harbors in 1979 and 1993 (under Section 107 of the 1960 River and Harbor Act).

Harbors and Rivers in Alaska, Survey Report, Interim Report No. 6, Northwestern Alaska, June 1957. The 1957 study considered water resources needs in Northwestern Alaska, defined as the mainland north and northwest of the Yukon River Drainage and St. Lawrence, Sledge, King, and Little Diomede Islands (an area of about 150,500 square miles). The study identified that climate extremes and lack of access roads hampered all economic development. The Corps was unable to identify any feasible navigation, flood control, hydroelectric power, or other water related project under then current conditions.

Point Barrow Beach Erosion Reconnaissance Report, Section 103 of River and Harbor Act of 1962, Point Barrow, Alaska, December 1969. The 1969 beach erosion study determined that, due to high alternative costs, insufficient economic benefits, and small relative percentage of public owned shores, Federal participation in structural measures was not justified. The Corps recommended that Barrow adopt a number of non-structural measures to reduce damage from erosion (i.e., relocate houses, businesses, and utilities and develop/enforce erosion zone ordinances).

Reconnaissance Report, Barrow Small Boat Harbor, March 1979. The 1979 Section 107 small boat harbor study looked at five lagoon sites to create a small boat harbor along the coast near Barrow. Sites between Barrow and Browerville, Tasigarok Lagoon, (estimated cost $963,000) and at Elson Lagoon ($638,000) appeared to be economically justified. The report recommended that a Detailed Project Investigation be initiated to determine design feasibility for a small boat harbor. The lagoon was used for sewage disposal prior to the study. Relocation of sewage disposal facilities was proposed as part of the harbor plan. Feasibility studies were terminated when it became apparent that the economic benefits did not offset project costs and that there were significant concerns about potential environmental impacts related to prior sewage discharges in Tasigarok Lagoon.

Barrow and Wainwright Shore Protection Studies, Alaska, 1991. The 1991 Section 103 beach erosion study looked at dredging material from an offshore site and transporting the material to the beach. The study determined that such a system (estimated cost $8.6 million) did not appear to be economically justified and thus lacked Federal interest. No Corps report was produced. Subsequently, the North Slope Borough implemented a similar dredging and beach nourishment plan. There is a detailed discussion of their project in Section 3.1.1.

Environmental Assessment and Finding of No Significant Impact, Department of Defense Environmental Restoration Program, Elson Lagoon, Alaska, May 1992. The 1992 DERP project removed about 1,200 tons of unsafe terrestrial debris from the Point Barrow Spit and about 300 tons of submerged unsafe debris up to 300 yards out from shore in Elson Lagoon. The debris consisted of landing craft, steel matting and tracks, storage tanks, and empty 55-gallon drums. The debris was from past Navy use of the area for storage and staging for exploration of Naval Petroleum Reserve No. 4 (1944-53), Air Force construction of the Distant Early Warning Line (1954-57), and Naval operation of the Naval Arctic Research Laboratory (NARL, 1947-66).

Preliminary Reconnaissance Report for Navigation Improvements, Barrow, Alaska, February 1993. The 1993 Section 107 small boat harbor study looked at three basic plans: a boat harbor at the Barrow gravel pit (estimated cost over $10 million), a shallow draft channel in Elson Lagoon ($2.8 million), and a small craft landing and channel from Elson Lagoon into North Salt Lagoon ($1.3 million). The reconnaissance study recommended that no further work was warranted since alternatives did not appear to be economically feasible.

Section 14 Emergency Bank Stabilization Study, Barrow, Alaska, 1999. The 1999 Section 14 erosion investigation agreed that there was an erosion problem occurring in front of Barrow and that the landfill and sewage lagoon were vulnerable to overtopping during a severe storm event. However, the cost of potential complete solutions ($20-$40 million) greatly exceeded the Federal participation limits ($1 million) of the Section 14 program. The draft Section 14 report recommended that the Section 14 studies be terminated and a General Investigation Study be started. No formal report was produced.

Barrow, Alaska, Section 905(b) (WRDA 86) Analysis, Storm Damage Reduction, Flood Reduction, and Navigation, June 2001. This 2001 analysis reviewed existing information and laid the basis for development of a Project Management Plan identifying the studies needed for a full feasibility study of Barrow’s water resources problems. The report concentrated on beach nourishment/road-way raise options ($80 million for 25,000 linear feet) with navigation improvement measures, if incidental to beach nourishment ($13 million). The analysis recommended a feasibility study of possible water resources measures for Barrow.

Alaska Village Erosion Technical Assistance Program, Examination of Erosion Issues in the Communities of Bethel, Dillingham, Kaktovik, Kivalina, Newtok, Shishmaref, and Unalakleet, April 2006. This report responded to legislation (2003 Appropriations Act for Corps) directing the Corps to examine erosion problems at the seven named Alaska Native villages. In addition, the 2006 Appropriations Act for the Corps provided funds under authority of Section 117 of the 2005 Appropriations Act (authorized projects for storm damage prevention and reduction, coastal erosion, and ice and glacial damage in Alaska) to consider nine villages (Kivalina, Newtok, Shishmaref, Kaktovik, Unalakleet, and Bethel—mentioned in the 2003 Act and also three new villages—Koyukuk, Barrow, and Point Hope). The 2006 report looked at the problems in the first seven villages and made recommendations for further consideration of each villages' problems individually (e.g., Shishmaref moving quickly to design and construction of preventative measures, followed by Unalakleet, Kivalina, and others as funds allowed). The three new 2006 Act villages would have had individual reports prepared for each, assessing implementation of a project under Section 117, if it had not been repealed.

1.1.2 Prior Congressional Authorizations

In recent years, Congress has passed several laws with sections relevant to coastal storm damages at Barrow. These are summarized in the following paragraphs.

Tribal Partnership Program, Consolidated Appropriations Act of 2005, Public Law 108-447, Division C – Energy and Water Development Appropriations Act, 2005. This legislation was implemented to provide additional funding through the Tribal Partnership program for technical activities for seven named communities: Kaktovik, Kivalina, Newtok, Shishmaref, Bethel, Dillingham and Unalakleet. Work using this appropriation considered the first four listed communities. Work for the last three was funded through other appropriations. The Alaska Baseline Erosion Assessment was initiated to identify, plan, and prioritize appropriate responses to ongoing erosion issues in almost 200 Alaska communities.

Section 117, Consolidated Appropriations Act of 2005, Public Law 108-447, Division C – Energy and Water Development Appropriations Act, 2005. This legislation (repealed by Congress in 2009) states as follows:

SEC.117. Notwithstanding any other provision of law, the Secretary of Army is authorized to carry out, at full Federal expense, structural and non-structural projects for storm damage prevention and reduction, coastal

erosion, and ice and glacier damage in Alaska, including relocation of affected communities and construction of replacement facilities.

Alaska Coastal Erosion, Energy and Water Appropriations Bill, 2006, Senate Report 109-84, Page 41. This report states:

"The Committee has provided $2,400,000 for Alaska Coastal Erosion. The following communities are eligible recipients of these funds: Kivalina, Newtok, Shishmaref, Koyukuk, Barrow, Kaktovik, Point Hope, Unalakleet, and Bethel. Section 117 of Public Law 108-447 will apply to this project."

With the limited amount of funds identified for construction activities, the money was primarily used for constructing shoreline protection for Shishmaref, Kivalina, and Unalakleet. The repeal of Section 117 in 2009 bars any future use of Alaska Coastal Erosion funds to perform work at full Federal expense.

Water Resources Development Act of 2007, Public Law 110-114, Title V – Miscellaneous. Section 5031 of this law provides construction authorization for a non-structural project at Barrow. The section states:

> *"SEC. 5031. BARROW, ALASKA.*
>
> > *The Secretary shall carry out, under section 117 of the Energy and Water Development Appropriations Act, 2005 (118 Stat. 2944), a nonstructural project for coastal erosion and storm damage prevention and reduction at Barrow, Alaska, including relocation of infrastructure."*

The repeal of Section 117 in 2009 bars implementation of any structural or non-structural measures at full Federal expense. Such measures can still be implemented under normal Corps planning procedures, including showing economic justification and using appropriate cost sharing as specified by the 1986 Water Resources Development Act. Projects can also be pursued under Section 116 authority, as described below.

Section 117, Consolidated Appropriations Act of 2009, Public Law 111-8. Section 117 of this law repeals Section 117 of the 2005 Appropriations Act, as follows:

"SEC. 117. Section 117 of the Energy and Water Development and Related Agencies Appropriations Act, 2005, as contained in division C of Public Law 108-447, is hereby repealed."

Section 116, Energy and Water Development and Related Agencies Appropriations Act of 2010, Public Law 111-85. Title 1 of this law provides authority for the Secretary of Army to carry out structural and non-structural projects for storm damage prevention and reduction, coastal erosion, and ice and glacial damage in Alaska, including relocation of affected communities and construction of replacement facilities. The section states:

> **"**The Secretary of the Army is authorized to carry out structural and non-structural projects for storm damage prevention and reduction, coastal

> erosion, and ice and glacial damage in Alaska, including relocation of affected communities and construction of replacement facilities: Provided, That the non-Federal share of any project carried out pursuant to this section shall be no more than 35 percent of the total cost of the project and shall be subject to the ability of the non-Federal interest to pay, as determined in accordance with 33 U.S.C. 2213(m)."

This authority allows the Corps to evaluate and select a recommended project based in part or wholly on non-monetary units (Environmental Quality or Other Social Effects) supported by a cost effectiveness/incremental cost analysis consistent with established evaluation procedures. Non-monetary benefits that may be considered include such things as public health and safety; local and regional economic opportunities; and, social and cultural values to the community.

1.1.3 Prior Related Reports by Others

Bluff and Shoreline Protection Study for Barrow, Alaska, August 1987 by Tekmarine, Inc., Pasadena, Ca. This study for the NSB developed a feasible shoreline protection methodology for Barrow. The study recommended providing the reach with the eroding bluff face a gravel fill covered with a linked concrete block mattress on a 1:3 slope. The lagoon reach would receive a road raised to +12 MLLW combined with an approximately 4-foot-high barrier on the shore side of the road. The estimated total initial project cost was about $36 million. No construction resulted from this study.

Mitigation Alternatives for Coastal Erosion at Wainwright and Barrow, Alaska, April 1989 by BTS/LCMF Limited, Barrow/Anchorage, AK. This study for the NSB reviewed and analyzed alternative actions that could be taken to mitigate coastal erosion. It recommended that beach nourishment by dredging be pursued. The project was estimated to cost $14.3 million over 8 years by placing 800,000 yd^3 of material on the beach at an average cost of $\$15.27/yd^3$. No construction resulted directly from this study.

Wainwright and Barrow Beach Nourishment Project and Plan Review, Final Report, September 1992, by Ogden Beeman & Associates, Inc., Portland, OR. This report for the NSB reviewed the plans for the beach nourishment by dredging project and made recommendations regarding changes to the dredging methodology and the specific tug and dredge design. This report combined with the July 1994, August 1994, and January 1995 reports, provided the basis for the NSB's beach nourishment project described in Section 2.1.2(1).

Barrow Beach Nourishment Project, A Synthesis of Pertinent Information, July 1994, by Coastline Engineering. This report for the NSB was intended to provide a summary of past information and the current NSB project to provide beach nourishment through dredging an offshore bar for third-party review by the Science Advisory Committee of the University of Alaska's Institute of Marine Science.

Review of the Barrow Beach Nourishment Project, August 1994, by NSB Science Advisory Committee, Fairbanks, AK. This review responded to citizen concerns regarding the proposed NSB dredging project and answered three specific questions posed by the NSB mayor. They determined that the material to be removed for beach nourishment would provide more benefits on the beach than offshore underwater, beaches down current would likely benefit, and suggested modifications to the dredging methodology to improve the project.

The Effect of Dredging Directly Offshore of Barrow on the Erosion of the Culturally Sensitive Bluffs, January 1995, by Coastline Engineering. This report for the NSB reviewed concerns raised by local residents about offshore dredging affecting shoreline bluff erosion in Barrow. The report concluded that neither the average run up nor the average littoral transport along the beach would be increased due to increased dredging offshore. No negative impacts would be experienced at the fill flanks due to presence of the fill.

Project Analysis Report, Barrow Landfill Closure Plan & Environmental Site Assessment – Phase 1, August 1997, by Montgomery Watson. This report for the NSB laid out the scope of work, cost, and schedule to perform the work necessary to develop plans to close the existing Barrow landfill, which is discussed in Section 3.3.

New Barrow Landfill Site Selection, May 2000, by Montgomery Watson, Anchorage, AK. This report for the NSB investigated and discussed the alternative sites available for a relocated Barrow Landfill and recommended a preferred site. The preferred Site E was located inland about 8 miles southeast of the old landfill near an existing gravel pit. Site C is about a mile north of the BIA Prospect Borrow area investigated as a material source by the current Corps study. Site E was selected for the new landfill, which is further discussed in Section 1.12.1.

Barrow Climatic and Environmental Conditions and Variations – A Compendium, 2005, by U of Colorado, Boulder, CO. This report for the National Science Foundation compiled what was known by residents and scientists about trends and processes affecting the Barrow environment over the previous half century. Findings were presented and recommendations made regarding a networking strategy for Barrow to use in acquiring assistance in relieving chronic erosion and flooding problems.

1.2 Civil and Native Governmental Organizations in Alaska

The relationship between civil governmental organization and Native organizations in Alaska are summarized in table 1. Because of unique circumstances involved in the development of Alaska during the last century, the relationship between the civil government and Native organizations, with one exception, is different from in the other

49 states. Civil government in Alaska provided for two levels of government under the state: boroughs (similar to counties) and cities of various classes. These levels were established in the Alaska State Constitution, which became effective upon statehood on January 3, 1959. Boroughs have been established covering less than half the area of the state, with the remainder being unorganized (unboroughed) at the regional level.

Table 1. Native and Civil Governments and Organizations

State	Tribal	Alaska Native Claims Settlement Act	Level
State of Alaska	Statewide Tribal Organization providing advocacy for tribes. **Alaska Inter-Tribal Council (177 tribes)**	Statewide Native Organization (non-tribal). **Alaska Federation of Natives (AFN)**	Statewide
Borough Assembly: State chartered regional municipal government. **North Slope Borough**	Regional Tribal Consortium/Non-Profit: Service delivery to tribal members/tribal advocacy. **Artic Slope Native Association**	ANCSA Regional Corporation: State chartered regional for profit; owns subsurface rights. **Artic Slope Regional Corporation**	Regional
City Council: State chartered municipal government. **City of Barrow**	Tribal Council: Federally recognized tribal government by Bureau of Indian Affairs. **Native Village of Barrow Inupiat Traditional Government** **Inupiat Community of the Arctic Slope**	ANCSA Village Corporation: For profit village corporation; owns surface rights. **Ukpeagvik Inupiat Corporation**	Local

Federally-recognized Tribes are defined as those Native entities within Alaska recognized and eligible to receive services from the Department of Interior, Bureau of Indian Affairs (BIA). The BIA has recognized 229 such entities in Alaska, most of which are relatively small. There is only one Indian Reservation in Alaska in which the tribal organization has control of the land, the Metlakatla Indian Community, on Annette Island south of Ketchikan at the southern end of the Alaska panhandle. Native land holdings come under provisions of the 1971 Alaska Native Claims Settlement Act (ANCSA) that extinguished aboriginal Native land claims in Alaska and vested the land rights for 44 million acres in Regional (subsurface rights) or Village (surface rights) Corporations. Both the Regional and Village Corporations are legal entities separate from the Federally recognized Tribe. Also, mainly for housing, health care, and social services, ANCSA Non-Profit Corporations were established. Subsequently, in 1980, the Alaska National Interest Lands Conservation Act (ANILCA) granted a subsistence preference for individual Alaska Natives on Native controlled land and for both Native and non-Native rural residents in the remainder of Alaska. In Barrow, the Federally-recognized entities are the Native Village of Barrow Inupiat Traditional Government (NVB) and the regional Inupiat Community of the Arctic Slope (ICAS). The ANCSA For-Profit Corporations are Ukpeagvik Inupiat Corporation (UIC) and the Arctic Slope Regional Corporation (ASRC). The ANCSA Not-For-Profit Corporation is the Arctic Slope Native Association (ASNA).

Barrow is in the North Slope Borough (NSB). Organized boroughs in Alaska are in some ways like counties in much of the rest of the United States, but with political structure and powers that may be substantially broader. The NSB includes almost all of Alaska north of the 68th Parallel with a total population of about 9,600 people, or about 1 person for every 10 square miles. By comparison, Wyoming, the least populated of the 50 states has about five people per 1 square mile (about 50 times the population density of the

NSB). Alaskan Natives make up about 87 percent of the population of the NSB. The regional Native corporation for this area, the Arctic Slope Regional Corporation (ASRC), has the same geographic boundary as that of the NSB.

1.3 Stakeholders in Barrow

In Barrow, there are a large number of stakeholders, partly due to the unique relationships in Alaska between civil and Native governments and organizations. The entities and their primary responsibilities are listed in this section as follows:

- **North Slope Borough (NSB).** The NSB is the county-like, civil government. Established in 1972, it provides general government services for the entire 95,000-acre borough (mayor, assembly, elections, planning, wildlife management, health and social services), specialized services in each of the eight villages within the borough (K-12 schools, police, fire, search and rescue, public works (streets, sidewalks, refuse collection and disposal, health clinics, etc.) and Ilisagvik College (IC) in Barrow at the old NARL site.
- **Inupiat Community of the Arctic Slope (ICAS).** ICAS is the BIA-recognized entity representing the entire Arctic Slope. They oversee Tribal operations, natural resources, realty, roads, wildlife, parks, and vocational rehabilitation. They have agreements with oil and gas developers over their North Slope operations and with the military for demolition and restoration of former Distant Early Warning (DEW) Line sites.
- **Arctic Slope Regional Corporation (ASRC).** ASRC, incorporated in 1972, is the regional, private, for-profit, Alaska Native owned corporation covering the same territory as the NSB and representing the business interests of the Arctic Slope Inupiat. ASRC represents the eight villages on the North Slope of Alaska and has title to about 5 million acres of land. ASRC operates subsidiary companies in the professional fields of engineering, civil construction, financial management, oil and gas support services, petroleum refining, and distribution for aviation, marine, retail, and home heating, communications, hotel and tour business, military base and training range operation and management, military housing, solid state phased array radar system, and air-space surveillance, intercept control, and navigational assistance. Operations are primarily in Alaska but also in Washington, California, New Mexico, Colorado, Kansas, Maryland, Louisiana, Alabama, Massachusetts, Canada, Greenland, Great Britain, and Russia.
- **Arctic Slope Native Association, Limited (ASNA).** ASNA is the regional, private, not-for-profit, Alaska Native owned corporation that operates the Samuel Simmonds Memorial Hospital, a 14-bed acute care facility serving all the people of the North Slope. It is the oldest healthcare facility in Alaska and operates under a contracting agreement with the Indian Health Service. In addition, the ASNA operates a summer youth camp to teach the skills necessary to stalk, kill, and prepare animals (such as caribou and fish) from the region in accordance with traditional Inupiat values.

- **Tagiugmiullu Nunamiullu Housing Authority (TNHA).** Established in 1974, TNHA provides housing assistance services to eight communities, including Barrow. Annually, tribes sign a resolution authorizing TNHA to be their tribally designated housing entity. Funding is provided by the Alaska Housing Finance Corporation and the United States Department of Housing and Urban Development's Indian Housing Block Grant Program.
- **City of Barrow.** The civil city government, incorporated as a first-class city in 1959, primarily provides recreational opportunities (Piuraagvik-recreation center, Tupiqpak-ice rink, roller rink, community center, playgrounds), permitting services (alcohol, taxis, overburden removal, etc.), and the cemetery for residents. Every year it stages several regional festivals: *Puiraagiaqta* (Spring Festival), *Nalukataq* (Summer Blanket Toss), *July 4th Games* (Eskimo-Indian Olympics), *Qitik* (Christmas), and *Kivgiq* (tri-annual Arctic celebration).
- **Native Village of Barrow Inupiat Traditional Government (NVB).** NVB is the BIA recognized entity representing Barrow. It provides tribal government administration, tribal courts, wildlife, realty, social services and workforce development services.
- **Ukpeagvik Inupiat Corporation (UIC).** UIC, incorporated in 1973, is the private, for-profit Alaska Native Corporation for Barrow. UIC operates subsidiary companies that provide construction services, gravel borrow, vehicle repair and rental, barge services for Alaska, direct cargo service from the Lower 48 to Alaska, service on Puget Sound in Washington, logistics planning and execution, engineering and technical services, program management, information technology and computer systems operation, environmental cleanup, and building roofing. A UIC subsidiary, Bowhead Transportation Company, which began operation in 1982, is the managing partner for a joint venture that supports the Army National Guard to include the National Guard Bureau and the programs and interests of the Guard in 54 states and territories. Bowhead Support Services supports the V-22 and UAV at NAS Patuxent, MD, as well as the NAVAIR, NAWCAD, and NAS public affairs offices. In addition, UIC operates its own gravel pit 6 miles south of Barrow to support local road projects and building pad construction (Barrow Global Climate Change Research Facility).
- **Barrow Utilities & Electric Cooperative, Inc. (BUECI).** BUECI, the not-for-profit, member-owned, cooperative that provides the village of Barrow with electricity, natural gas, water, and sewer services, was formed in 1964. The water supply is provided from Isatkoak Reservoir and passed through a microfiltration/nanofiltration system prior to delivery to homes. The seven electric generators can produce 20.5 megawatts (double peak demand). Wastewater flows are pumped to South Salt Lagoon where "facultative treatment" occurs for a year. The lagoon contents are then pumped into Middle Salt Lagoon, where they sit for another year before they are discharged into the Arctic Ocean. Utilities are provided in Barrow either by direct bury or in a utilidor. The utilidor is a trapezoidal, buried, wood structure, 6 feet high by 6 feet wide at the base (5 feet wide at the top) carrying utility lines (potable water, sewage collection,

telephone, TV cable, fiber optic communications, and electric service lines. Gas delivery lines are direct-bury throughout Barrow.

- **Arctic Slope Telephone Association Cooperative (ASTAC)** ASRC is the not-for-profit, member-owned cooperative that provides the village of Barrow and the rest of the North Slope with telecommunications, including telephone, dial up and DSL Internet access, and facilities mapping.
- **Barrow Arctic Science Consortium (BASC)** BASC is a not-for-profit, community-based organization, established in 1995 and dedicated to the encouragement of research and educational activities pertaining to Alaska's North Slope and the adjacent portions of the Arctic Ocean. The NSB, UIC, and IC contributed to the creation and support of BASC. The BASC manages the Barrow Environmental Observatory (BEO), which is the facility previously operated by the U.S. Navy as the Naval Arctic Research Laboratory (NARL), and promotes transfer of information between scientists and community members. A cooperative agreement with the Office of Polar Programs of the National Science Foundation provides funding for BASC's activities. BASC will operate the Barrow Global Climate Change Research Facility, which is currently under construction.
- **GCI.** GCI is a private Alaskan corporation providing cable TV, internet, and long distance telephone service in Barrow since 2005, when they acquired Barrow Cable TV.
- **Alaska Eskimo Whaling Commission (AEWC).** AEWC was formed in 1977 to represent whaling communities and to coordinate with agencies responsible for the management of subsistence whaling. It promotes the protection and enhancement of the Eskimo culture, traditions, and activities associated with bowhead whales and subsistence whale hunting. The AEWC works cooperatively with the International Whaling Commission (IWC). Each whaling community also has a local organization of captains. The Barrow Whaling Captains represent local whalers at the AEWC and IWC meetings.
- **Inupiat Heritage Center (IHC).** IHC, dedicated in February 1999, houses exhibits, artifact collections, library, gift shop, and traditional crafts. The NSB owns and manages the IHC, which was designated as an affiliated area of New Bedford Whaling Historical Park in New Bedford, Massachusetts to ensure the contributions of Alaska Natives to the history of whaling are recognized.
- **Alaska Department of Transportation and Public Facilities (ADOT&PF).** ADOT&PF owns and operates most of the airports in the State of Alaska, including the Wiley Post-Will Rogers Memorial Airport in Barrow. The Department in recent years has been lengthening, widening, and adjusting the centerline of the main runway and upgrading the runway safety area, taxiways, aprons, navigational aids, lighting, and adjacent streets. They moved more than a million cubic yards of material from the borrow area, 50 acres in the southwest corner of the airport property, to form the higher/wider embankments. The borrow pit floor could be mined no deeper than 5 feet above mean high tide elevation to prevent erosion of the access road and shoreline during storm events. This borrow area is immediately adjacent to the NSB borrow area, which has been

used for decades to provide fill materials for the development of Barrow's infrastructure and building pads, but is now largely depleted. The end of the embankment for the west end of the new runway safety zone will be about 600 feet from the existing eroding shoreline.

- **United States Air Force (USAF).** A subsidiary of ASRC has the contract from the USAF to operate the network of 19 geographically separate radar stations forming the Alaska Radar System (ARS). Its mission is to provide air space surveillance, intercept control, and navigational assistance to military and civilian aircraft. The ARS covers over 590,000 square miles of Alaska (about twice the combined size of Texas and Louisiana). Ten sites are north of the Arctic Circle, including the Barrow radar site. It is about a half mile south of the old NARL aircraft hangers. The Barrow radar was originally constructed in 1953 as part of the Distant Early Warning System, which was designed to detect Soviet long-range bombers. The radars onsite have undergone several upgrades over the years. The continued operation of the Barrow site is an essential element of National Security.
- **National Oceanic and Atmospheric Administration (NOAA).** In 1973, NOAA established the Point Barrow Observatory (PBO) for their Earth System Research Laboratory about a quarter mile south of the USAF radar site. The Barrow Observatory is host to numerous cooperative global atmospheric research projects from around the world. Other similar NOAA observatories are on Mauna Loa, HI, American Samoa, the South Pole, and Trinidad Head.
- **United States Department of Energy (USDOE).** The Scandia National Laboratories of the USDOE, located in Albuquerque, New Mexico, established their Atmospheric Radiation Measurement (ARM) facility at the NOAA PBO. The ARM program involves data collection in Barrow and Atqasuk, Alaska, Darwin, Australia, and Manus and Nauru Islands in the Pacific. The ARM observatory has become an integral part of international collaborations and U.S. government research programs involving polar environment, ground-based, remote sensing for climate modeling and weather forecasting sponsored by NASA and NOAA. It also provides accommodations to scientific researchers on a space available basis.

1.4 Current and Future Projects of Other Agencies

In recent years, a number of Barrow stakeholders have been actively involved in planning, designing, and/or constructing major new facilities. One characteristic common to the facilities being replaced or upgraded is that they are relatively close to the shoreline and would or could suffer significant damages during extreme storm events. Local entities have taken seriously the erosion and flooding threat and generally employed the non-structural choice of retreat and relocation farther from danger for their vulnerable facilities. An exception is the airport, where the State extended the runway and safety zone toward the eroding coastline. These new projects will reduce future erosion and flood damages. Even though these projects reduced possible NED benefits for a new Corps project, the local community chose wisely to move out of harm's way what they can, when they can. The following paragraphs briefly discuss each of these major capital improvement projects. Their planned sites are shown on figure 3. In any event, although millions are being spent on these projects, large portions of commercial, residential, and public land and structures remain susceptible to erosion and flooding from extreme storm events. The current study provides an opportunity to address these smaller buildings and facilities that are critical to the long-term economic and social well-being of Barrow and the entire NSB.

1.4.1 Barrow Landfill

The existing Barrow landfill, owned and operated by the NSB, is along Stevenson Street in the northeast half of South Salt Lagoon. The existing landfill is unpermitted and operates under a Compliance Order by Consent Agreement (COBCA) with the Alaska Department of Environmental Conservation (ADEC). The COBCA mandates closing the existing landfill and developing a new Class II landfill (less than 20 tons/day) for the community. The old landfill will be encapsulated to freeze waste as a permanent landfill. The NSB conducted site selection studies in the 1990's and chose a 55-acre site inland, about 8 miles southeast of the old landfill near the existing UIC gravel pit. Design considerations included airport safety, floodplains, wetlands, seismic zones and unstable areas, subsistence resources, discharges, cover, etc. A permafrost landfill design was selected that first encapsulates the waste material and then encourages its freezeback. All sites considered were at least a mile or two from the shoreline, beyond any reasonable prediction of shoreline erosion or ocean flooding. The state issued the permit for the new landfill in 2004. Construction on the site creating the initial gravel pad and access road began in the winter of 2005 using an ice road from the UIC borrow pit to the site. Construction on the new landfill site is completed and the landfill operational.

The current Barrow landfill, located in the northeast half of the South Salt Lagoon, is being closed because of a 1997 state order. The U.S. Navy, U.S. Air Force, the NSB, the Native Village of Barrow, and the Department of Justice in 2002 negotiated a financial plan for the closure of that landfill. That plan provided for the Department of Defense to supply a majority of the funding for the closure, with the provision that no additional Federal funds would be given to support the landfill. The landfill closure plan included some minimal measures (such as jersey barriers along the road seaward of the landfill) to reduce flood damages that might be experienced in the future by the landfill. However, these measures are limited and assume that the beach and the road will remain in place and will not be eroded and/or damaged in the future. Because of lack of Congressional funding, the 2002 agreement was never implemented. In July 2005, the earlier agreement was replaced by a subsequent one, which implemented a $16 million settlement for landfill closure. The feasibility study will consider the coastal erosion and storm damage problems and measures to resolve them in the Barrow-Browerville area, which could include resolving erosion/storm problems, if there are any, on the beach at the landfill.

1.4.2 Barrow Wastewater Treatment Facility

The existing wastewater treatment for Barrow involves reduction of organic wastes solely by "facultative" treatment in the southwest half of South Salt Lagoon for a year followed by a second year in Middle Salt Lagoon, with ultimate discharge to the Arctic Ocean, generally during June of every year. The BASC sewage treatment plant also discharges its effluent into Middle Salt Lagoon. BUECI has selected a site for a new treatment facility to be located along Laura Madison Street, directly south of the landfill portion of the South Salt Lagoon. The first floor of the facility will be set on a gravel pad at elevation +22.5 feet MSL, well above any reasonably foreseen flooding. Instead of the existing wastewater collection system ending at the pump facility along the ocean edge of South Salt Lagoon, the pipe will be routed from Stevenson Street down Ahmaogak, Karluk, Uula, and Laura Madison Streets to the new plant. Construction began in the summer of 2006.

1.4.3 Barrow Hospital Replacement

The existing Samuel Simmonds Memorial Hospital, built in 1963, is a critical access facility serving as the only hospital available to residents of an area larger than Washington State. The hospital offers emergency, clinic, and urgent care facilities. However, the Indian Health Service (HIS) will fund a $104 million project creating a hospital four times larger than the current hospital (109,000 square feet) with an increase of about 140 jobs. The site selection process for the new hospital lasted 8 years, considering eight different sites. Location criteria included land parcel size, floodplains, environmental, utilities, community impact, and user/employee considerations. A 20-acre site in the Browerville subdivision of Barrow was selected in 2004. The old hospital was on the shore of Lower Isatkoak Lagoon, about 600 feet from the Arctic Ocean shoreline, potentially susceptible to damage from extreme storm events. The new hospital will sit on high ground at the intersection of Yugit and Uula Streets, just northeast of Upper Isatkoak Lagoon, the water supply for Barrow. Hospital work is currently underway. Building design was completed in 2007, and building construction is scheduled for completion in 2009.

1.4.4 Barrow Global Climate Change Research Facility (BGCCRF)

BASC has been coordinating the nation-wide planning of the approximately 89,000 square-foot facility that will provide modern research, housing, and maintenance and storage areas for future Arctic research. The facility will service the global scientific community and local and regional Inupiat Eskimo population and replace many of the old NARL facilities originally built during and shortly after World War II. In 2005 Congress authorized $61 million for a five-phase project in the FY 2005 Energy Bill. The site selected for the buildings is on the west shore of Imikpuk Lake, approximately 1,000 feet southeast of the existing NARL site. The 13-acre parcel was an undeveloped area with a tundra mantle underlain by permafrost with a surface elevation of about +8 feet MSL. Access roads will initially be extended from the NARL site, with a possible future connection to Cake Eater Road. The potential for flooding from coastal storms was a significant consideration in the facility design. A gravel pad was placed on the site founded on a geotextile membrane over the tundra, raising the surface to an average of +12 feet MSL, above expected storm surges. The bottom soffit of the pile supported research building was set at +15 MSL, with a finish floor at approximately +18 MSL. The detached maintenance/storage building is a slab-on-grade with a floor elevation of +14.5 MSL. The grand opening of the $20 million Phase 1 of the facility was held on June 1, 2007, just in time for the March 2007 beginning of the International Polar Year (2007-2008).

1.4.5 New BASC Access Road (Uivaqsaagiaq Road)

Associated with construction of the new BGCCRF, planning has been undertaken to provide a new access road to both the new facility and the remainder of the old NARL site. This road would start at Cake Eater Road, just south of its crossing over the creek that drains into the Middle Salt Lagoon, and run north along relatively high ground. This route would not be in as much danger of imminent attack by storms as is Stevenson Street every summer and fall. If the 2.5-mile-long-road were raised at low spots about 4 to 5 feet above the surrounding tundra, it would be able to maintain access between Browerville and NARL/BASC/IC during expected flood events. The new road would also serve as an evacuation route during storms. The NSB has indicated that after the BGCCRF, the new sewage treatment plant, and this new road are completed in a few years, the NSB will not continue to try to keep Stevenson Street operational during storm events east of Ahmaogak Road, but will let it flood. Also, the new road to the sewage treatment plant (Laura Madison Street) may be connected to the new "backdoor" road to BASC.

1.4.6 Itasigrook Dam Renovation

The fresh water supply for Barrow is collected in what originally was the natural Isatkoak Lagoon, between the Barrow and the Browerville parts of the city. In the 1960's, the Bureau of Indian Affairs constructed an earth, concrete, and oil barrel dam. This divided the lagoon into a lower and an upper section, just northeast of the existing hospital site. The Tasigarook Lagoon served as receiving waters for the secondary sewage treatment plant of the local hospital in 1959. That effluent was scheduled to be rerouted to another lagoon.

The dam has an approximately 80-foot-wide concrete spillway set at about +4.5 MSL. The upper part of Isatkoak Lagoon was subsequently divided into a middle and an upper reservoir when Ahkovak Street was built across the lagoon just north of the new grade school. A series of corrugated metal pipe (CMP) culverts under the roadbed hydraulically join the waters on both sides. The water surface elevation is generally only a little higher in the upper reservoir as in the middle portion. Barrow's water supply intake is on the eastern (upstream) side of the road. The pipe runs along the road to water treatment facilities at the BUECI plant where the water is treated to remove minerals, solids, and potentially pathogenic bacteria using a state-of-the-art Microfiltration-Nanofiltration System.

Over the years, the dam that separates the middle reservoir and lower lagoon (now Itasigrook Lagoon) has deteriorated to the point that the core has washed out and the concrete spillway apron has failed. The dam fix consists of adding a steel sheet-pile weir with buried steel sheet-pile wingwalls to form a sharp crested weir set at the same elevation as the current spillway. Additional gravel fill will be added to the seaward face of the dam to cover existing slope and toe protection consisting of exposed steel drums filled with concrete. The NSB renovated the dam during the summer of 2006. The renovated dam will still be subject to wave attack during storms if the shoreline berm and the Eben Hopson Street embankment are overtopped and/or breached. However, the dam and spillway should be better able to resist damages than in their present condition.

1.5 Local Government Past Damage Reduction Measures

The NSB and others have attempted to curb the erosion and flooding that impact the coast in front of Barrow and its associated facilities. Following is a list of the coastal erosion and flooding mitigation measures, discussed in following paragraphs, for avoiding damages from storm events:

- Pushing beach material into berms during storm events
- Placing sacrificial berms along the shoreline road
- Offshore dredging for beach nourishment
- Geotextile sack revetment
- Filled utilidor seawall
- Laid back tar barrels
- Longard geotextile tubes
- HESCO Concertainers

1.5.1 Placing Beach Material into Berms During Storm Events

The NSB actively moves beach material at critical locations during storm conditions, operating D7/D8 dozers on the beach in the surf zone (figures 1 and 2). The NSB has stated that although the berms provide limited protection during larger storms, they will continue doing what they can to keep the berms in place, even if that means continued operation of the dozers in salt water. When the dozers are operated this way, additional maintenance is required to keep this equipment in order. Due to the corrosive nature of the salt, the electrical systems are the hardest to keep in working order. The dozers must routinely be steam cleaned to keep salt off, while the electrical connections are shrink-wrapped to prevent salt from entering the connections.

Figure 1. Bulldozer working on the beach building berms at Itasigrook Lagoon

Figure 2. Bulldozer pushing beach material during heavy surf.

1.5.2 Placing Sacrificial Berms Along the Shoreline Road

Over the past decade sacrificial berm building has been the first protection against storms for the community. These sacrificial berms are sand and gravel mounds generally anywhere from 6 to 8 feet above the ground surface (crest would be at about elevation +13 to +15 feet). They are placed at the crest of the beach as a protection measure against rising water from storm surge and wave attack. The NSB normally uses lower grade material since they have a limited supply of gravel. Higher quality material is saved for maintaining the community's roads. Although the material is of a lower grade, the material still costs about the same per cubic yard as the higher quality ($37/cubic yard). This is due to the cost to extract the material from the borrow pit. Approximately 15,000 cubic yards of material is placed annually to form the berms (material cost, $548,000). Labor and fuel accounted for another $19,000, for a total placement cost of $567,000 annually in 2007 values. Storms that hit the community generally range in length from 3 to 5 days. When storms are larger, the berms do not last very long, often gone after 8 to 10 large waves.

During a 2000 storm, floodwater overtopped Stevenson St. (figure 3) and flowed into the Lower Salt Water Lagoon. Four sections of the shoreline road BASC were lost (up to 200 yards in length). Approximately $330,000 was spent to repair these sections of road out to the boat launch at Nixeruk (figure 4). It is estimated that this road needs to be repaired about every 3 years, or approximately $110,000 annually. Stevenson St, adjacent to the shoreline and susceptible to direct storm attack, provides an important transportation connection to Pt. Barrow, where fish camps used for subsistence harvesting are located on Elson Lagoon. The subsistence harvesting season for salmon, whitefish, and other types of fish all occur during open water periods, which is when most storm events occur. Many residents spend days or weeks at their camps. If the road was washed out, some residents would not be able to travel easily to or from their camps and Barrow. Some spend only weekends at their camp, but many return to Barrow regularly to buy food, fuel, and other supplies. Rebuilding these roads in Barrow has become difficult due to the number of projects that have reduced the availability of gravel (there is no stockpile readily available). The estimated annual damage to roads and berms under existing conditions is approximately $628,000. In the current without project condition, this cost will continue until a project is built that controls wave activity and protects the roads during storm events or the roads are relocated.

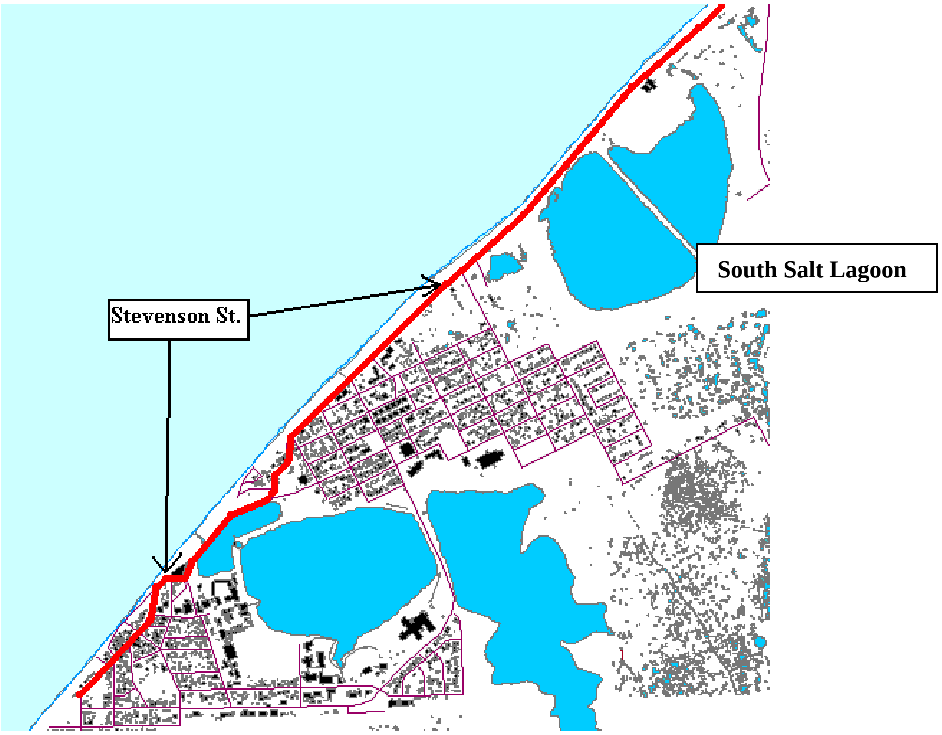
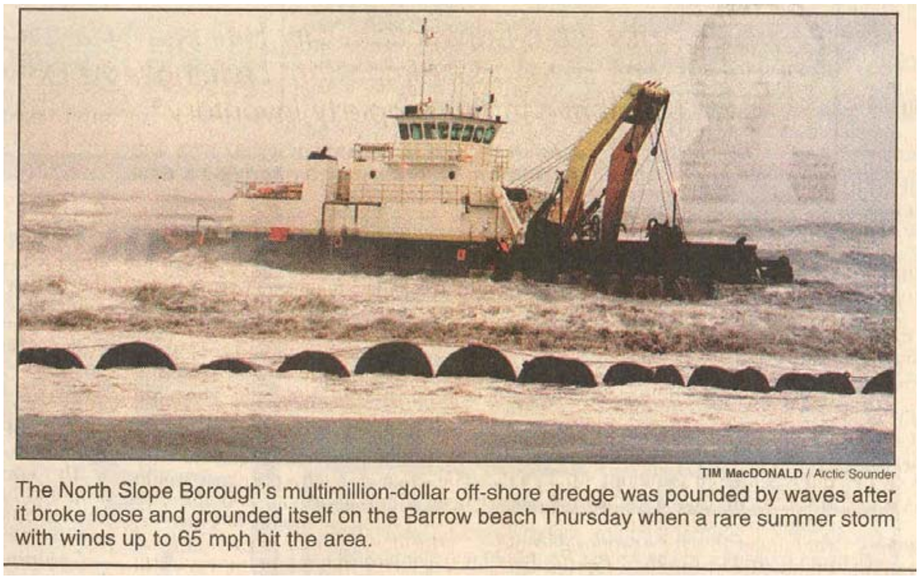


Figure 3. Location of Stevenson Street

Figure 4. Sacrificial berms placed along road.

1.5.3 Offshore Dredging with Beach Nourishment.

From 1989 through 2000 the NSB first studied and then implemented a major program to dredge offshore at Wainwright (a smaller community about 90 miles southwest of Barrow) and Barrow to provide materials for beach nourishment. The program, authorized by the NSB Assembly in August 1991, envisioned using a specially-built, barge-mounted dredge over a period of 8 years to remove about 800,000 cubic yards (yd^3) of material at Barrow and place it on the eroding beach for nourishment at a unit cost of about $15 per yd^3. After a number of construction delays, the NSB took delivery in Wainwright during July 1995 of the dredge, shore barge, and dredge tender. The 1995 season was spent dredging and providing beach nourishment for Wainwright. The 1996 season was spent completing dredge modifications to improve the working rate and conducting a 29-day dredging season (17.5 operating days) at Barrow. Material encountered offshore required additional dredge modifications to obtain efficient production. Dredging operations were suspended during 1997 and 1998. In 1999 additional dredge modifications were made and a full dredging season (July18 to September 3) was completed. About 64,000 yd^3 of material were placed along 1,800 feet of shoreline at a unit cost of about \$78/yd^3 in place. Dredging resumed in the summer of 2000, continuing until August 10, when the dredge was severely damaged during a storm (figure 5). In July 2001, the NSB authorized selling the dredge and all specialized equipment and expressed support for further study of erosion processes, including both NSB work underway for the landfill closure and future Corps of Engineers studies. The NSB has stated that unless a suitable gravel source (sufficient sized gravel and economical) is found, a beach dredging nourishment program will not be considered in the future. About $28 million was spent over a decade on the NSB's Beach Nourishment Program to place about 100,000 yd^3 of material onto Barrow beach. After the program was initiated, NSB determined that the actual material dredged was not of a sufficient


TIM MacDONALD / Arctic Sounder

The North Slope Borough's multimillion-dollar off-shore dredge was pounded by waves after it broke loose and grounded itself on the Barrow beach Thursday when a rare summer storm with winds up to 65 mph hit the area.

Figure 5. Dredge beached during 2000 storm.

size/quality to significantly protect the beach. Excess program funds of $11 million were transferred to an area wide erosion control account, which has supplied the local cost share for this feasibility study. Figure 6 shows the results of a storm eroding the beach nourishment materials.

Figure 6. Remains of beach nourishment after storm.

1.5.4 Other Measures.

Over the years, the community has tried a number of erosion prevention measures along portions of the shoreline with varying degrees of success. These include the following: large rubber or geotextile “supersacks” laid on the bank slope along Egasak Street (figure 7); surplus, earth-filled, wooden utilidor sections serving as a seawall near sewage lagoons (figure 8); old tar barrels laid on the upper beach slope near Brower’s Café (figure 9), and Longard geotextile tubes laid along the base of the bank or berm near sewage lagoons (figure 10).

Figure 7. Supersack revetment.

Figure 8. Wooden utilidors backfilled with local material.

Figure 9. Tar barrels lay on beach at an angle.

Figure 10. Longard tube type protection.

1.5.5 HESCO Concertainers.

The most recent storm damage reduction measure tried was the installation of a seawall type structure using geotextile fabric (on vertical surfaces) encased in a wire basket. Two segments were installed in Barrow during the summer of 2004. One segment was placed just southwest of the filled utilidor revetment at the sewage lagoon and the other is just northeast of Egasak Street (figure 11). To date, it has held up well in Barrow through four winters without a major failure, but has failed at three other coastal applications in Alaska. In June 2006, minor damage to the lowest basket tier was noted at the Egasak gabions. The cause of the damage is uncertain, but appears to be either ice override or heavy equipment impact. The cause of the gabion system failure at the other locations in the State is not certain. Factors that would increase the system's survivability at Barrow include the fact that the system was not exposed to a storm event during or immediately after construction, which gave it time to saturate with water and freeze during the winter. Once frozen, the system acts more as a solid block rather than loose granular material that could be washed out by wave action. The system at Barrow was also put in place to stem road and bluff erosion, so it is set back from the shoreline typically out of the zone of wave impact unlike other applications in Alaska.

Figure 11. HESCO Concertainers near Okoksik Street.

1.5.6 Utqiagvik Village Archeological Site

The Utqiagvik Village Site is an historic/archeological site in northwestern Barrow adjacent to the shoreline bluffs. The Utqiagvik Village Site has been occupied for more than 2,500 years and at one time covered a large portion of what is now Barrow. The remaining archeological site has been set aside by the city and is the last portion of the former Utqiagvik Village Site along the coast that has not been redeveloped. The site is eligible for the National Register of Historic Places. The site suffers occasional damage/loss from coastal erosion of the Barrow bluff.

1.5.7 Barrow's Historic Importance for the Nation

Barrow has been important to the United States for both scientific and military advancements. During the First International Polar Year (1882-1883) a U.S. Naval expedition established one of two American research stations, studying magnetism, tides, meteorology, natural history, and ethnography of Inupiat Eskimos. The Weather Service began Barrow observations in the 1920's. During World War II in 1943, the Navy Seabees established a base at Barrow (with satellite bases at Cooper Island and inland at Umiat on the Colville River) to explore the National Petroleum Reserve for gas and oil badly needed for the war effort. The base was realigned to become the Naval Arctic Research Laboratory (NARL) in 1947 to provide facilities and support for scientists conducting research in oceanography, atmospheric science, and terrestrial and marine biology. During the Cold War, the Air Force established Early Warning Radar sites throughout the north and west coasts of Alaska. An Aircraft Control & Warning Center was established at Barrow with the other north Alaska radar sites feeding their target data to Barrow for analysis. Defense radars continue to be located at Barrow today. The NARL operations were decommissioned in 1980 and the facilities turned over to the UIC in 1989. In 1995 the Barrow Arctic Science Consortium (BASC) was formed to perform research and educational activities in cooperation with Ilisagvik College on the NARL

2.0 PUBLIC INVOLVEMENT AND NATIVE TRIBE CONSULTATION

2.1 Introduction

Public Involvement for this project was important because this was a long study with many technical components that required updates with the sponsor and the community. The public involvement activities summarized here includes coordination with the U.S. Fish and Wildlife Service, public meetings, meetings with whaling captains, and Native tribe consultations.

2.2 Notice of Intent

A Notice of Intent to Prepare an Environmental Impact Statement (EIS) was printed in the Federal Register on April 17, 2003. The Environmental Protection Agency responded to the notice with a letter outlining their review responsibilities under Section 309 and National Environmental Policy Act (NEPA) and the significant issues that need to be addressed in the EIS, such as: provide a clear purpose and need, analyze reasonable alternatives, consult with Tribal governments, analyze environmental justice issues, and seek traditional knowledge for alternative formulation.

2.3 U.S. Fish and Wildlife Service Coordination

Coordination with the U.S. Fish and Wildlife Service (USFWS) was initiated in 2003. The USFWS participated in the first public meeting, some team meetings, and in planning for geotechnical drilling and field investigations. A Planning Aid Letter was received in February 11, 2004. The USFWS believes that the project's gravel source location and methods of gravel extraction will be the most significant issues affecting fish and wildlife resource. The beach at Barrow is heavily disturbed so does not provide a lot of habitat. Cooper Island was the most sensitive area. Winter gravel mining was recommended. The BIA site is near nesting habitat for the threatened Spectacled and Steller's eider sea ducks. Winter gravel extraction is recommended here also. Complete mining and reclamation plans will be required. A draft Coordination Act Report (CAR) was received in August 2006. The current design and use of the existing gravel pit would not have significant environmental affects to fish and wildlife resources. If in the future gravel quantities are not available for the revetment project, the BIA site may have to be used and the USFWS would require further consultation under the Endangered Species Act.

2.4 Public Meetings

2.4.1 June 12, 2003

The first scoping meeting was held June 12, 2003 in Barrow. The Corps presented an overview of the planning process including the EIS process and the importance of public participation. Project purpose, objectives, and preliminary alternatives were discussed, which generated comments such as would the elevated road/dike cause drainage patterns or impoundment behind the road? Graves and cultural resources were cited as a concern along the beach. Residents encouraged the Corps to consider elder knowledge of conditions, consider climatic events beyond the 50- or 100-year events and to guard against seeking only institutional remedies for problems. An independent review of alternatives was recommended. Comments on a possible gravel borrow area on Cooper Island indicated concerns with cultural resources, traditional use areas, and bird habitat. The process of economic justification was discussed. People wanted to know how a cost/benefit analyses was done. Residents have become accustomed to modern services in Barrow, such as the utilidor, which contains water, sewer, and power. They are similar to services expected and depended upon most U.S. towns. Moving the utilidor would be very costly. There are fears that quality of life issues may not be captured as benefits. In order to get information and receive comments from the public, a project Web site was set up. The Corps also promised to hold meetings and provide written project updates.
A written update was sent to every box holder in November 2004.

2.4.2 April 6, 2005

On April 6, 2005 a study progress meeting was held in Barrow, but public attendance was sparse due to conflicts with local whaling activities that night. The Corps presented and explained the study progress information provided in the November 2004 mailout. Measures to address the erosion and flooding problems were discussed as well as the planned summer field activities. Local residents identified possible impacts caused by various measures and suggested other measures for consideration. Major concerns were expressed about environmental and cultural impacts associated with opening new borrow areas and potential dike alignments.

2.4.3 August 23, 2006

On August 23, 2006 a study progress meeting was held in Barrow and attended by more than 60 residents. The meeting was held in both English and Inupiaq. The Corps presented the major results of studies to date: the beach appears currently stable and beach erosion is not a problem, but bluff erosion still is a problem along with flooding; beach nourishment is no longer being considered due to economic, environmental, and cultural concerns; the prime measures under consideration are revetment protecting the bluffs and a coastal dike preventing flooding. In addition, the Corps was going to look at non-structural measures, such as building raising and/or relocation. The public was informed that as part of any Corps project, the community would have to participate in the National Flood Insurance Program. Meeting participants identified impacts associated with measures being proposed and were concerned that any project would perform as designed, particularly in resisting the severe ice forces any project along the Barrow shoreline would encounter. As a result of public comments, the study team added physical model tests of the proposed dike/revetment section to the study plan. Earlier in the day, Corps study team members participated in a bi-lingual radio call-in show discussing the study and possible project alternatives on KBRW, the local AM radio station.

2.5 Meetings with the Whaling Captains

An informal meeting was set up to discuss the project plan alternatives with the whaling captains and the North Slope Borough in June 2006. The Corps wanted to get some insight into what the social implications might be with a high revetment along the beach front. Three members of the public, one of whom was a whaling captain, and a Borough official attended the lunch meeting. The Corps brought the worst case flood map to show the areas of potential wetting and revetment alignment figures. The Corps indicated that the maximum protection from the rock revetment would extend to the 16-foot elevation. If the beach is at 0 elevation, this would mean a rock wall 16 feet high causing a permanent visual block to the sea for some residences. This would also mean limited access to the beach, and in some cases, it would take up the entire beach. Comments on this concept were that a secure flood and erosion block was a desirable outcome. The beach berms now constructed are already a visual block. Access, if combined with boat launches, would be a good thing and the more the better. Questions on the alternatives were asked such as what about dikes at the end of the runway. Could this structure catch gravel and therefore nourish the beach? Can something like dolos (large concrete forms that fit together) be used instead of armor rock? The thought was that possibly they could be made in Barrow reducing costs. What about concrete mattresses used for erosion? Many of these ideas have been explored by the Corps and discounted because of lack of feasibility and were too costly. The subject of local gravel sources was brought up.The feasibility of using the available gravel at Point Barrow was decidedly rejected because of the impacts to a culturally important archeological village and burial site. Development of the BIA gravel site was socially acceptable because it would be economically beneficial. However, there is an existing gravel site that could supply the same quality of gravel/sand as the BIA site and this would be the favored site.

2.6 Native Tribe Consultation (Government to Government)

Coordination and consultation have been maintained with the Native organizations in Barrow throughout the study, including the IRA elements (the Native Village of Barrow and the Inupiat Community of the Arctic Slope). Government to Government notification of the project was initiated in May 8, 2003. A meeting in 2003 with both groups occurred to describe the project and to ask their input and concerns. Both groups were supportive of the study and the outcome of the project. The Inupiat Community of the Arctic Slope indicated that officials with the Native Village of Barrow could represent them on this study. The NVB participated in the study by providing boat services for instrument deployment and providing transportation for the fish surveys as a contractor for the North Slope Borough.

3.0 FEDERAL EMERGENCY MANAGEMENT AGENCY POLICIES & PROCEDURES

3.1 Participation in National Flood Insurance Program and Preparation of Floodplain Management Plan

As discussed in the main report, participation by the local community in the NFIP is a requirement mandated by Congress in WRDA 1988. As part of the local sponsor responsibilities, the NSB or the City of Barrow, will be required to agree to join and participate in the NFIP prior to construction of a Corps project. Under current FEMA procedures, communities first enter what is called the Emergency Phase of the NFIP. This gets the community started in the process quickly and makes flood insurance available for sale. The community will need to pass an ordinance to enter the NFIP. The ordinance includes provisions for requiring development permits that ensure new development is reviewed to see that proposed construction will be reasonably safe from flooding, that buildings in flood prone areas will be anchored, and that new construction will use methods and practices to minimize flood damages. Flood Hazard Boundary Maps (FHBM) are prepared to show the general area flooded by a one percent chance event. Flood Insurance Rate Maps (FIRM) are prepared showing the water surface elevation of the one percent coastal/riverine flood event, which enables the community to join the Regular Phase of the NFIP. The FIRM provides the basis for actuarial rates for insurance based on the structures lowest floor elevation relative to the one percent flood. At that time the community must adopt more stringent development regulations. Structures and contents can be insured. Flood insurance covers direct losses due to a general condition of flooding, which includes flood related erosion loss. The average annual flood insurance policy premium in Alaska was $655 per year as of February 2007. Under Congressional mandate, the community is required to prepare a Floodplain Management Plan within 1 year of signing a Project Cooperation Agreement and implement the plan within 1 year after project completion. This plan documents how the community will address flood hazards in the future and can be prepared as part of a FEMA All-Hazards Analysis. The NSB has already prepared an All-Hazards Analysis (with the exception of the Flood Hazard Analysis).

FEMA mapping requirements and criteria are contained in the *Final Draft Guidelines for Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States, January 2005*. That document requires that for any protective effects of coastal levees or levee systems to be recognized by the NFIP and incorporated into FIRM's, they must be constructed , operated, and maintained to resist erosion and prevent any flooding or wave overtopping landward of the levee crest during the one percent chance flood conditions. The levee must be certified as providing protection from flooding. FEMA's freeboard requirement specific to coastal levees is: (1) the crest elevation must be elevated at least 2 feet above the one percent chance still water elevation, and (2) either 1 foot above the one percent chance wave height or the maximum wave run up elevation, whichever is greater.

The Corps of Engineers, upon completion of construction, would certify to FEMA that the project had been adequately designed and constructed to provide protection against the base flood (one percent event). The Corps would verify that all FEMA criteria (44 C.F.R. 65.10) had been met. The major FEMA requirements include provisions for freeboard, closures, embankment protection, foundation stability analysis, settlement, and interior drainage. An operations manual needs to be developed covering flood warning, flood operations, closures, manual backups, and periodic inspections. The Corps works with each of its sponsors to prepare a project Operation and Maintenance Manual during late stages of design and construction. That Manual documents the formal procedure to maintain stability, height, and overall integrity of the structure and its associated systems.

3.2 Questions and Answers About FEMA and the NFIP

The following pages provide questions and answers taken from the Federal Emergency Management Agency official web site. These cover information pertaining to the legislative authority, requirements, rules, regulations, and procedures of the National Flood Insurance Program. Additional information is available on their website www.fema.gov.

3.2.1 Introduction to the NFIP

1. **What is the National Flood Insurance Program (NFIP)?**
   The NFIP is a Federal program enabling property owners in participating communities to purchase insurance protection against losses from flooding. This insurance is designed to provide an insurance alternative to disaster assistance to meet the escalating costs of repairing damage to buildings and their contents caused by floods.

   Participation in the NFIP is based on an agreement between local communities and the Federal Government that states if a community will adopt and enforce a floodplain management ordinance to reduce future flood risks to new construction in Special Flood Hazard Areas, the Federal Government will make flood insurance available within the community as a financial protection against flood losses.

2. **Why was the NFIP established by Congress?**
   For decades, the national response to flood disasters was generally limited to constructing flood-control works such as dams, levees, sea-walls, and the like, and providing disaster relief to flood victims. This approach did not reduce losses, nor did it discourage unwise development. In some instances, it may have actually encouraged additional development. To compound the problem, the public generally could not buy flood coverage from insurance companies, and building techniques to reduce flood damage were often overlooked.

   In the face of mounting flood losses and escalating costs of disaster relief to the general taxpayers, the U.S. Congress created the NFIP. The intent was to reduce future flood damage through community floodplain management ordinances, and provide protection for property owners against potential losses through an insurance mechanism that requires a premium to be paid for the protection.

3. **How was the NFIP established and who administers it?**
   The U.S. Congress established the NFIP on August 1, 1968, with the passage of the National Flood Insurance Act of 1968. The NFIP was broadened and modified with the passage of the Flood Disaster Protection Act of 1973 (PDF 446KB) and other legislative measures. It was further modified by the National Flood Insurance Reform Act of 1994 (PDF 294KB) and the Flood Insurance Reform Act of 2004. The NFIP is administered by Federal Emergency Management Agency (FEMA) a component of the Department of Homeland Security (DHS).

4. **What is a Special Flood Hazard Area (SFHA)?**
   In support of the NFIP, FEMA identifies flood hazard areas throughout the U.S. and its territories by producing Flood Hazard Boundary Maps (FHBMs), Flood Insurance Rate Maps (FIRMs), and Flood Boundary & Floodway Maps (FBFMs). Several areas of flood hazards are commonly identified on these maps. One of these areas is the Special Flood Hazard Area (SFHA) or high risk area defined as any land that would be inundated by a flood having a 1-percent chance of occurring in any given year (also referred to as the base flood).

   The high-risk area standard constitutes a reasonable compromise between the need for building restrictions to minimize potential loss of life and property and the economic benefits to be derived from floodplain development. Development may take place within the SFHA, provided that development complies with local floodplain management ordinances, which must meet the minimum Federal requirements. Flood insurance is required for insurable structures within high-risk areas to protect Federal financial investments and assistance used for acquisition and/or construction purposes within communities participating in the NFIP.

5. **What is a flood?**
   "Flood" is defined in the Standard Flood Insurance Policy (SFIP), in part, as:

   A general and temporary condition of partial or complete inundation of two or more acres of normally dry land area or of two or more properties (at least one of which is your property) from overflow of inland or tidal waters, from unusual and rapid accumulation or runoff of surface waters from any source, or from mudflow.

6. **What is the NFIP's Write Your Own (WYO) program?**
   The Write Your Own (WYO) Program, begun in 1983, is a cooperative undertaking of the insurance industry and FEMA. The WYO Program allows participating property and casualty insurance companies to write and service the Standard Flood Insurance Policy in their own names. The companies receive an expense allowance for policies written and claims processed while the Federal Government retains responsibility for underwriting losses. The WYO Program operates within the context of the NFIP, and is subject to its rules and regulations.

   The goals of the WYO Program are:
   - Increase the NFIP policy base and the geographic distribution of policies;
   - Improve service to NFIP policyholders through the infusion of insurance industry knowledge; and
   - Provide the insurance industry with direct operating experience with flood insurance.

   Currently, about 100 insurance companies write flood insurance with FEMA.

7. **Do the state insurance regulators have any jurisdiction over the NFIP in their respective states?**
   As established by the U.S. Congress, the sale of flood insurance under the NFIP is subject to the rules and regulations of FEMA. FEMA Division has elected to have State-licensed insurance companies' agents and brokers sell flood insurance to consumers. State regulators hold the insurance companies' agents and brokers accountable for providing NFIP customers with the same standards and level of service that the States require of them in selling their other lines of insurance.

   Private insurance companies participating in the Write Your Own (WYO) Program must be licensed and regulated by States to engage in the business of property insurance in those States in which they wish to sell flood insurance.

8. **How does the NFIP benefit property owners? Taxpayers? Communities?**
   Through the NFIP, property owners in participating communities are able to insure against flood losses. By employing wise floodplain management, a participating community can protect its citizens against much of the devastating financial loss resulting from flood disasters. Careful local management of development in the floodplains results in construction practices that can reduce flood losses and the high costs associated with flood disasters to all levels of government.

9. **What is the definition of a community?**
   A community, as defined for the NFIP's purposes, is any State, area, or political subdivision; any Indian tribe, authorized tribal organization, or Alaska native village, or authorized native organization that has the authority to adopt and

enforce floodplain management ordinances for the area under its jurisdiction. In most cases, a community is an incorporated city, town, township, borough, or village, or an unincorporated area of a county or parish. However, some States have statutory authorities that vary from this description.

10. **Why is participation in the NFIP on a community basis rather than on an individual basis?**
    The National Flood Insurance Act of 1968 (PDF 446KB) allows FEMA to make flood insurance available only in those areas where the appropriate public body has adopted adequate floodplain management regulations for its flood-prone areas. Individual citizens cannot regulate building or establish construction priorities for communities. Without community oversight of building activities in the floodplain, the best efforts of some to reduce future flood losses could be undermined or nullified by the careless building of others. Unless the community as a whole is practicing adequate flood hazard mitigation, the potential for loss will not be reduced sufficiently to affect disaster relief costs. Insurance rates also would reflect the probable higher losses that would result without local floodplain management enforcement activities.

11. **Is community participation mandatory?**
    Community participation in the NFIP is voluntary (although some States require NFIP participation as part of their floodplain management program). Each identified flood-prone community must assess its flood hazard and determine whether flood insurance and floodplain management would benefit the community's residents and economy. However, a community that chooses not to participate within 1 year after the flood hazard has been identified and an NFIP map has been provided is subject to the ramifications explained in the answer to Question 20.

    A community's participation status can significantly affect current and future owners of property located in Special Flood Hazard Areas (SFHAs). The decision should be made with full awareness of the consequence of each action.

12. **What is the NFIP's Emergency Program?**
    The Emergency Program is the initial phase of a community's participation in the NFIP and was designed to provide a limited amount of insurance at less than actuarial rates. A community participating in the Emergency Program either does not have an identified and mapped flood hazard or has been provided with a Flood Hazard Boundary Map (FHBM), and the community is required to adopt limited floodplain management standards to control future use of its floodplains. Less than 1 percent of the 20,000 communities participating in the NFIP remain in the Emergency Program; FEMA hopes to convert all communities to the Regular Program of the NFIP. For additional information on mapping, please refer to the "Flood Hazard Assessment and Mapping Requirements" section of this booklet.

13. **What is the NFIP's Regular Program?**
    A community participating in the Regular Program of the NFIP is usually

provided with a Flood Insurance Rate Map (FIRM) and a detailed engineering study, termed a Flood Insurance Study (FIS). (Additional information on FIRMs and FISs is provided in the "Flood Hazard Assessment and Mapping Requirements" section of this booklet.) Under the Regular Program, more comprehensive floodplain management requirements are imposed on the community in exchange for higher amounts of flood insurance coverage.

14. **What happens when a community does not enforce its floodplain management ordinance?**
    Communities are required to adopt and enforce a floodplain management ordinance that meets minimum NFIP requirements. Communities that do not enforce these ordinances can be placed on probation or suspended from the program. This is done only after FEMA has provided assistance to the community to help it become compliant.

15. **What is probation?**
    Probation is the formal notification by FEMA to a community that its floodplain management program does not meet NFIP criteria. It is an action authorized under Federal regulations.

16. **When can a community be placed on probation?**
    A community can be placed on probation 90 days after FEMA provides written notice to community officials of specific deficiencies. Probation generally is imposed only after FEMA has consulted with the community and has not been able to resolve deficiencies. The FEMA Regional Director has the authority to place communities on probation.

17. **How long will probation last?**
    Probation may be continued for up to 1 year after the community corrects all Program deficiencies and remedies all violations to the maximum extent possible.

18. **What penalties are imposed when a community is placed on probation?**
    An additional $50 charge is added to the premium for each policy sold or renewed in the community. The additional charge is effective for at least 1 year after the community's probation period begins. The surcharge is intended to focus the attention of policyholders on the community's non-compliance to help avoid suspension of the community, which has serious adverse impacts on those policyholders. Probation does not affect the availability of flood insurance.

19. **What is suspension?**
    Suspension of a participating community (usually after a period of probation) occurs when the community fails to solve its compliance problems or fails to adopt an adequate ordinance. The community is provided written notice of the impending suspension and granted 30 days in which to show cause why it should not be suspended. Suspension is imposed by FEMA. If suspended, the community becomes non-participating and flood insurance policies cannot be written or

renewed. Policies in force at the time of suspension continue in force for the policy term.

20. **What happens if a community does not participate in the NFIP?**
    Flood insurance under the NFIP is not available within that community. Furthermore, Section 202(a) of Public Law 93-234, as amended, prohibits Federal officers or agencies from approving any form of financial assistance for acquisition or construction purposes in a Special Flood Hazard Area (SFHA). For example, this would prohibit loans guaranteed by the Department of Veterans Affairs, insured by the Federal Housing Administration, or secured by the Rural Housing Services. Under Section 202(b) of Public Law 93-234, if a Presidentially declared disaster occurs as a result of flooding in a non-participating community, no Federal financial assistance can be provided for the permanent repair or reconstruction of insurable buildings in SFHAs. Eligible applicants may receive those forms of disaster assistance that are not related to permanent repair and reconstruction of buildings.

    If the community applies and is accepted into the NFIP within 6 months of a Presidential disaster declaration, these limitations on Federal disaster assistance are lifted.

21. **Explain the discounts on premiums that can be obtained in communities that qualify for the Community Rating System (CRS) because they have floodplain management programs that go beyond the minimum requirements to participate in the NFIP.**
    The NFIP's Community Rating System (CRS) recognizes community efforts beyond the NFIP minimum standards by reducing flood insurance premiums for the community's property owners. The discounts may range from 5 to 45 percent. The discounts provide an incentive for new flood mitigation, planning, and preparedness activities that can help save lives and protect property in the event of a flood.

22. **What procedures must be followed for a community to participate in the Community Rating System?**
    Participation in the CRS is voluntary. A community in compliance with the rules and regulations of the NFIP may apply. The community's Chief Executive Officer must appoint a CRS coordinator to handle the application work and serve as the liaison between the community and FEMA. The first step in the application process is for the community to obtain a copy of the CRS Coordinator's Manual, which describes the program and gives details on the eligible activities. The CRS coordinator should fill out and submit an application for participation in the CRS. The CRS will verify the information and arrange for flood insurance premium discounts.

23. **How can a community acquire the CRS Coordinator's Manual and other information describing the program?**
    The CRS Coordinator's Manual, additional CRS publications, and software may

be ordered online or by writing, phoning, or faxing a request to the NFIP/CRS. Contact information is listed in the "Additional Reading" section at the end of the booklet. All publications are free, and the computer software for completing the application is also available at no charge.

3.2.2 Prospective Buyer Information

24. **Who may purchase a flood insurance policy?**
NFIP coverage is available to all owners of insurable property (a building and/or its contents) in a community participating in the NFIP. Owners and renters may insure their personal property against flood loss. Builders of buildings in the course of construction, condominium associations, and owners of residential condominium units in participating communities all may purchase flood insurance.
Condominium associations may purchase insurance coverage on a residential building, including all units, and its commonly owned contents under the Residential Condominium Building Association Policy Form (PDF 328KB, TXT 76KB). The unit owner may separately insure personal contents as well as obtain additional building coverage under the Dwelling Policy Form (PDF 332KB, TXT 81KB) as long as the unit owner's share of the RCBAP and his/her added coverage do not exceed the statutory limits for a single-family dwelling. The owner of a non-residential condominium unit may purchase only contents coverage for that unit.

25. **How can property owners or renters find out if they are eligible to purchase flood insurance?**
NFIP coverage is available only in participating communities. Almost all of the nation's communities with serious flooding potential have joined the NFIP. The NFIP provides a listing of participating communities in the Community Status Book. To learn if a community participates in the NFIP, refer to this listing online at http://www.fema.gov/fema/csb.shtm or contact a community official or insurance agent.

26. **How can a property owner determine if the property is in a Special Flood Hazard Area (SFHA)?**
FEMA publishes maps indicating a community's flood hazard areas and the degree of risk in those areas. Flood insurance maps usually are on file in a local repository in the community, such as the planning and zoning or engineering offices in the town hall or the county building. A property owner may consult these maps to find out if the property is in an SFHA.

    In addition, maps can be viewed and ordered online or by writing, phoning, or faxing a request to the FEMA Map Service Center. Contact information is listed in the "NFIP Program Information" section at the back of this booklet. Delivery is usually within 2 to 4 weeks. There is a minimal charge for maps for most users, so it is advisable to call for detailed information.

27. **What types of property may be insured against flood loss?**
    Almost every type of walled and roofed building that is principally above ground and not entirely over water may be insured if it is in a participating community. In most cases, this includes manufactured (i.e., mobile) homes that are anchored to permanent foundations and travel trailers without wheels that are anchored to permanent foundations and are regulated under the community's floodplain management and building ordinances or laws. (However, this does not include converted buses or vans.) Contents of insurable walled and roofed buildings also may be insured under separate coverage.

28. **What kinds of property are not insurable under the NFIP?**
    Buildings entirely over water or principally below ground, gas and liquid storage tanks, animals, birds, fish, aircraft, wharves, piers, bulkheads, growing crops, shrubbery, land, livestock, roads, machinery or equipment in the open, and most motor vehicles are not insurable. Most contents and finishing materials located in a basement or in enclosures below the lowest elevated floor of an elevated building constructed after the FIRM became effective are not covered. (See "Coverage" section for coverage limitations in basements and below lowest elevated floors.) Information on the insurability of any special property may be obtained by contacting a property insurance agent or a broker.

29. **Are there certain buildings that cannot be covered?**
    Flood insurance is not available for buildings that FEMA determines have been declared by a State or local zoning authority or other appropriate authority to be in violation of State or local floodplain management regulations or ordinances. No new policies can be written to cover such buildings; nor can an existing policy be renewed.

    New construction or substantially improved structures located within a designated Coastal Barrier Resources System (CBRS) area are not eligible for flood insurance, but existing structures that predate CBRS designation are eligible for flood insurance coverage. These areas are located in nearly 400 communities on the Atlantic and Gulf coasts and along the Great Lakes shores, and are delineated on the communities' flood maps. If, at the time of a loss, it is determined that a post-CBRS-designation building is located in a CBRS area, the claim will be denied, the policy canceled, and the premium refunded. (See the answers to Questions 44 and 45 for a description of CBRS.)

30. **How is flood insurance purchased?**
    After a community joins the NFIP, a policy may be purchased from any licensed property insurance agent or broker who is in good standing in the State in which the agent is licensed or through any agent representing a Write Your Own (WYO) company, including an employee of the company authorized to issue the coverage.

The steps leading to the purchase of a flood insurance policy are:

- A property owner or renter perceives a risk of flooding to an insurable building or its contents and elects to purchase flood insurance, or a lender making, renewing, increasing, or extending a loan, or at any time during the term of the loan, informs the builder or potential buyer that the building is in a Special Flood Hazard Area (SFHA) and flood insurance must be purchased as required by the Flood Disaster Protection Act of 1973 (PDF 446KB) and the National Flood Insurance Reform Act of 1994 (PDF 294KB). The builder or borrower contacts an insurance agent or broker or a Write Your Own (WYO) company.
- The insurance agent completes the necessary forms for the builder or buyer. In the case of a building constructed in an SFHA after the issuance of a Flood Insurance Rate Map (FIRM), the builder or buyer must obtain an elevation certificate completed by a licensed engineer, architect, surveyor, or appropriate community official.
- The insurance agent submits the application, necessary elevation certification, and full premium to the NFIP or to a participating WYO company.

31. **How are flood insurance premiums calculated?**
A number of factors are considered in determining the premium for flood insurance coverage. They include the amount of coverage purchased; location; age of the building; building occupancy; design of the building; and, for buildings in SFHAs, elevation of the building in relation to the Base Flood Elevation (BFE). Buildings eligible for special low-cost coverage at a pre-determined, reduced premium rate are single-family, one- to four-family dwellings, and non-residential buildings located in moderate-risk Zones B, C, and X. For these exceptions, certain loss limitations exist. (See the "Flood Hazard Assessment and Mapping Requirements" section for definitions of flood zones.)

32. **Is the purchase of flood insurance mandatory?**
The Flood Disaster Protection Act of 1973 and the National Flood Insurance Reform Act of 1994 mandate the purchase of flood insurance as a condition of Federal or Federally related financial assistance for acquisition and/or construction of buildings in SFHAs of any community. The purchase of flood insurance on a voluntary basis is frequently prudent even outside of SFHAs. The Acts prohibit Federal agency lenders, such as the Small Business Administration (SBA) and United States Department of Agriculture's (USDA) Rural Housing Service, and Government-Sponsored Enterprises for Housing (Freddie Mac and Fannie Mae) from making, guaranteeing, or purchasing a loan secured by improved real estate or mobile home(s) in an SFHA, unless flood insurance has been purchased, and is maintained during the term of the loan.

The Acts apply to lenders under the jurisdiction of Federal entities for lending institutions. These Federal entities include the Board of Governors of the Federal

Reserve System, the Federal Deposit Insurance Corporation, the Comptroller of the Currency, the Office of Thrift Supervision, the National Credit Union Administration, and the Farm Credit Administration. The Acts also require Freddie Mac and Fannie Mae to implement procedures designed to ensure compliance with the mandatory purchase requirements of the Acts.

The purchase of flood insurance does not apply to conventional loans made by Federally regulated lenders when the community in which the building is located is not participating in the NFIP. Although Federal flood insurance is not available for new construction or substantially improved structures in CBRS areas, conventional loans may be made there by Federally regulated lenders. In these cases, the lending institution is required to notify the borrower that, in the event of a flood-related Presidentially declared disaster, Federal disaster assistance will not be available for the permanent repair or restoration of the building. Federally regulated or insured lending institutions are required in all cases to notify the borrower when the building being used to secure a loan is in an SFHA.

33. **Why is there a requirement to purchase flood insurance in communities that have not suffered flooding in many years or ever?**
    A major purpose of the NFIP is to alert communities to the danger of flooding and to assist them in reducing potential property losses from flooding. Therefore, FEMA determines flood risk through the use of all available information for each community. Historical flood data are only one element used in determining flood risk. More critical determinations can be made by evaluating the community's rainfall and river-flow data, topography, wind velocity, tidal surge, flood-control measures, development (existing and planned), community maps, and other data.

34. **Why is my lender requiring the purchase of flood insurance?**
    For virtually every mortgage transaction involving a structure in the United States, the lender reviews the current NFIP maps for the community in which the property is located to determine its location relative to the published SFHA and completes the Standard Flood Hazard Determination Form (SFHDF). If the lender determines that the structure is indeed located within the SFHA and the community is participating in the NFIP, the borrower is then notified that flood insurance will be required as a condition of receiving the loan. A similar review and notification is completed whenever a loan is sold on the secondary loan market or perhaps when the lender completes a routine review of its mortgage portfolio. This fulfills the lender's obligation under the Flood Disaster Protection Act of 1973 and the National Flood Insurance Reform Act of 1994 that requires the purchase of flood insurance by property owners who are being assisted by Federal programs or by Federally regulated institutions in the acquisition or improvement of land, or facilities, or structures located or to be located within an SFHA.

35. **Are lenders required to escrow flood insurance payments?**
    The statute requiring Federally regulated lenders, their services, and Federal

Agency lenders to escrow for flood insurance became effective on October 1, 1996. If escrow for taxes, insurance, and/or other reasons is already required, escrow for flood insurance on loans secured by improved residential real estate or mobile homes is also required. Lenders who escrow will comply 100 percent with the statutory requirement by maintaining flood insurance during the term or life of the loan.

36. **What if I disagree with my lender's determination that I am in the flood zone?**
Property owners may not contest the requirement if the lending institution has established the requirements as a part of its own standard lending practices. However, if a lending institution is requiring the insurance to meet mandatory flood insurance purchase requirements, the property owner and lender may jointly request that FEMA review the lending institution's determination. This request must be submitted within 45 days of the date the lending institution notified the property owner that a building or manufactured home is in the SFHA and flood insurance is required. In response, FEMA will issue a Letter of Determination Review (LODR). The LODR does not result in an amendment or revision to the NFIP map. It is only a finding as to whether the building or manufactured home is in the SFHA shown on the NFIP map. The LODR remains in effect until the NFIP map panel affecting the subject building or manufactured home is revised.

37. **What fees and data are required for LODRs?**
A fee of $80 must be submitted with all LODR requests. The fee payment may be in the form of a check or money order, in U.S. funds, made payable to the "National Flood Insurance Program." The fee must be accompanied by copies of the following: (1) the completed SFHDF; (2) the dated notification letter to the property owner; (3) a letter, signed by the property owner and lending institution, requesting FEMA's review; (4) an annotated copy of the effective NFIP map panel for the community showing the location of the structure or manufactured home; and (5) a copy of all material used by the lending institution or designated third party to make the determination.

38. **How many buildings or locations (and their contents) may be insured on each policy?**
Normally, only one building and its contents can be insured on each policy. The Dwelling Form of the Standard Flood Insurance Policy does provide coverage for up to 10 percent of policy amount for appurtenant detached garages but not for carports, tool and storage sheds, and the like. In addition, the Scheduled Building Policy is available to cover 2 to 10 buildings. The policy requires a specific amount of insurance to be designated for each building, and all buildings must have the same ownership and the same location.

39. **What is the flood insurance policy term?**
Flood insurance coverage is available for a 1-year term.

40. **Is there a minimum premium for a flood insurance policy?**
    There is a minimum premium for all flood insurance policies. Because the minimum premium is subject to change, anyone interested in purchasing a flood insurance policy should contact a local property insurance agency or company that writes flood insurance coverage to obtain the current minimum premium amount.

41. **Is there a waiting period for flood insurance to become effective?**
    There is normally a 30-day waiting period before flood insurance goes into effect. There are two exceptions:
    - If the initial purchase of flood insurance is in connection with the making, increasing, extending, or renewing of a loan, there is no waiting period. The coverage becomes effective at the time of the loan, provided the application and presentment of premium are made at or prior to loan closing.

    - If the initial purchase of flood insurance is made during the 13-month period following the revision or update of a Flood Insurance Rate Map for the community, there is a 1-day waiting period.

      In addition to the two basic exceptions, FEMA has issued a policy decision specifying the following four exceptions:

        - The 30-day waiting period will not apply when there is an existing insurance policy and an additional amount of flood insurance is required in connection with the making, increasing, extending, or renewing of a loan, such as a second mortgage, home equity loan, or refinancing. The increased amount of flood coverage will be effective as of the time of the loan closing, provided the increased amount of coverage is applied for and the presentment of additional premium is made at or prior to the loan closing.
        - The 30-day waiting period will not apply when an additional amount of insurance is required as a result of a map revision. The increased amount of coverage will be effective at 12:01 a.m. on the first calendar day after the date the increased amount of coverage is applied for and the presentment of additional premium is made.
        - The 30-day waiting period will not apply when flood insurance is required as a result of a lender's determining a loan that does not have flood insurance coverage should be protected by flood insurance. The coverage will be effective upon the completion of an application and the presentment of payment of premium.
        - The 30-day waiting period will not apply when an additional amount of insurance offered in the renewal bill is being obtained in connection with the renewal of a policy.

42. **What is "presentment of payment"?**
"Presentment of payment" is the receipt of premium and is considered to be the time payment is actually received by the NFIP or the WYO company. Delivery to an insurance agent or broker or mailing a premium by ordinary mail with placement of a postmark does not constitute presentment to the NFIP.

A premium mailed in a timely manner by certified mail and received by the NFIP is considered to have been delivered to and received by the NFIP as of the date of certification by the delivery service. (In this context, the term "certified mail" extends not only to the U.S. Postal Service but also to such third-party delivery services as Federal Express [FedEx], United Parcel Service [UPS], and courier services and the like that provide proof of mailing.) If time is short and coverage is needed, the certified mail transmittal of payment should be considered.

43. **Is there a special rating procedure applicable to coastal high hazard areas (V zones)?**
In calculating the applicable rates for buildings that were constructed or substantially improved in V zones after October 1, 1981, the actuarial formula takes into account the ability of the building to withstand the impact of wave action. The agent must follow the special instructions in the NFIP Flood Insurance Manual in preparing an application for coverage for buildings located in V zones. (See the "Flood Hazard Assessment and Mapping Requirements" section for a further explanation of V zones.)

44. **What is the Coastal Barrier Resources System?**
The U.S. Congress passed the Coastal Barrier Resources Act of 1982, and the Coastal Barrier Improvement Act of 1990, defining and establishing a system of protected coastal areas (including the Great Lakes) known as the Coastal Barrier Resources System (CBRS) and Otherwise Protected Areas (OPAs). The Acts define areas within the CBRS as depositional geologic features consisting of unconsolidated sedimentary materials; subject to wave, tidal and wind energies; and protecting landward aquatic habitats from direct wave attack. The Acts further define coastal barriers as "all associated aquatic habitats, including the adjacent wetlands, marshes, estuaries, inlets and near shore waters, but only if such features and associated habitats contain few manmade structures and these structures and man's activities on such features, and within such habitats do not significantly impede geomorphic and ecological processes." Otherwise Protected Areas (OPAs) means an undeveloped coastal barrier within the boundaries of an area established under Federal, State, or local law, or held by a qualified organization, primarily for wildlife refuge, sanctuary, recreational, or natural resource conservation purposes. The Acts provide protection to CBRS areas by prohibiting most expenditures of Federal funds within the CBRS. These prohibitions refer to "any form of loan, grant, guarantee, insurance, payment, rebate, subsidy or any other form of direct or indirect Federal assistance," with specific and limited exceptions.

45. **Is Federal flood insurance available in CBRS?**
    Federal flood insurance is available in a CBRS area if the subject building was constructed (or permitted and under construction) before the CBRS area's effective date. For CBRS areas designated by the 1982 Act, the sale of Federal flood insurance is prohibited for structures built or substantially improved after October 1, 1983. For subsequent additions to the CBRS, the insurance prohibition date is shown on the Flood Insurance Rate Map (FIRM). For structures located in OPAs, insurance may be obtained if written documentation is provided certifying that the structure is used in a manner consistent with the purpose for which the area is protected. If an existing insured structure is substantially improved or damaged, any Federal flood insurance policy will not be renewed. If a Federal flood insurance policy is issued in error, it will be canceled and the premium refunded; no claim can be paid, even if the error is not found until a claim is made.

46. **Can flood insurance be cancelled at the request of the insured with a refund of premium?**
    Flood insurance can be canceled, and a refund can be issued, only in certain circumstances, because all of the premium is fully earned on the first day of the policy term. Premium will be refunded on a pro-rata basis when the policyholder no longer owns or has an insurable interest in the insured property, provided no claim has been paid or is pending. There are other limited cancellation provisions for the refunding of premium. To discuss cancellation criteria and procedures, policyholders should contact the insurance agent who wrote the policy or call the NFIP toll-free at 1-800-427-4661.

47. **Is there a "grace period" for an insured under the NFIP policy conditions?**
    All policies expire at 12:01 a.m. on the last day of the effective term. (For the ease and convenience of insurance agents and brokers, lenders, and policyholders, NFIP rules allow for "renewal" of expiring policies and no new application is required.) Coverage remains in force for 30 days after the expiration of the policy, and claims for losses that occur in the period will be honored providing the full renewal premium is received by the end of the 30-day period. Coverage also remains in force for any mortgagee named in the policy for 30 days after written notice to the mortgagee of the expiration of a policy.

48. **What is the requirement for purchasing flood insurance after receiving disaster assistance?**
    The NFIRA requires individuals in SFHAs who receive disaster assistance after September 23, 1994, for flood disaster losses to real or personal property to purchase and maintain flood insurance coverage for as long as they live in the dwelling. If flood insurance is not purchased and maintained, future disaster assistance will be denied. If the structure is sold, the current owner is required to notify the buyer of the house of the need to purchase and maintain flood insurance. If the buyer is not notified, suffers uninsured flood losses, and receives Federal disaster assistance, the seller may be required to repay the Federal Government any Federal disaster assistance the buyer received.

3.2.3 Coverage

49. **How much flood insurance coverage is available?**
The following coverage limits are available under the Dwelling Form and the General Property Form of the Standard Flood Insurance Policy. Coverage limits under the Residential Condominium Building Association Policy are listed in the NFIP Flood Insurance Manual.

	Emergency Program	**Regular Program**
Building Coverage		
Single-family dwelling*	$ 35,000*	$250,000
Other residential*	$35,000*	$250,000
Other residential	$100,000*	$250,000
Non-residential	$100,000*	$500,000
Contents Coverage		
Residential	$ 10,000	$100,000
Non-residential including Small Business	$100,000	$500,000

50. **Under the Emergency Program, higher limits of building coverage are available in Alaska, Hawaii, the U.S. Virgin Islands, and Guam**.

52. **Are there limitations on the amount of insurance available for certain types of property?**
General coverage limitations are explained in the answers to Questions 28 and 29. In addition, items such as artwork, photographs, collectibles, memorabilia, rare books, autographed items, jewelry, watches, gems, articles of gold, silver, or platinum and furs are limited to $2,500 coverage in the aggregate. This limitation does not apply to other items that are personal property or household contents usual or incidental to the occupancy of the building as a residence. For other limitations under the Standard Flood Insurance Policy, see the current policy or contact a property insurance agent or broker.

53. **What flood losses are covered?**
The Standard Flood Insurance Policy (SFIP) Forms contain complete definitions of the coverages they provide. Direct physical losses by "flood" are covered. Also covered are losses resulting from flood-related erosion caused by waves or currents of water activity exceeding anticipated cyclical levels, or caused by a severe storm, flash flood, abnormal tidal surge, or the like, which result in flooding, as defined. Damage caused by mudflows, as specifically defined in the policy forms, is covered.

54. **What coverage is available in basements and in enclosed areas beneath the lowest elevated floor of a elevated building?**
Coverage is provided for foundation elements, including posts, pilings, piers, or other support systems for elevated buildings. Coverage also is available for basement and enclosure utility connections, certain mechanical equipment necessary for the habitability of the building, such as furnaces, hot water heaters, clothes washers and dryers, food freezers, air conditioners, heat pumps, electrical junctions, and circuit breaker boxes. Finished structural elements such as paneling and linoleum, and contents items such as rugs and furniture are not covered. The SFIP has a complete list of covered elements and equipment.

55. **What is a basement?**
The NFIP's definition of "basement" includes any part of a building where all sides of the floor are located below ground level. Even though a room may have windows and constitute living quarters, it is still considered to be a basement if the floor is below ground level on all sides.

56. **Are losses from land subsidence, sewer backup, or seepage of water covered?**
We will pay for losses from land subsidence under certain circumstances. Subsidence of land along a lake shore or similar body of water, which results from the erosion or undermining of the shoreline caused by waves or currents of water exceeding cyclical levels that result in a flood, is covered. All other land subsidence is excluded.

We do not insure for direct physical loss caused directly or indirectly by any of the following:

- Back ups through sewers or drains; or
- Discharges or overflows from a sump, sump pump, or related equipment;
- Seepage or leaks on or through the covered property; unless there is a general condition of flooding in the area and the flood is the proximate cause of the sewer or drain backup, sump pump discharge or overflow, or seepage of water.

57. **Does the NFIP apply a deductible to losses?**
A minimum deductible is applied separately to a building and its contents, although both may be damaged in the same flood. Higher deductibles are available, and an insurance agent can provide information on specific amounts of available deductibles. Optional high deductibles reduce policy premiums but will have to be approved by the mortgage lender.

58. **Are costs of preventive measures covered under the SFIP?**
Some are. When an insured building is in imminent danger of being flooded, the reasonable expenses incurred by the insured for removal of insured contents to a safe location and return will be reimbursed up to $1,000, and the purchase of sandbags and sand to fill them, plastic sheeting and lumber used in connection

with them, pumps, fill for temporary levees, and wood will be reimbursed up to $1,000. No deductible is applied to this coverage.

59. **Does insurance under the NFIP provide coverage at replacement cost?**
Only for single-family dwellings and residential condominium buildings, if several criteria are met. Replacement cost coverage is available for a single-family dwelling, including a residential condominium unit that is the policyholder's principal residence and is insured for at least 80 percent of the unit's replacement cost at the time of the loss, up to the maximum amount of insurance available at the inception of the policy term. Replacement cost coverage does not apply to manufactured (i.e., mobile) homes smaller than certain dimensions specified in the policy. Losses are adjusted on a replacement cost basis for residential condominium buildings insured under the Residential Condominium Building Association Policy (RCBAP). The principal residence and the 80 percent insurance to value requirements for single-family dwellings do not apply to the RCBAP. However, coverage amounts less than 80 percent of the building's full replacement cost value at the time of loss will be subject to a co-insurance penalty.

Contents losses are always adjusted on an actual cash value basis. If the replacement cost conditions are not met, the building loss is also adjusted on an actual cash value basis. Actual cash value means the replacement cost of an insured item of property at the time of loss, less the value of physical depreciation as to the item damaged.

60**. Does the flood insurance dwelling policy provide additional living expenses, if the insured dwelling is flood damaged and cannot be occupied while repairs are being made?**
No. The policy only covers direct physical flood damage to the dwelling and does not provide additional living expenses.

61. **What is Increased Cost of Compliance coverage**?
Increased Cost of Compliance (ICC) coverage under the Standard Flood Insurance Policy (SFIP) provides for the payment of a claim to help pay for the cost to comply with State or community floodplain management laws or ordinances from a flood event in which a building has been declared substantially damaged or repetitively damaged. When an insured building is damaged by a flood and the State or community declares the building to be substantially damaged or repetitively damaged, ICC coverage will help pay for the cost to elevate, floodproof, demolish, or relocate the building up to a maximum benefit of $30,000. This coverage is in addition to the building coverage for the repair of actual physical damages from flood under the SFIP.

62. **Is there a limit to the amount a policyholder can collect under ICC coverage?**
Yes. The maximum amount a policyholder may collect under ICC is $30,000. This amount is in addition to the amount the policyholder receives for physical

damages by flood. The total amount the policyholder receives for combined physical structural damage from flood and ICC is always capped by the maximum limit of coverage established by Congress. The maximum amount collectible for both ICC and physical damage from flood for a single-family dwelling is $250,000.

63. **Is ICC coverage included in all Standard Flood Insurance Policies?**
No. Insured under the Group Flood Insurance Policy and insured’s with condominium unit owner's coverage are ineligible for ICC coverage. Policies issued or renewed in Emergency Program communities are not eligible for ICC coverage. All other policies include the coverage.

3.2.4 Filing a Flood Insurance Claim

64. **How does a policyholder file a claim for flood loss?**
A flood insurance policyholder should immediately report any flood loss to the insurance company or agent who wrote the policy. A claims adjuster will be assigned the loss, and the policyholder must file a "proof of loss" within 60 days of the date of loss. A policyholder whose policy is with a WYO company must follow the company's claim procedures. The 60-day time limit for filling a proof of loss remains the same.

65. **What is a "proof of loss"?**
A proof of loss-the policyholder's valuation of claimed damages-is a sworn statement made by the policyholder that substantiates the insurance claim and is required to be submitted to the NFIP or WYO company within 60 days of the loss. A printed form usually is available from the adjuster assigned to the claim.

66. **What is a "loss in progress"?**
A loss in progress occurs when actual flood damage to a building or its contents started before the inception of the policy.

67. **Is a loss in progress covered?**
The NFIP does not cover damage caused by a loss in progress under any of the flood insurance policies.

68. **What is the maximum that can be collected for a loss under the NFIP policy?**
An insured will never be paid more than the value of the covered loss, less deductible, up to the amounts of insurance purchased. Therefore, purchasing insurance to value is an important consideration. The amount of insurance a property owner needs should be discussed with an insurance agent or broker.

3.2.5 Floodplain Management Requirements

69. **What is the role of the community in floodplain management?**
When the community chooses to join the NFIP, it must adopt and enforce minimum floodplain management standards for participation. FEMA works

closely with State and local officials to identify flood hazard areas and flood risks. The floodplain management requirements within the SFHA are designed to prevent new development from increasing the flood threat and to protect new and existing buildings from anticipated flood events.

When a community chooses to join the NFIP, it must require permits for all development in the SFHA and ensure that construction materials and methods used will minimize future flood damage. Permit files must contain documentation to substantiate how buildings were actually constructed. In return, the Federal Government makes flood insurance available for almost every building and its contents within the community.

Communities must ensure that their adopted floodplain management ordinance and enforcement procedures meet program requirements. Local regulations must be updated when additional data are provided by FEMA or when Federal or State standards are revised.

70. **Do State governments assist in implementing the NFIP?**
At the request of FEMA, each Governor has designated an agency of State or territorial government to coordinate that State's or territory's NFIP activities. These agencies often assist communities in developing and adopting necessary floodplain management measures.

Some States require more stringent measures than those of the NFIP. For contact information, see the list of State Coordinating Agencies in the back of this booklet.

71. **Do Federal requirements take precedence over State requirements?**
The regulatory requirements set forth by FEMA are the minimum measures acceptable for NFIP participation. More stringent requirements adopted by the local community or State take precedence over the minimum regulatory requirements established for flood insurance availability.

72. **What is meant by "floodplain management measures"?**
"Floodplain management measures" refers to an overall community program of corrective and preventive measures for reducing future flood damage. These measures take a variety of forms and generally include zoning, subdivision, or building requirements, and special-purpose floodplain ordinances.

73. **Do the floodplain management measures required by the NFIP affect existing buildings?**
The minimum Federal requirements affect existing buildings only when an existing building is substantially damaged or improved. There may also be situations where a building has been constructed in accordance with a local floodplain management ordinance, and the owner subsequently alters it in violation of the local building code, without a permit. Such unapproved

modifications to an existing building may not meet the minimum Federal requirements.

74. **What constitutes "substantial improvement" or "substantial damage"?**
"Substantial improvement" means any rehabilitation, addition, or other improvement of a building when the cost of the improvement equals or exceeds 50 percent of the market value of the building before start of construction of the improvement. The term includes buildings that have incurred "substantial damage." "Substantial damage" means damage of any origin sustained by a building when the cost of restoring the building to its pre-damaged condition would equal or exceed 50 percent of the market value of the building before the damage occurred. Substantial damage is determined regardless of the actual repair work performed.

    Substantial improvement or damage does not, however, include any project for improvement of a building to correct existing violations of State or local health, sanitary, or safety code specifications identified by local code enforcement officials as the minimum specifications necessary to assure safe living conditions. Also excluded from the substantial improvement requirement are alterations to historic buildings as defined by the NFIP.

75. **Do the floodplain management requirements apply to construction taking place outside the SFHAs within the community?**
The local floodplain management regulations required by the NFIP apply only in SFHAs. However, communities may regulate development in areas of moderate flood hazard.

76. **Can modifications be made to the basic floodplain management requirements?**
In developing their floodplain management ordinances, participating communities must meet at least the minimum regulatory standards issued by FEMA. NFIP standards and policies are reviewed periodically and revised whenever appropriate.

77. **Does elevating a structure on posts or pilings remove a building from the Special Flood Hazard Area (SFHA)?**
Elevating a structure on posts or pilings does not remove a building from the SFHA. If the ground around the supporting posts or pilings is within the floodplain, the building is still at risk. The structure is considered to be within the floodplain, and flood insurance will be required as a condition of receipt of Federal or Federally related financing for the structure. The reason for this, even in cases where the flood velocity is minimal, is that the hydrostatic effects of flooding can lead to the failure of the structure's posts or pilings foundation. The effects of ground saturation can lead to decreased load bearing capacity of the soil supporting the posts or pilings, which can lead to partial or full collapse of the structure. Even small areas of ponding will be subject to the hydrodynamic effects

of flooding; no pond or lake is completely free of water movement or wave action. This movement of water can erode the ground around the posts or pilings and may eventually cause collapse of the structure.

3.2.6 Flood Hazard Assessments and Mapping Requirements

78. **What is the difference between an FHBM and a FIRM?**
A Flood Hazard Boundary Map (FHBM) is based on approximate data and identifies, in general, the SFHAs within a community. It is used in the NFIP's Emergency Program for floodplain management and insurance purposes. A Flood Insurance Rate Map (FIRM) usually is issued following a flood risk assessment conducted in connection with the community's conversion to the NFIP's Regular Program. If a detailed assessment, termed a Flood Insurance Study (FIS), has been performed, the FIRM will show Base Flood Elevations (BFEs) and insurance risk zones in addition to floodplain boundaries. The FIRM may also show a delineation of the regulatory floodway. (See the answer to Question 80 for a description of "regulatory floodway.") After the effective date of the FIRM, the community's floodplain management ordinance must be in compliance with appropriate Regular Program requirements. Actuarial rates, based on the risk zone designations shown on the FIRM, are then applied for newly constructed, substantially improved, and substantially damaged buildings.

79. **How are flood hazard areas and flood levels determined?**
Flood hazard areas are determined using statistical analyses of records of riverflow, storm tides, and rainfall; information obtained through consultation with the community; floodplain topographic surveys; and hydrologic and hydraulic analyses. The FIS covers those areas subject to flooding from rivers and streams, along coastal areas and lake shores, or shallow flooding areas.

80. **What is the role of the local community in its flood hazard assessment?**
In conducting a FIS, FEMA considers all available information for use in the study. Public meetings are usually held with community officials and other interested parties in an effort to obtain all relevant information to help ensure accurate study results. FEMA also works closely with community officials before and during the study to describe technical and administrative procedures and to obtain community input before the FIRM and collateral FIS report are published. Before the FIS is initiated, FEMA representatives, the selected contractor, and community officials meet to discuss the areas to be studied and the level of study required. This meeting is called a "time and cost" meeting.

81. **What flood hazard zones are shown on the Flood Insurance Rate Map and what do they mean?**
Several areas of flood hazard are commonly identified on the FIRM. One of these areas is the SFHA, which is defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent-annual-chance flood is also referred to as the "base flood." SFHAs are labeled as Zone A, Zone AO, Zone AH, Zones A1-A30, Zone AE, Zone 99,

Zone AR, Zone AR/AE, Zone AR/AH, Zone AR/AO, Zone AR/A1-A30, Zone AR/A, Zone V, Zone VE, and Zones V1-V30. Moderate flood hazard areas, labeled Zone B or Zone X (shaded), are also shown on the FIRM, and are the areas between the limits of the base flood and the 0.2-percent-annual-chance. The areas of minimal flood hazard, which are the areas outside the SFHA and higher than the elevation of the 0.2-percent-annual-chance flood, are labeled Zone C or Zone X (unshaded). The definitions for the various flood hazard areas are presented below.

Zone V: Areas along coasts subject to inundation by the 1-percent-annual-chance flood event with additional hazards associated with storm-induced waves. Because detailed hydraulic analyses have not been performed, no BFEs or flood depths are shown. Mandatory flood insurance purchase requirements apply.

Zones VE and V1-V30: Areas along coasts subject to inundation by the 1-percent-annual-chance flood event with additional hazards due to storm-induced velocity wave action. BFEs derived from detailed hydraulic analyses are shown within these zones. Mandatory flood insurance purchase requirements apply. (Zone VE is used on new and revised maps in place of Zones V1-V30.)

Zone A: Areas subject to inundation by the 1-percent-annual-chance flood event. Because detailed hydraulic analyses have not been performed, no BFEs or flood depths are shown. Mandatory flood insurance purchase requirements apply.

Zones AE and A1-A30: Areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods. BFEs are shown within these zones. Mandatory flood insurance purchase requirements apply. (Zone AE is used on new and revised maps in place of Zones A1-A30.)

Zone AH: Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. BFEs derived from detailed hydraulic analyses are shown in this zone. Mandatory flood insurance purchase requirements apply.

Zone AO: Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average flood depths derived from detailed hydraulic analyses are shown within this zone. Mandatory flood insurance purchase requirements apply.

Zone A99: Areas subject to inundation by the 1-percent-annual-chance flood event, but which will ultimately be protected upon completion of an under-construction Federal flood protection system. These are areas of special flood hazard where enough progress has been made on the construction of a protection system, such as dikes, dams, and levees, to consider it complete for insurance rating purposes. Zone A99 may only be used when the flood protection system has reached specified statutory progress toward completion. No BFEs or flood depths are shown. Mandatory flood insurance purchase requirements apply.

Zone AR: Areas that result from the decertification of a previously accredited flood protection system that is determined to be in the process of being restored to provide base flood protection. Mandatory flood insurance purchase requirements apply.

Zones AR/AE, AR/AH, AR/AO, AR/A1-A30, AR/A: Dual flood zones that, because of the risk of flooding from other water sources that the flood protection system does not contain, will continue to be subject to flooding after the flood protection system is adequately restored. Mandatory flood insurance purchase requirements apply.

Zones B, C, and X: Areas identified in the community FIS as areas of moderate or minimal hazard from the principal source of flood in the area. However, buildings in these zones could be flooded by severe, concentrated rainfall coupled with inadequate local drainage systems. Local stormwater drainage systems are not normally considered in the community's FIS. The failure of a local drainage system creates areas of high flood risk within these rate zones. Flood insurance is available in participating communities but is not required by regulation in these zones. (Zone X is used on new and revised maps in place of Zones B and C.)

Zone D: Unstudied areas where flood hazards are undetermined, but flooding is possible. No mandatory flood insurance purchase requirements apply, but coverage is available in participating communities.

82. **What is a regulatory floodway and who designates it?**
The regulatory floodway, which is adopted into the community's floodplain management ordinance, is the stream channel plus that portion of the overbanks that must be kept free from encroachment in order to discharge the 1-percent-annual-chance flood without increasing flood levels by more than 1.0 foot (some states specify a smaller allowable increase). The intention of the floodway is not to preclude development. Rather, it is intended to assist communities in prudently and soundly managing floodplain development and prevent additional damages to other property owners. The community is responsible for prohibiting encroachments, including fill, new construction, and substantial improvements, within the floodway unless it has been demonstrated through hydrologic and hydraulic analyses that the proposed encroachment will not increase flood levels within the community. In areas that fall within the 1-percent-annual-chance floodplain, but are outside the floodway (termed the "floodway fringe"), development will, by definition, cause no more than a 1.0-foot increase in the 1-percent-annual-chance water-surface elevation. Floodplain management through the use of the floodway concept is effective because it allows communities to develop in flood prone areas if they so choose, but limits the future increases of flood hazards to no more than 1.0 foot.

83. **What procedures are available for changing or correcting a Flood Insurance Rate Map?**
FEMA has established administrative procedures for changing effective FIRMs and FIS reports based on new or revised scientific or technical data. A physical change to the affected FIRM panels and portions of the FIS report is referred to as a "Physical Map Revision," or "PMR." Changes can also be made by a Letter of Map Change (LOMC). The three LOMC categories are Letter of Map Amendment (LOMA), Letter of Map Revision based on Fill (LOMR-F), and Letter of Map Revision (LOMR). These LOMC categories are discussed in more detail later.

84. **What comprises technical or scientific data?**
In general, the scientific or technical data needed to effect a map amendment or revision include certified topographic data and/or hydrologic and hydraulic analyses to support the request for amendment or revision.

85. **What is a Physical Map Revision (PMR)?**
A PMR is an official republication of a community's NFIP map to effect changes to BFEs, floodplain boundary delineations, regulatory floodways, and planimetric features. These changes typically occur as a result of structural works or improvements, annexations resulting in additional flood hazard areas, or correction to BFEs or SFHAs.

The community's chief executive officer must submit scientific and technical data to FEMA to support the request for a PMR. The data will be analyzed, and the map will be revised if warranted. The community is provided with copies of the revised information and is afforded a review period. When BFEs are changed, a 90-day appeal period is provided. A 6-month period for formal approval of the revised map(s) is also provided.

86. **What is a Letter of Map Revision Based on Fill (LOMR-F)?**
A LOMR-F is an official revision by letter to an effective NFIP map. A LOMR-F states FEMA's determination concerning whether a structure or parcel has been elevated on fill above the BFE and is, therefore, excluded from the SFHA.

87. **What is a Letter of Map Amendment (LOMA)?**
A LOMA is an official revision by letter to an effective NFIP map. A LOMA results from an administrative procedure that involves the review of scientific or technical data submitted by the owner or lessee of property who believes the property has incorrectly been included in a designated SFHA. A LOMA amends the currently effective FEMA map and establishes that a specific property is not located in an SFHA.

88. **What is a Letter of Map Revision (LOMR)?**
A LOMR is an official revision to the currently effective FEMA map. It is used to change flood zones, floodplain and floodway delineations, flood elevations, and

planimetric features. All requests for LOMRs should be made to FEMA through the chief executive officer of the community, since it is the community that must adopt any changes and revisions to the map. If the request for a LOMR is not submitted through the chief executive officer of the community, evidence must be submitted that the community has been notified of the request.

89. **What is a conditional map revision?**
NFIP maps must be based on existing, rather than proposed, conditions. Because flood insurance is a financial protection mechanism for real-property owners and lending institutions against existing hazards, flood insurance ratings must be made accordingly. However, communities, developers, and property owners often undertake projects that may alter or mitigate flood hazards and would like FEMA's comment before constructing them. A Conditional Letter of Map Revision (CLOMR) is FEMA's formal review and comment as to whether a proposed project complies with the minimum NFIP floodplain management criteria. If it is determined that it does, the CLOMR also describes any eventual revisions that will be made to the NFIP maps upon completion of the project.

While obtaining a CLOMR may be desired, obtaining conditional approval is not automatically required by NFIP regulations for all projects in the floodway or 1-percent annual chance floodplain. A CLOMR is required only for those projects that will result in a 1-percent annual chance water surface elevation increase of greater than 1.00 foot for streams with BFEs specified, but no floodway designated, or any 1-percent annual chance water surface elevation increase for proposed construction within a regulatory floodway. The technical data needed to support a CLOMR request generally involve detailed hydrologic and hydraulic analyses and are very similar to the data needed for a LOMR request.

In addition to the situations described above, property owners and developers who intend to place structures in the 1-percent annual chance floodplain may need to demonstrate to the lending institutions and local officials before construction that proposed structures will be above the base flood elevation. If the project involves only the elevation of structures on natural high ground, they can request a Conditional Letter of Map Amendment (CLOMA) from FEMA. If the elevation of structures on earthen fill is the sole component of the project (i.e., there is no associated channelization, culvert construction, etc., that would alter flood elevations) and there is no fill placed in the regulatory floodway, they can request from FEMA a CLOMR based on fill or a CLOMR-F. Requests for CLOMAs and CLOMRS should be made by the community and addressed to the Mitigation Division Director at the appropriate FEMA Regional Office. The addresses of all FEMA Regional Offices are provided in the back of this booklet. Until a LOMR is issued, this property remains in the floodplain and is subject to the community floodplain management ordinance and the mandatory flood insurance purchase requirements.

90. **Who should be contacted in FEMA to initiate a LOMA, LOMR, or Physical Map Revision?**
Requests for conditional and final map revisions should be sent to the FEMA LOMA Depot. Any questions regarding LOMA/LOMR should be directed to one of FEMA's Flood Map Specialists. Contact information is provided in the "FEMA LOMA Depot" section at the back of this booklet.

91. **How long does it take to obtain a LOMA, LOMR, or PMR?**
For single-building or single-lot determinations that do not involve changes to BFEs or floodways, a LOMA or LOMR-F generally can be issued within 4 weeks. LOMAs and LOMRs involving multiple lots or multiple buildings require up to 8 weeks to process. Times are specified from the date of receipt of all technical, scientific, or legal documentation. LOMRs involving decreases in BFEs or floodways take approximately 90 days for processing. If changes in flooding conditions are extensive or if BFEs increase, a PMR will be required, which will take 12 months or longer.

92. **If a LOMA, LOMR-F, or LOMR is issued by FEMA, will a lending institution automatically waive the flood insurance requirement?**
Although FEMA may issue a LOMA, it is the lending institution's prerogative to require flood insurance as a condition of its own beyond the provisions of the Flood Disaster Protection Act of 1973 and the National Flood Insurance Reform Act of 1994, before granting a loan or mortgage. Those seeking a LOMA should first confer with the affected lending institution to determine whether the institution will waive the requirement for flood insurance if a LOMA is issued. If it will, the policyholder may cancel flood insurance coverage and obtain a premium refund. If not, amending the NFIP map to remove the structure from the SFHA will generally lower the flood insurance premium.

93. **If a LOMA, LOMR-F, or LOMR is granted and the lender waives the requirement for flood insurance, how can a flood insurance policy be cancelled?**
To effect a cancellation of a flood insurance policy, the policyholder must supply a copy of the LOMA, LOMR-F, or LOMR and a waiver for the flood insurance purchase requirement from the lending institution to the insurance agent or broker who services the policy. A completed cancellation form with the LOMA, LOMR-F, or LOMR and the waiver must be submitted by the agent to the NFIP or the appropriate WYO company. When a LOMA, LOMR-F, or LOMR is issued and cancellation requested, the policyholder may be eligible for a refund of the premium paid for the current policy year only if no claim is pending and no claim has been paid during the current policy year.

94. **Why is the burden of proof on the person requesting a map change?**
FEMA and its Federal and private-sector contractors exercise great care to ensure that analytical methods employed in FISs are scientifically and technically correct, the engineering practices followed meet professional standards, and the

results of the FIS are accurate. In making amendments and revisions to NFIP maps and reports, FEMA must adhere to the same engineering standards applied in preparing the effective maps and reports. Therefore, when requesting changes to NFIP maps, community officials and property owners are required to submit adequate supporting data. FEMA would have no justification for changing a flood hazard determination without sufficient evidence that the change is appropriate.

95. **Are fees assessed for map change requests submitted by community officials, developers, and property owners?**
To minimize the financial burden on the policyholders while maintaining the NFIP as self-sustaining, FEMA implemented procedures to recover costs associated with reviewing and processing requests for conditional and final map amendments and map revisions. The fee schedule for these requests is published in the Federal Register and applies to all types of requests except those that are specifically exempted in Section 72.5(c) of the NFIP Regulations. Community officials and other individuals who have questions regarding the required review and processing fees should contact the appropriate FEMA Regional Office as listed at the back of this booklet.

96. **What is the purpose of the application/ certification forms that are required for map change requests?**
FEMA implemented the use of forms for requesting revisions or amendments to NFIP maps to provide a step-by-step process for requesters to follow. The forms are comprehensive; therefore, requesters are reasonably assured of preparing a complete request that includes all the necessary support data without having to go through an iterative process of providing additional information in a piecemeal fashion. Experience has shown piecemeal submissions to be time-consuming and expensive. Also, because use of the forms assures the requesters' submissions are complete and more logically structured, FEMA can complete its review in a shorter time frame. While completing the forms may appear to be burdensome, FEMA believes it is prudent to do so because of the advantages that result for the requester.

97. **How can someone obtain copies of the technical data used in preparing the published NFIP maps?**
Technical supporting data may be obtained by contacting a FEMA Flood Map Specialist listed in the "FEMA LOMA Depot" section at the back of this booklet. The letter should give the name of the community for which the data are sought, provide specific information as to the portion of the community and type of data needed, and give the requester's name and telephone number. Before the request is serviced, a representative will call to discuss the request. If a charge is necessary for the service, the extent of the service and the costs will be discussed during the call.

3.3 Contacts for the NFIP

The Alaska State Coordinator for Floodplain Management Programs is Tannie Boothby, who is located in the Division of Community Advocacy of the Alaska Department of Commerce Community and Economic Development. The office is in Anchorage, AK, at 550 West 7th Avenue, Suite 1770, telephone: (907) 269-4583. The web site is: http://www.commerce.state.ak.us/dca.

The FEMA office responsible for the state of Alaska is Region X in Bothell, Washington. The Region X NFIP contact's office is located at 19125 Northcreek Parkway, Suite 108, telephone: (425) 482-0316.
Information on FEMA Region X can be found at the Region's web site at: http://www.fema.gov/about/contact/regionx.shtm.
Additional information on the NFIP can be found on the Floodsmart web site at: http://www.floodsmart.gov/floodsmart/pages/about/nfip_about.jsp.

SECTION 4.0 GLOSSARY

Accretion: The buildup of land along the shore. Natural accretion occurs by the action of forces of nature. Artificial accretion occurs by the action of man (groin, breakwater, etc.).

Alignment: The course along which the centerline of a channel, levee, road, etc. is located.

Alluvium: Material (soil, sand, mud, etc.) deposited by moving water.

Alongshore: Parallel to or near the shoreline.

Armor Stone: Relatively large quarry stone or concrete shape selected for its geometric characteristics and density.

Ballasting: Filling of the ship's ballast tanks with sea water for stability and maneuverability.

Bank: Rising ground bordering a lake, river, or sea.

Bar: Submerged or emerged embayment of sand, gravel, or other unconsolidated material built on the sea floor in shallow water by waves and currents.

Barrier Beach: A bar essentially parallel to shore the crest of which is above normal high water level.

Barrier Island: A detached portion of a barrier beach between two inlets. (e.g., Cooper Island)

Barrier Lagoon: A bay roughly parallel to the coast and separated from the open ocean by barrier islands. (e.g., Elson Lagoon)

Barrier Spit: Similar to a barrier island, but connected to the mainland. (e.g., Point Barrow)

Base Flood Elevation: The flood with a one-percent chance of occurring in any year (also referred to as the 100-year flood).

Bathymetry: The measurement of depths of water in oceans, seas, and lakes.

Benthic: Relating to or occurring at the bottom of a body of water.

Bluff: A high, steep bank or cliff.

Bollard: A mooring device mounted on a dock that is used for securing a ship's mooring line.

Borrow Site: Site from which construction materials would be extracted.

Breakwater: A man-made structure protecting a shore area, harbor, or basin from waves.

Channel: The part of a body of water deep enough to be used for navigation through an area otherwise too shallow for navigation.

Coastal High Hazard Area: That part of the coastal floodplain where wave heights during the base flood will be three feet or more.

Controlling Depth: The least depth in the navigable parts of a waterway, governing the maximum draft of vessels that can enter.

Current: The flowing of water or other liquid or gas.

Cost Apportionment: The process by which construction and operation & maintenance costs for a project are divided between the Federal government and the non-Federal local project sponsor.

Cross Section: surveyed information that describes a linear feature (road, dike, beach, etc.) at a particular point.

Day Mark: A visual navigational aid used by pilots for aligning a ship's path with a channel or fixing a position.

Design Capacity: The capacity on which basis design calculations are made. Usually, the design capacity equals the peak capacity or higher, depending on the degree of "safety factors" applied.

Dike: Earth structure along sea or river that protects low lands from flooding by high waters.

Draft: The vertical distance between a ship's waterline and its keel.

Dredging: Excavating the bottom or shoreline of a water body.

Eminent Domain: Governmental power to acquire a property without the owner's consent.

Executive Order 11988-Floodplain Management: A directive by the President that sets procedures that Federal Agencies must follow before they take or fund an action in the floodplain.

Executive Order 12898-Environmental Justice: A directive by the President that requires Federal Agencies to address disproportionately high and adverse human health and environmental effects on minority and low income populations.

Fetch: The area in which waves are generated by a wind having a constant direction and speed.

Flood-Coastal: High levels of coastal waters associated with severe storms, possibly combined with unusually high tides.

Floodplain: Any land area susceptible to being inundated by flood waters of any source.

Floodproofing: Protective measures added or incorporated in a building that is not elevated above the base flood elevation to prevent or minimize flood damage.

Floodproofing, Dry: Measures designed to keep water from entering a building.

Floodproofing, Wet: Measures that minimize damage to a structure and its contents from water that is allowed to enter a building.

Flood-Riverine: A periodic overbank flow of rivers and streams due to heavy and/or sustained rainfall.

Gabion: Steel wire-mesh basket that holds stones or crushed rock to protect a bank or bottom from erosion.

Gravel: Unconsolidated natural accumulation of rounded rock fragments coarser than sand but finer than pebbles (2-4mm diameter).

Gravity Structure: A structure that derives its lateral load resistance primarily by virtue of its weight. (e.g., caissons and sheetpile cells).

Groin: Narrow, roughly shore-normal structure built to reduce longshore currents and/or trap and retain littoral material.

Ice Scour: Ice forms in the open ocean and along the shore. As ice moves, it cracks, breaks, merges, often forming pressure ridges that have deep keels that impact and scour the near shore sea bottom and the beach.

Ivu: Floating ice is pushed by winds and/or currents onto the shore and inland, possibly damaging structures and facilities and endangering residents.

Jackup Barge: A floating barge equipped with retractable legs and jacks. After floating the barge into position, the legs are lowered to the sea bottom, and the jacks are used to elevate the barge hull on the legs to an elevation above the surface of the water.

Knot: A speed of one nautical mile per hour (one nautical mile = 1852 meters or 6,076.115 feet)

Lighter: A barge used for transporting goods between ships and shore in shallow water.

Littoral Drift: The sedimentary material moved in the littoral zone under the influence of waves and currents.

Littoral Zone: An indefinite zone extending seaward from the shoreline to just beyond the breaker zone.

Load (sediment load): The quantity of sediment transported by a current, including the suspended load of small particles, and the bedload of large particles that move along the bottom.

Longshore: Parallel to and near the shoreline.

Mean Lower Low Water: The average height of the lower low waters over a 19 year period. The lower low waters are the lowest of the two low waters in any tidal day.

Market Value: The price a willing buyer and a willing seller agree upon.

Mooring Buoy: A floating buoy equipped with a mooring hook that is used for mooring a ship at a berth.

National Economic Development Plan (NED Plan): The alternative plan that maximizes national economic development according to COE criteria.

Nautical Mile: The length of a minute of arc, 1/21,600 of an average great circle of the earth. Generally one minute of latitude is considered equal to one nautical mile. One nautical mile = 6,076.115 feet or 1.15 statute miles or 1,852 meters.

Navigable Waters: Waters that are either tidally-influenced, navigable in fact, or navigable in law.

Nearshore: An indefinite zone extending seaward from the shoreline well beyond the breaker zone (typically to water depths of 20 meters).

Non-structural Risk Reduction Measures: Measures that reduce risk by modifying the characteristics of buildings and structures subject to risk or modify the behavior of persons who live in the risk area. Typical non-structural measures would be administrative tools such as flood plain regulations and building codes, elevation of buildings, floodproofing of buildings, relocation of buildings and buyout & demolition of buildings.

Nourishment: The process of replenishing a beach either naturally by longshore transport or artificially by the addition of materials from another location.

Optimization: The application of a technique to identify parameters that maximize net economic benefit.

Permafrost: Perennially frozen ground,

Polynya: Semi-permanent open lead in sea ice.

Ponding: Runoff that collects in depressions and can not drain out.

Probability: A statistical term having to do with the size of a flood and the odds of that size of flood occurring in any year.

Profile: A graph that shows elevations of linear features.

Refraction: The process by which the direction of a wave moving in shallow water at an angle to the contours is changed. The part of the wave advancing in shallower water moves more slowly than the part still advancing in deeper water, causing the wave crest to bend toward alignment with the underwater contours.

Revetment: A facing of stone, concrete, etc. built to protect an embankment or shore structure against erosion by wave action or currents.

Riprap: A protective layer of quarrystone, usually well graded within wide size limits, randomly placed to prevent erosion, scour, or sloughing of an embankment or bluff.

Rock Anchor: In the context of a piled marine structure, a rock anchor is a method of anchoring piling to underlying bedrock, as a means of resisting uplift forces generated by lateral loads on the structure (generally caused by ice, waves, wind, or ship berthing).

Run up: The rush of water up a structure or beach on the breaking of a wave. The amount of run up is the vertical height above stillwater level that the rush of water reaches.

Sand: Sediment particles with a diameter between 0.062 mm and 2 mm, generally classified as fine, medium, coarse, or very coarse.

Scour: Removal of underwater material by waves and currents, especially at the base or toe of a shore structure.

Sediment: Loose, fragments of rocks, minerals, or organic material that are transported from their source for varying distances and deposited by air, wind, ice, and/or water.

Sheet flow: Floodwater that spreads out over a large area that does not have defined channels at a somewhat uniform depth.

Significant Wave Height: The average height of one-third of the highest waves of a given wave group.

Seismic: Related to or caused by earthquakes or man-made earth tremors.

Stationing: Determining the distance along a linear feature.

Storm Surge: A rise above normal water level on the open coast due to the action of wind stress on the water surface.

Structural Risk Reduction Measure: Measures that reduce risk by modifying the characteristics of the flood or erosion event. They do not modify the characteristics of buildings and structures at risk or modify the behavior of persons in the risk area. Typical structural measures would be revetments, groins, breakwaters, beach nourishment, etc.

Tombolo: A sand or gravel bar connecting an island with the mainland or another island.

Utilador: An insulated conduit that carries utilities (water, sewer, power, phone, etc) either above ground or underground.

Wave Height: The vertical distance between a crest and a preceding trough.

Wave Period: The time for a wave crest to traverse a distance equal to one wavelength. The time for two successive wave crests to pass a fixed point.

Wave Response: A hydrodynamic effect on a ship's hull caused by waves.

Wave Run up: Wave run up occurs when waves hit the shore and the water is moving with such a force that it keeps traveling inland.

Wind Set up: The difference in stillwater levels on the windward and leeward sides of a body of water caused by wind stresses on the surface of the water.

SECTION 5.0 UNITS, ABBREVIATIONS, AND ACRONYMS

Ac	acres
ACHP	Advisory Council of Historic Preservation
ACMP	Alaska Coastal Management Program
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish & Game
ADGC	Alaska Department of Governmental Coordination
ADNR	Alaska Department of Natural Resources
ADOT&PF	Alaska Department of Transportation & Public Facilities
AEWC	Alaska Eskimo Whaling Commission
ANCSA	Alaska Native Claims Settlement Act of 1971
ANILCA	Alaska National Interest Lands Conservation Act of 1980
ARM	Atmospheric Radiation Measurement
ASA (CW)	Assistant Secretary of Army for Civil Works
ASHPO	Alaska State Historic Preservation Office
ASNA	Arctic Slope Native Association, Limited
ASRC	Arctic Slope Regional Corporation
ASTAC	Arctic Slope Telephone Association Cooperative
BASC	Barrow Arctic Science Consortium
BCR	Benefit-to-Cost Ratio
BEO	Barrow Environmental Observatory
BFE	Base Flood Elevation
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BUECI	Barrow Utilities and Electric Cooperative, Inc.
C	Vertical Clearance
CAR	Coordination Act Report (US Fish & Wildlife Service)
CB	City of Barrow
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CHL	Coastal & Hydraulics Laboratory of ERDC
CI	Cumulative Impacts
CMP	Corrugated Metal Pipe
COBCA	Compliance Order by Consent Agreement
COE	U.S. Army Corps of Engineers
CRREL	Cold Regions Research and Engineering Laboratory
CZMP	Coastal Zone Management Program
DA	Department of Army
DEW	Distant Early Warning (radar system)
DI	Department of Interior
DIIFR&EIS	Draft Integrated Interim Feasibility Report and Environmental Impact Statement
EIS	Environmental Impact Statement
EO	Executive Order
EPA	Environmental Protection Agency

ER	Engineering Regulation
ERDC	Engineering & Development Center, Vicksburg, MS
FAA	Federal Aviation Administration
FCSA	Feasibility Cost Sharing Agreement
FEL	Front End Loader
FEMA	Federal Emergency Management Agency
FHBM	Flood Hazard Boundary Map
FIA	Federal Insurance Administration
FIS	Flood Insurance Study
FIRM	Flood Insurance Rate Map
fpm	feet per minute
ft	foot or feet
H	horizontal
h	hour
HQUSACE	Headquarters, US Army Corps of Engineers, Washington, D.C.
ICAS	Inupiat Community of the Arctic Slope
IDC	Interest During Construction
IFR	Interim Feasibility Report
IFS	Interim Feasibility Study
IHC	Inupiat Heritage Center
IHS	Indian Health Service
IRA	Indian Reorganization Act
IWR	Institute for Water Resources, Ft. Belvoir, VA
knots	nautical miles per hour
kW	kilowatt
LER	Lands, Easements, Rights-of-Way
LERR	Lands, Easements, Rights-of-Way, and Relocations
LPP	Locally Preferred Plan
m	meter
m^2	square mile
MHW	Mean High Water
MLLW	Mean Lower Low Water
MSL	Mean Sea Level
m/s	meters per second
Mw	megawatt
NAAQS	National Ambient Air Quality Standards
NANA	Northwest Alaska Native Association
NARL	Naval Arctic Research Laboratory
NED	National Economic Development
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NGVD	National Geodetic Vertical Datum
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NOAA	National Oceanic & Atmospheric Administration
NOS	National Ocean Survey
NPS	National Park Service

NSB	North Slope Borough, Barrow, AK
NSF	National Science Foundation
NVB	Native Village of Barrow Inupiat Traditional Government
NWAB	Northwest Arctic Borough, Kotzebue, AK
OMB	Office of Management and Budget
OMRR&R	Operation, Maintenance, Repair, Replacement & Rehabilitation
OSE	Other Social Effects
PBO	Point Barrow Observatory
P&G	Principles and Guidelines
PDT	Project Delivery Team
PL	Public Law
PMP	Project Management Plan
POA	Pacific Ocean Division-Alaska District, Anchorage, AK
POD	Pacific Ocean Division-Headquarters, Ft. Shafter, HI
RED	Regional Economic Development
ROD	Record of Decision
RP	Recommended Plan
SPM	Shore Protection Manual (Corps of Engineers)
TIC	Total Investment Cost
tph	tons per hour
UAA	University of Alaska at Anchorage
UAF	University of Alaska at Fairbanks
UIC	Ukpeagvik Inupiat Corporation
USC	United States Code
USCG	United States Coast Guard
USFWS	U.S. Fish and Wildlife Service
v	vertical
w	Width
WEIO	World Eskimo Indian Olympics
WRDA	Water Resources Development Act
yd	yard
yd^3	cubic yard

6.0 CONVERSION TABLE FOR SI (METRIC) UNITS

Units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To obtain
cubic feet	0.0283	cubic meters
cubic yards	0.7646	cubic meters
acre	0.4049	hectare
Fahrenheit degrees	*	Celsius degrees
feet	0.3048	meters
feet per second	0.3048	meters per second
inches	0.396	centimeters
knots (international)	0.5144	meters per second
miles (U.S. statute)	1.6093	kilometers
miles (nautical)	1.8520	kilometers
square miles	2.590	square kilometers
miles per hour	1.6093	kilometers per hour
pounds (mass)	0.4536	kilograms
short ton (2,000 lb)	0.9072	megagram
U.S. gallon	3.7854	liter
part per million	1.0000	milligram per liter

To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$.

7.0 LIST OF PREPARERS AND CONTRIBUTORS

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WMAC(NS) 2000-

U.S. Army Corps
of Engineers
Alaska District

Barrow, Alaska

Coastal Storm Damage Reduction Interim Feasibility Report

Appendix J – Gravel Exploration Report

March 2005

US Army Corps of Engineers
Alaska District
Soils and Geology Section

COASTAL STORM DAMAGE REDUCTION GRAVEL EXPLORATION
(CWIS 013656)
Barrow, Alaska

March 2005

COASTAL STORM DAMAGE REDUCTION
GRAVEL EXPLORATION
BARROW, ALASKA
MARCH 2005

1. Introduction

The City of Barrow, Alaska has a severe erosion problem due to storm wave action during summer and fall on the beach adjacent to town. The North Slope Borough and the U.S. Army Corps of Engineers have agreed to identify and explore for approximately two million cubic yards of gravel for the purpose of beach nourishment at Barrow. A literature search and a site visit identified three areas near Barrow as potential gravel sources. These potential source locations are shown on the Project Location and Vicinity Map presented as Figure 1. The sites have been designated as Cooper Island, BIA Prospect, and the Submerged Spit. The investigation presented in this report discusses the exploration performed at Cooper Island, the BIA Prospect and the Submerged Spit as well as four borings drilled along the beach adjacent to the City of Barrow (Beach Area Site) to help define the existing beach conditions.

The purpose of this exploration effort was to determine the characteristics of the soils along the beach adjacent to Barrow and to explore for a source of gravel or sand (approximately two million cubic yards) at the potential source locations identified as Cooper Island, the BIA Prospect, and the Submerged Spit.

Photo 1. View of beach area in front of Barrow in mid-April 2004.

2. Field Exploration

Onshore Exploration:

The onshore subsurface exploration for the project was conducted 28 March through 27 April 2004. Two drill rigs owned and operated by Denali Drilling of Anchorage, Alaska were mobilized to Barrow for the exploration. The drill rigs were CME-45's mounted on N-60 Nodwell carriers. During the exploration, covered enclosures were constructed over the drill engines to allow heating the engines prior to starting. The engines of the Nodwell carriers remained running during the entire exploration. The exploration was performed in temperatures ranging from –25 to 15 degrees Fahrenheit with wind chills to –60 degrees. The drill rigs were fitted with continuous flight, eight-inch diameter, hollow-stem auger. An engineer with the Corps supervised the drilling. The engineer from the Corps and a geologist under contract to the Corps from R&M Consultants Inc. logged the test borings in accordance with ASTM D-2488, "Description and Identification of Soils (Visual - Manual Procedure)". Each drill rig was accompanied by a trained "bear-guard" supplied by LCMF, LLC (under contract to the North Slope Borough). The bear-guard's responsibility was to patrol the drilling area and watch for polar bears that are a constant threat in the area.

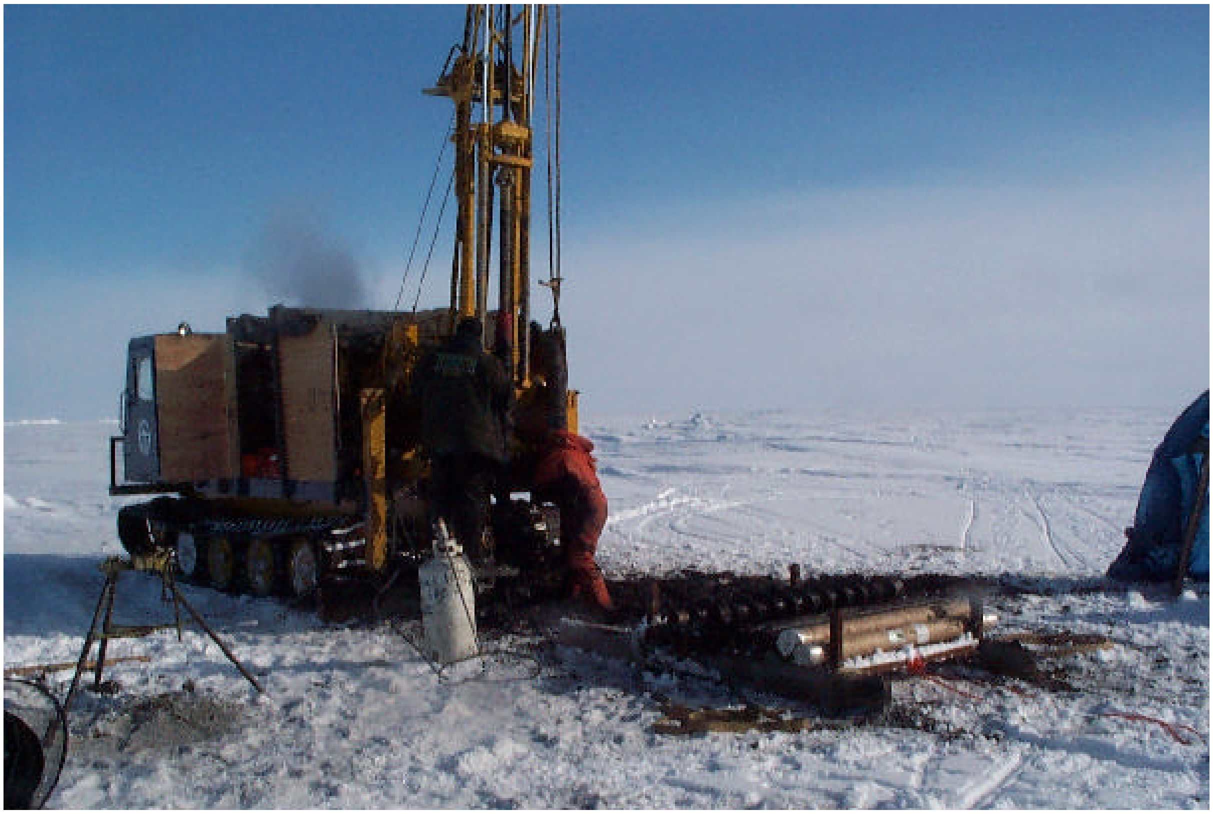


Photo 2. Drilling operation on Cooper Island.

The test boring locations were determined using a handheld GPS unit and referencing existing topographic features. These locations are only as accurate as the method implies. The coordinates for each of the boring locations shown on the boring logs are in NAD 83, UTM (feet). The boring locations are shown on the enclosed Test Boring Location Maps, Figures 2, 3, 4 and 5.

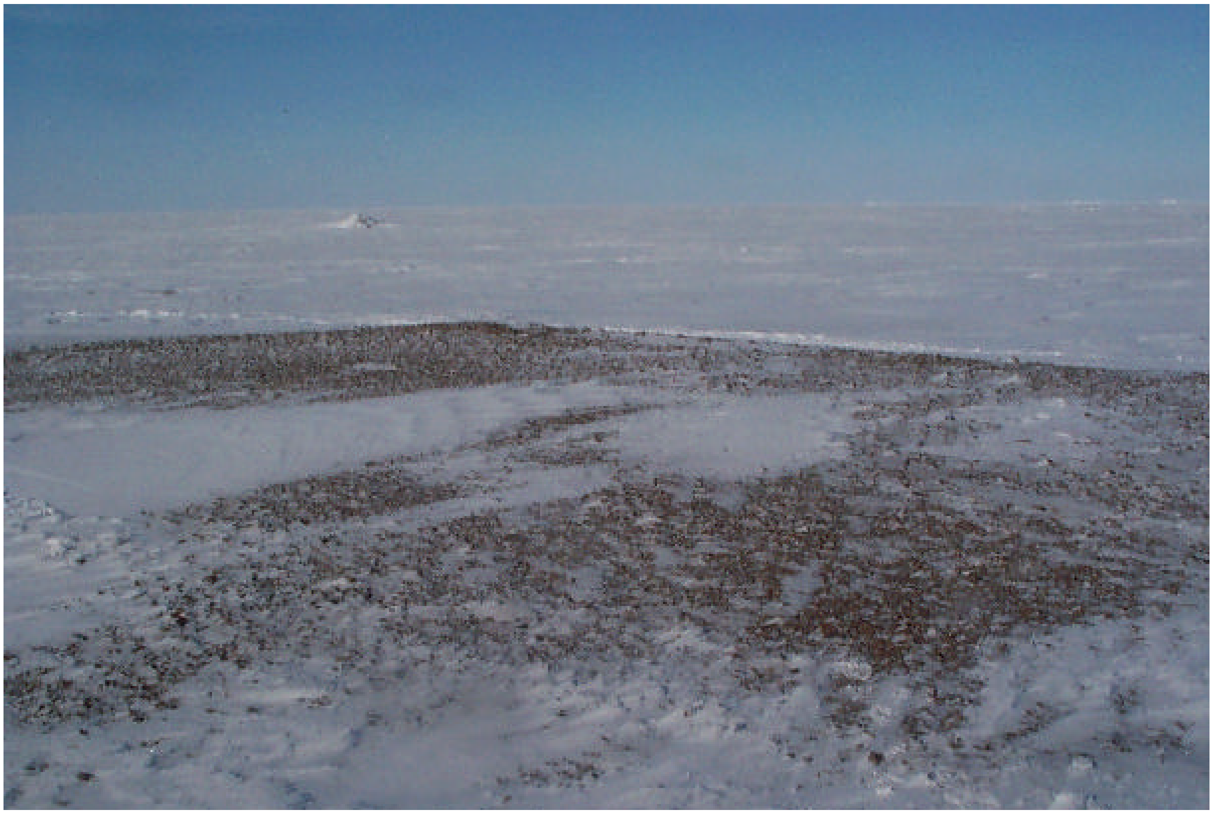


Photo 3. Wind blown surface of Cooper Island.

Soil samples generally were procured near the ground surface, at five feet below the surface, and at five-foot intervals thereafter. Grab samples were taken at the surface. Subsequent samples were taken with a 2.5-inch inside diameter, split spoon sampler driven with a 340-pound hammer falling 30 inches operated with a cathead and rope system. The sampler was driven 18 inches ahead of the auger or to refusal. The number of blows required to drive each six-inch increment is recorded on the exploration logs. The blow count is an indication of the relative density or consistency of the soil, but in this case, most of the soils are in a frozen state and the blow counts are not indicative of the thawed density of the soil encountered. In some cases where significant quantity of sample could not be recovered with the split spoon sampler, a grab sample was obtained from the auger flight upon reaching the surface. In the relatively smooth sided holes augered into the frozen soils, the drill advance was purposefully stopped at the top of the sample interval to clear auger cuttings from the hole. Then the auger was advanced a foot and the cuttings were sampled as they were transported to the surface on the auger flight.

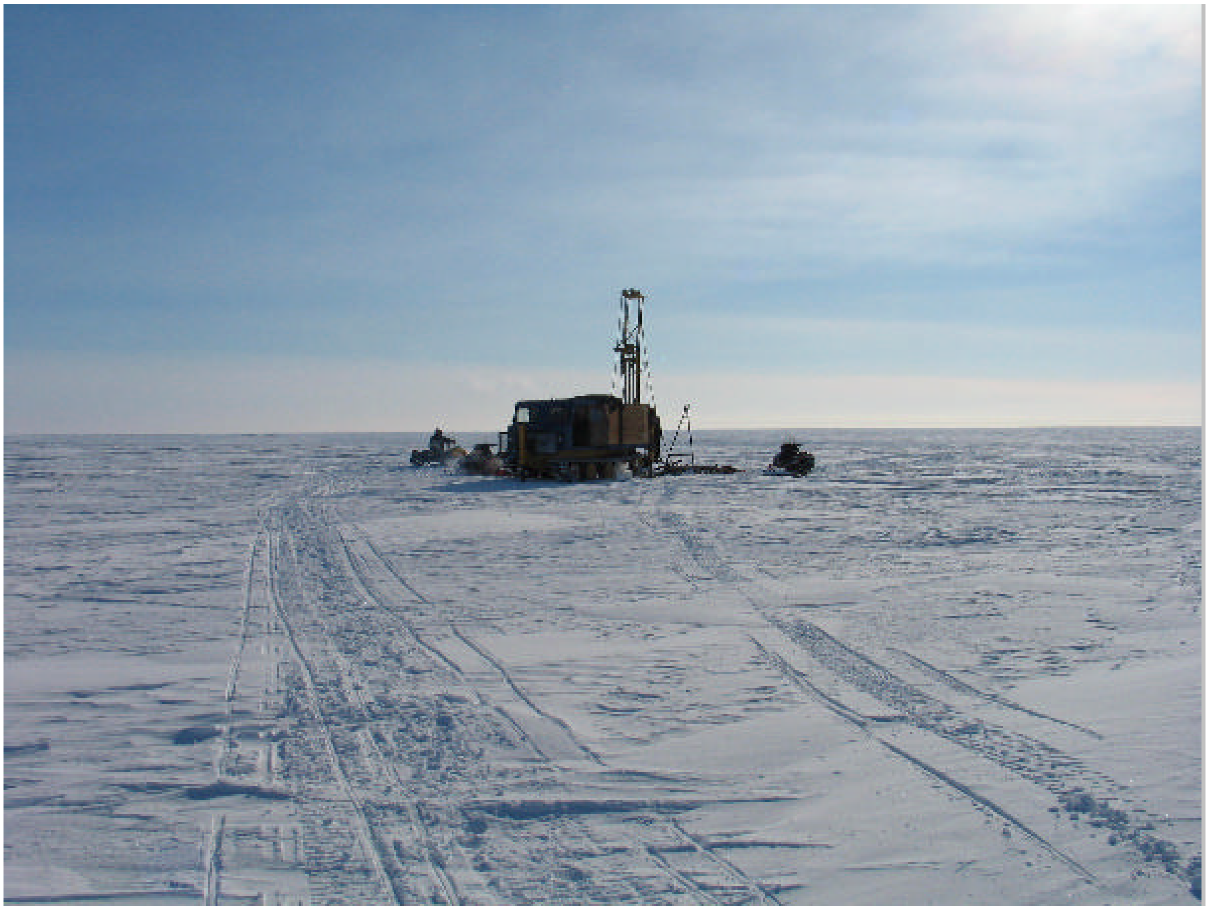


Photo 4. Drilling operation at the BIA Prospect.

<u>Offshore Exploration</u>:

The offshore exploration was conducted from 3 to 14 August, 2004. The drilling operation was performed from a 127-foot landing craft from Anchorage, Alaska. Two track mounted Mobile B-61 drill rigs and backup drilling equipment were transported aboard the landing craft from Anchorage to Barrow. The drilling operation and landing craft were furnished and operated by Denali Drilling under contract to the Corps. The transit time from Anchorage to Barrow required about 12 days each way. The offshore drilling operation was impacted by several weather conditions that included significant winds, seas to six feet or more, and extensive floating ice and ice bergs.

An engineer with the Corps supervised the drilling. The supervising engineer and a geologist under contract to the Corps from R&M Consultants Inc. logged the test borings in accordance with ASTM D-2488, "Description and Identification of Soils (Visual - Manual Procedure)”. The borings were drilled by setting four-inch conductor pipe into the sea bottom to the depth of sampling and then drilling the soil out of the pipe with a tri-cone bit and wash rotary drill methods. Soil samples generally were procured at five feet below mud-line, and at five-foot intervals thereafter. Samples were acquired with a 2.5-inch inside diameter, split spoon sampler driven with a 340-pound hammer falling 30 inches operated with an automatic hammer system. The sampler was driven 18 inches ahead of the conductor pipe drive-shoe. The number of blows required to drive each 6-inch increment is recorded on the exploration logs. The blow count is an indication of the relative density or consistency of the soil.

Photo 5. Drilling operation on the landing craft off Point Barrow.

The test boring locations were determined using the GPS unit on board the landing craft. The coordinates for each of the boring locations shown on the boring logs are in NAD 83, UTM (feet). The boring locations are shown on the enclosed Test Boring Location Map, Figure 5.

3. Laboratory Testing and Soils Classification

A laboratory testing program was established to classify and determine physical properties of the soils encountered. The testing program consisted of a total of 144 sieve analyses. The samples recovered from the borings along the beach and the offshore samples were all tested and the samples from the BIA Prospect and Cooper Island that consisted of granular soil were generally selected for testing. Samples from the BIA Prospect and Cooper Island that were obviously silt/clay by visual classification were not selected for testing. The tests were performed in accordance with the latest edition of the following methods.

- ASTM D 422, "Standard Test Method for Particle Size Analysis of Soils".
- ASTM D 2487, "Standard Practice for Classification of Soils for Engineering Purposes (Uniform Soil Classification System)".

The soil descriptions and classifications contained in this report and presented on the final exploration logs are the project engineer's interpretation of the field logs and results of the laboratory testing program. The stratification lines represent approximate boundaries between soil types; the transitions are often gradual or not discernible by drill action. The exploration logs and the laboratory test results that apply to those logs are enclosed as Appendix A (Beach Borings), Appendix B (Cooper Island), Appendix C (BIA Prospect) and Appendix D (Submerged Spit).

4. Regional Geology

General: The arctic coastal plain of Alaska is a broad, roughly triangular area bordered by the arctic foothills on the south and the Arctic Ocean on the north, and extending from Cape Beaufort on the west to the international boundary on the east. It is more than 400 miles long with a maximum width of 85 miles, and encompasses roughly 25,000 square miles. It is characterized by low topographic relief, thousands of lakes and swamps, and numerous meandering streams. For the most part, the plain is underlain by Cretaceous strata capped unconformably by a thin mantle of dominantly marine Quaternary sediments, called the Gubik formation. The surface continues beneath the ocean, and forms the shallow continental shelf, which is terminated offshore by the rim of the deeper basin of the Arctic Ocean.

Photo 6. Example of a high ice content sample from the BIA Prospect.

It is estimated that 50-75 percent of the coastal plain near Barrow is covered by lakes or marshes that occupy low areas of former lake basins. The basins are elongated and their long axes are parallel and oriented a few degrees west of north.

Plant assemblages range in composition from place to place according to the type, texture, and drainage of the land on which they grow. They are generally characterized by a mat that includes lichens, mosses, grasses, sedges, and shrubs. Near Barrow, all shrubs are dwarf and prostrate, but further south willows and alders may grow several feet high along rivers and streams. Factors affecting plant distribution include temperature, moisture, soil texture, fertility, site stability, snow depth, and wind exposure.

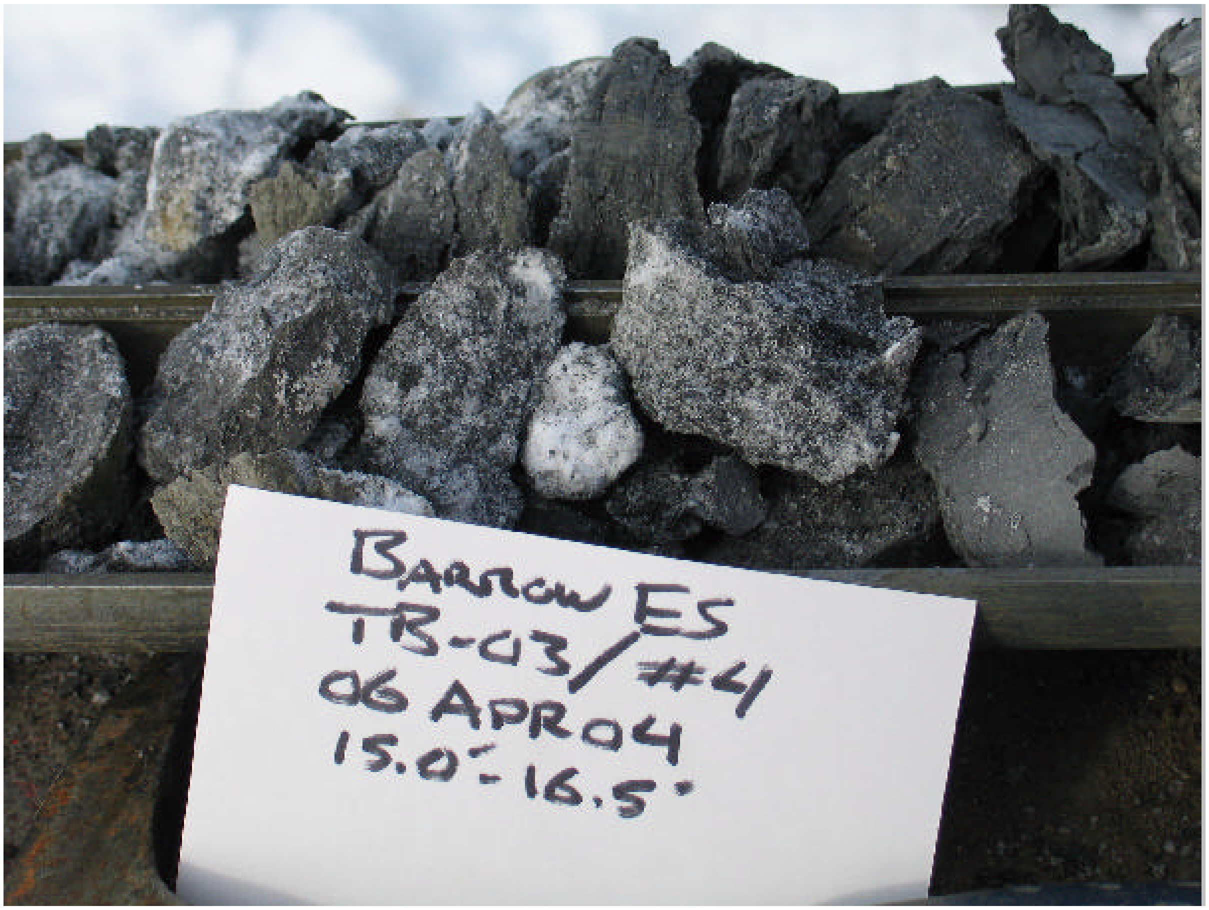


Photo 7. Example of the silt with high ice content encountered at the BIA Prospect.

5. Site Conditions

Surface:

At the time of the land-based exploration all areas were snow and ice covered although in some areas the ground surface was exposed by the wind. At Cooper Island the area is relatively flat and rises about eight to 10 feet above sea level. It appears that little or no vegetation exists on the island although driftwood and other scattered debris were observed protruding from the snow. The borings at Cooper Island were all drilled in areas where the snow could be removed and sand or gravel exposed.

The beach area adjacent to Barrow was covered with heavy snow and broken ice. Ice ridges to five feet in the work area and ridges to 40 feet or more could be seen a short distance offshore. The borings along the beach were all drilled through the sea ice.

The BIA Prospect area is gently rolling tundra with scattered lakes. The BIA Prospect area was wind blown and heavily drifted with snow to three feet.

During the offshore portion of the exploration the temperatures were generally in the 30's to low 40's and the wind was blowing constantly at 15 to 35 miles per hour. The wave action is a product of the ocean currents merging between the Beauford Sea and the Chukchi Sea and the wind. In general, the waves in the submerged spit area were seldom less than five feet in height. Although the tides are generally less than one foot in amplitude, the currents in the submerged spit area are on the order of at least three miles per hour. At times icebergs were numerous in the area and a hazard to the landing craft.

Photo 8. Typical "gravel" deposit in sidewall of existing borrow area.

Subsurface:

Beach Area—The four borings along the beach were drilled at increasing distances from the beach as they progress from east to west. These borings were given the designations BE-01 to BE-04. The soils encountered in the borings nearest the beach consisted of clean sand and as the distance from the surf-zone increased the soils contained more silt. Samples contained up to 30 percent gravel, but in general the soils have only about 10 percent gravel sized

Photo 9. Typical Poorly Graded Sand with Gravel (SP) encountered on the BIA Prospect.

material. The soil classifications ranged from clean sands (SP and SW) to silty sand (SM) and silt with sand (ML). The grain size analyses performed on the samples from the four borings along the beach consist predominately of fine sands. Boring BE-03 encountered sediments with a strong sewer odor assumed to be a result of sewage discharge from the nearby sewer lagoon.

<u>Cooper Island</u>—Ten borings were drilled on Cooper Island and the extension of Cooper Island to the east. The borings stretch over a distance of about four miles. These borings indicate that the island consists of a relatively clean sand layer above the silt and clay that compose the shallow sea floor. In general the sands extend only a few feet below sea level. The sands contain up to 40 percent gravel near the surface and the gravel content decreases with depth. Also, the silt content is near zero at the surface and increases with depth. In general, the sands contain 10-20 percent gravel and about five percent silt. The thickness of the sand layer varies with the topography of the island, but the average thickness of the sand layer encountered in the ten borings was 11 feet.

Photo 10. Typical sand encountered during the drilling operation.

BIA Prospect—The purpose of the exploration in the BIA Prospect area was to determine if the deposit currently used as the gravel borrow pit for projects in Barrow extends to the south. The general conclusion from this exploration is that the existing pit may be expanded but that expansion is limited by the gravel available. The entire area is underlain with permafrost. In general, the near surface soils at the site consist of frozen silts (ML) and silty sand (SM). These silty soils generally contain some organics and in some areas the ice content exceeds the percentage of soil. In general this surface layer is from 10 to 20 feet thick. Below the surface layer the soils generally consist of sands. In some areas the sands have sufficient silt content to classify as silty sand (SM). In other areas the sands are relatively clean and contain variable amounts of gravel that are generally less than ¾-inch in diameter. The most extensive deposit of relatively clean sand with gravel was encountered within the area defined by test borings BIA-16, BIA-30, BIA-31 and BIA-21. The soils below the sand generally consist of frozen silt (ML).

Submerged Spit—The soils recovered from the borings in the submerged spit area generally consist of silt (ML) or fine sand with 10 to 40 percent silt (SP-SM or SM). None of the samples recovered contained more than five percent gravel sized particles. The six borings drilled from Point Barrow north cover a substantial area but none of the borings encountered any material that appears to be appropriate for borrow.

6. Conclusions

Beach Area –The soils along the Barrow beach consist generally of fine sands with variable silt contents. Most of the soils encountered contain only minor percentages of gravel sized particles.

Cooper Island—The soils on Cooper Island consist of clean sands with variable percentages of gravel. The granular soils extend from the island surface to the approximate elevation of the surrounding ocean surface. In general, this average thickness is about 10 feet or less. The granular soils are exposed at the surface and no overburden removal will be required for extraction. It appears that there is more than two million cubic yards of granular material available on the island.

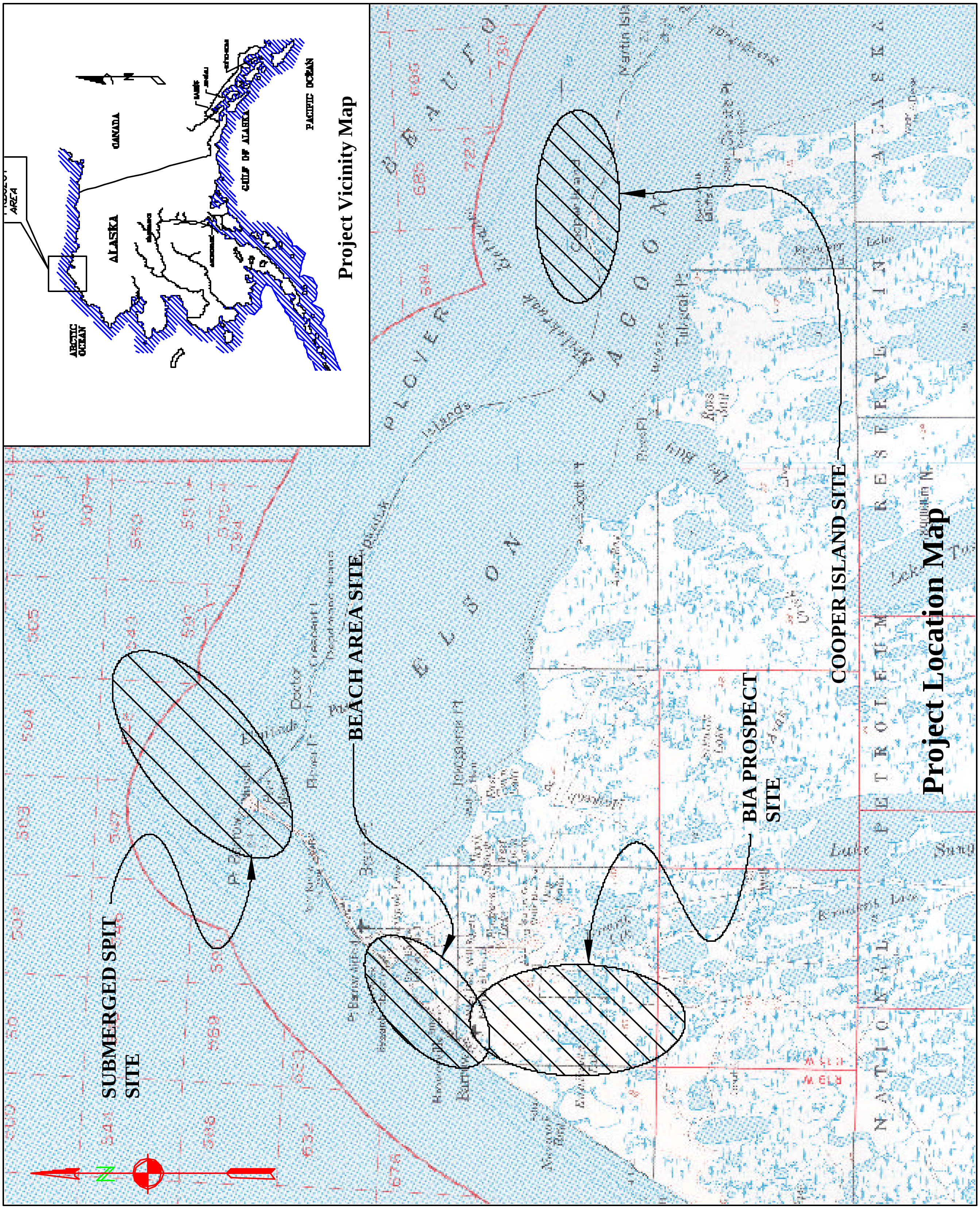
BIA Prospect—The BIA prospect has about two million cubic yards of granular soil that could be extracted and used for this project. The granular soils generally consist of sands with variable percentages of gravel and on the order of ten percent silt. The granular soils are covered with a mantle of frozen silt, organics and ice that generally is only slightly less in thickness than the granular deposit. The extraction of the granular material will require removal of overburden in volumes approximately equal to the volume of extracted granular material.

Submerged Spit—The exploration in the offshore area north of Point Barrow did not identify any significant volume of usable granular soils. The soils encountered generally consisted of fine silty sands or sandy silts. These materials are deemed unsuitable for use as material for beach nourishment.

Enclosures:

1. Figure 1 - Project Location and Vicinity Map
2. Figure 2 - Test Boring Location Map – Beach Area Site
3. Figure 3 - Test Boring Location Map - Cooper Island Site
4. Figure 4 – Test Boring Location Map – BIA Prospect Site
5. Figure 5 – Test Boring Location Map – Submerged Spit Site
6. Appendix A - Test Boring Logs and Laboratory Data – Beach Area
7. Appendix B – Test Boring Logs and Laboratory Data – Cooper Island
8. Appendix C – Test Boring Logs and Laboratory Data – BIA Prospect
9. Appendix D – Test Boring Logs and Laboratory Data – Submerged Spit

CORPS OF ENGINEERS U.S. ARMY



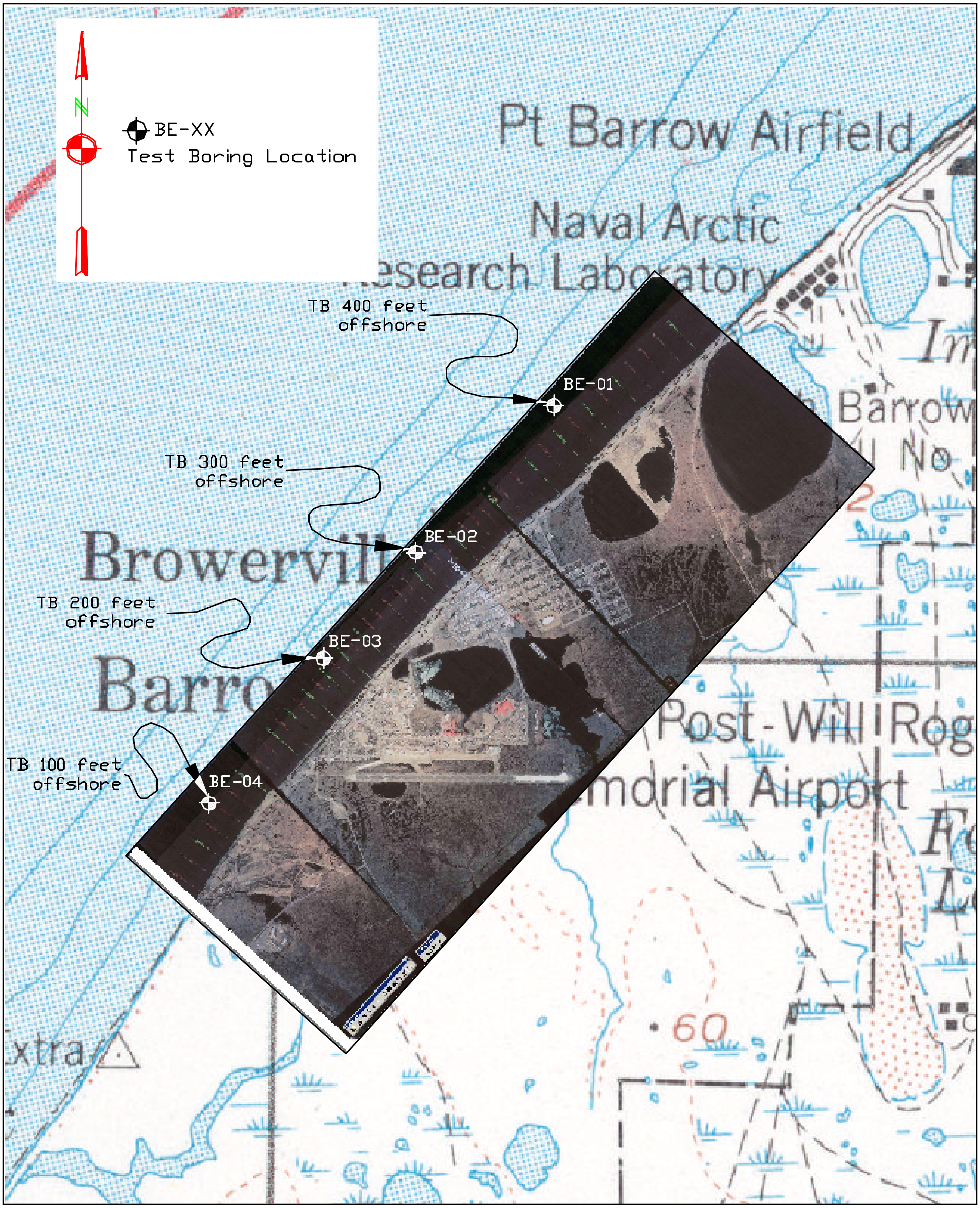
ALASKA DISTRICT
CORPS OF ENGINEERS
SOILS AND GEOLOGY

PROJECT LOCATION AND VICINITY MAP
Barrow SDR (CWIS 013656)
BARROW, ALASKA

SCALE:	NTS
DATE:	FEBRUARY 2005
DRAWN/RVW:	RTW/CRW

FIGURE 1

CORPS OF ENGINEERS U.S. ARMY



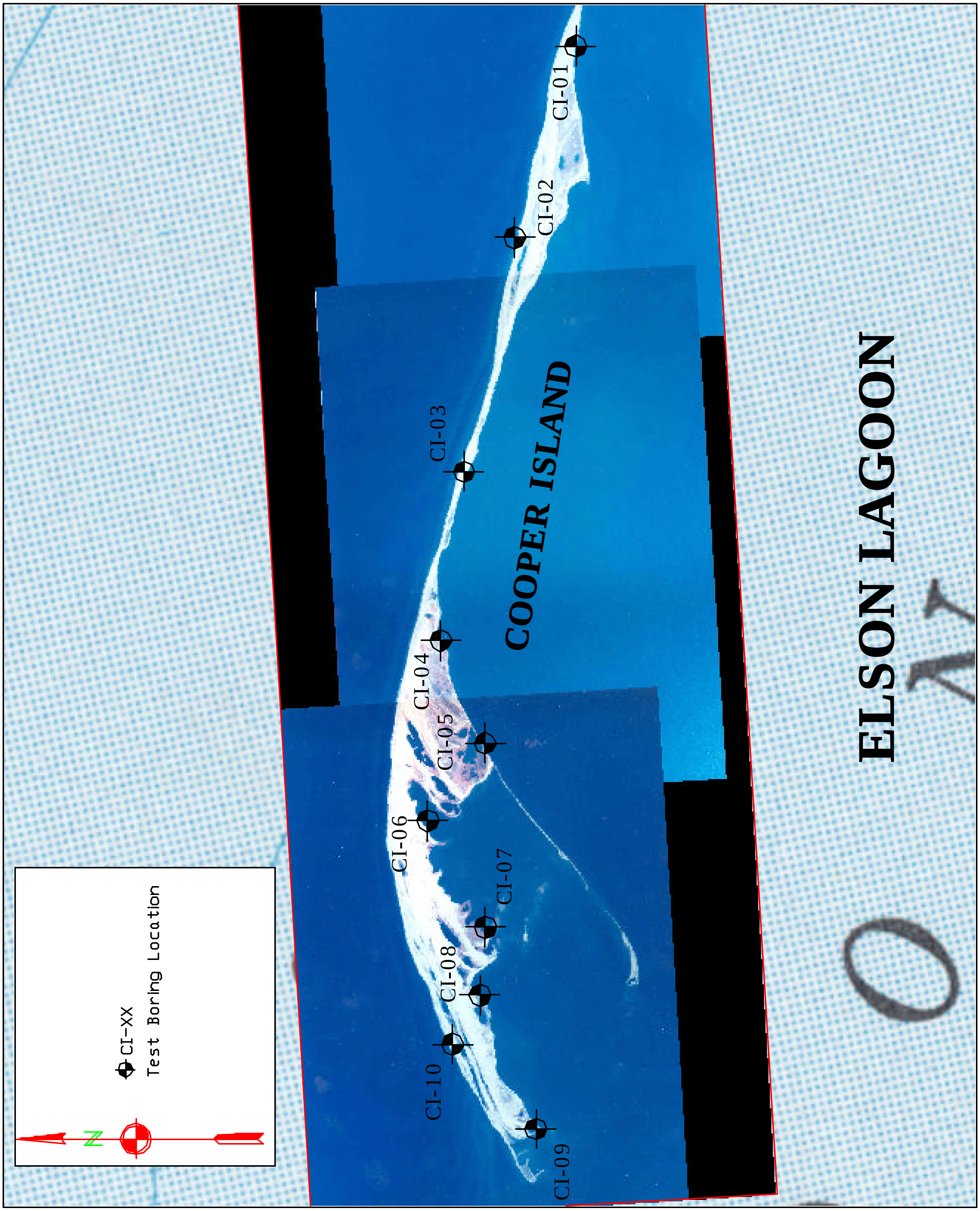
ALASKA DISTRICT
CORPS OF ENGINEERS
SOILS AND GEOLOGY

TEST BORING LOCATION MAP
Barrow SDR (CWIS 013656)
Beach Area Site
BARROW, ALASKA

SCALE:	NTS
DATE:	FEBRUARY 2005
DRAWN/RVW:	RTW/CEA
FIGURE 2	

CORPS OF ENGINEERS

U.S. ARMY



ALASKA DISTRICT
CORPS OF ENGINEERS
SOILS AND GEOLOGY

TEST BORING LOCATION MAP
BARROW SDR (CWIS 01656)
COOPER ISLAND SITE
BARROW, ALASKA

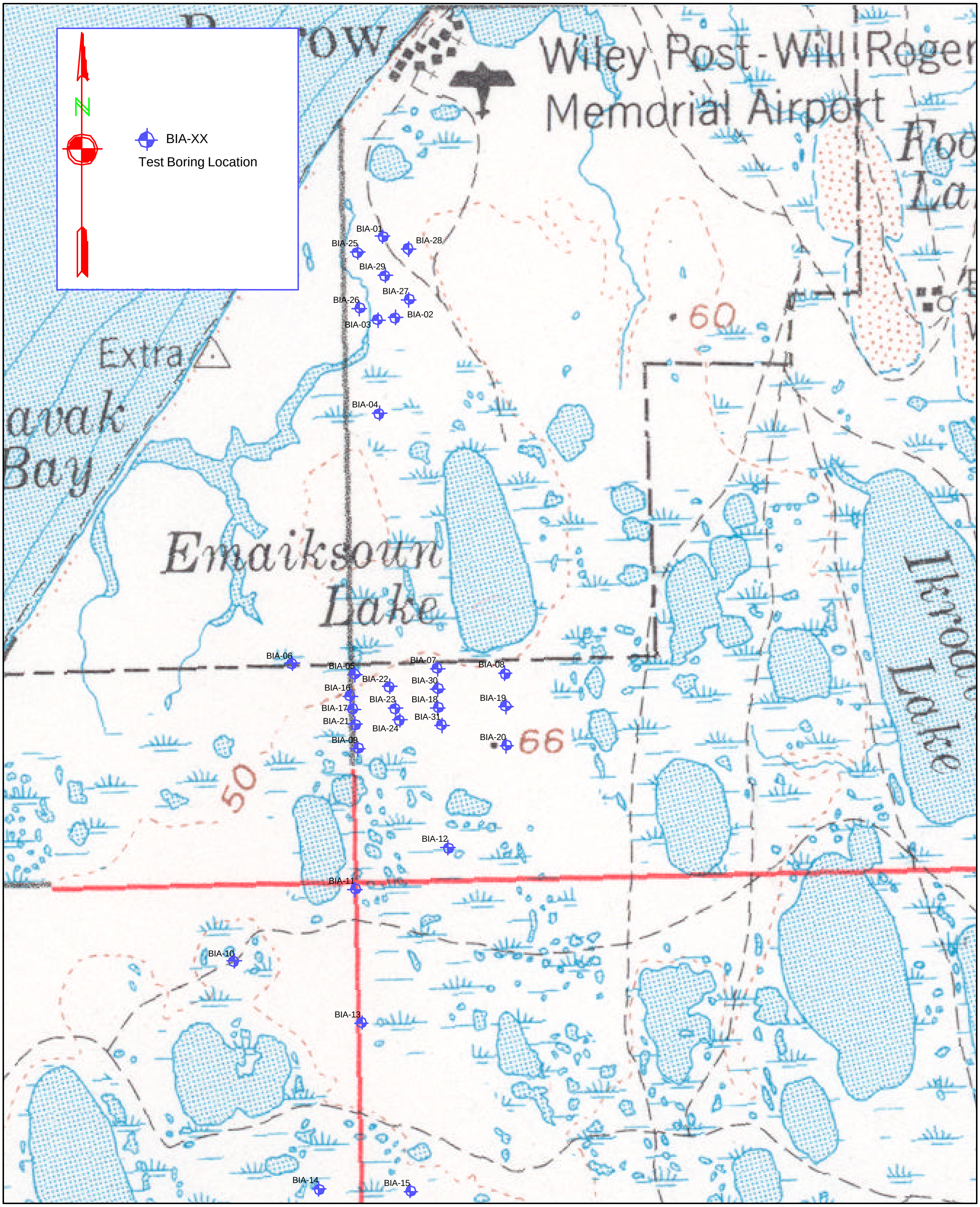
SCALE: NTS

DATE: February 2005

DRWN/RVW: KDM/CRW

FIGURE 3

CORPS OF ENGINEERS U.S. ARMY

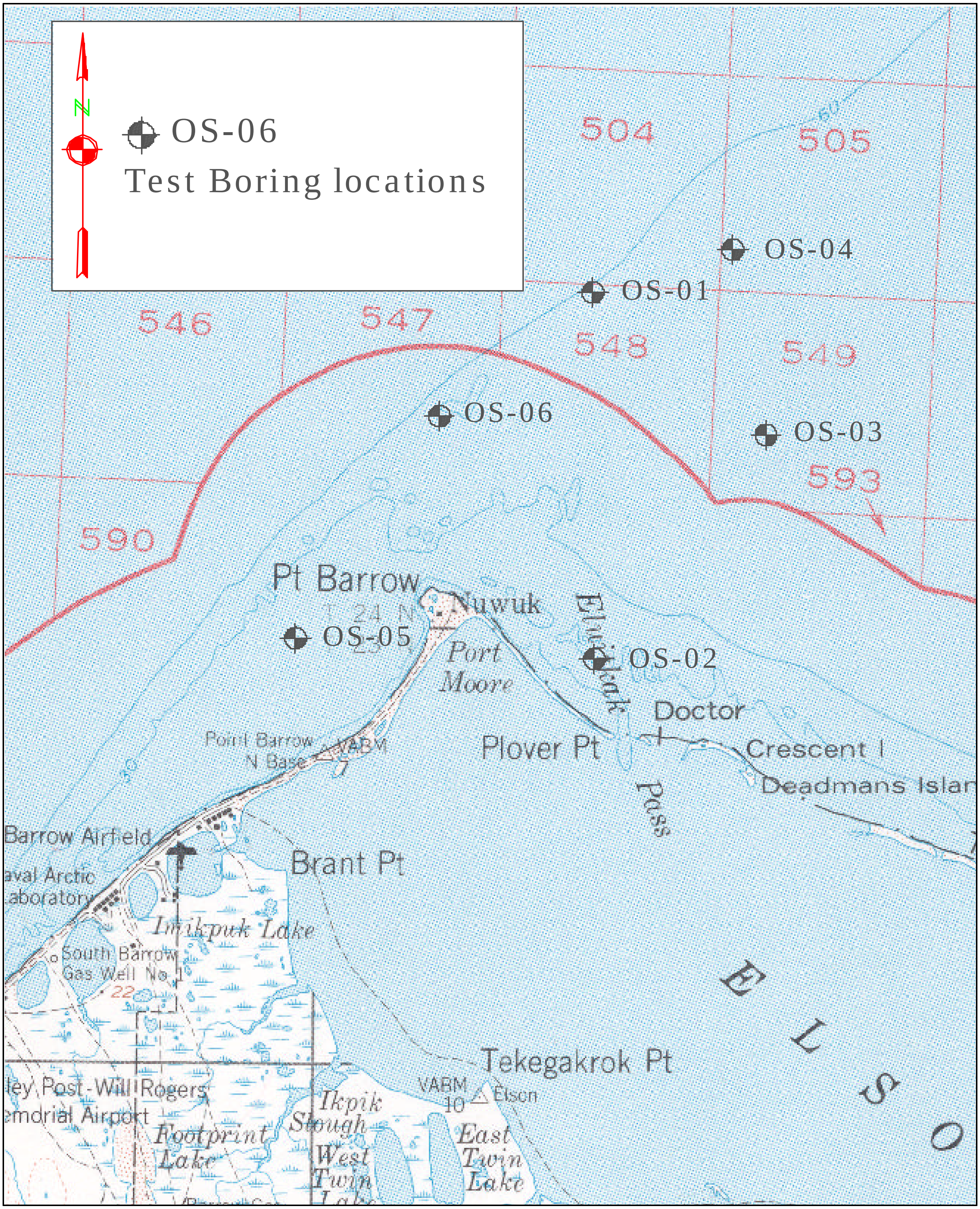


ALASKA DISTRICT
CORPS OF ENGINEERS
SOILS AND GEOLOGY

TEST BORING LOCATION MAP
Barrow SDR (CWIS 013656)
BIA PROSPECT SITE
BARROW, ALASKA

SCALE: NTS
DATE: February 2005
DRAWN/RVW: CEA/RTW
FIGURE 4

CORPS OF ENGINEERS U.S. ARMY



ALASKA DISTRICT
CORPS OF ENGINEERS
SOILS AND GEOLOGY

TEST BORING LOCATION MAP
Barrow SDR (CWIS 013656)
Submerged Spit Site
BARROW, ALASKA

SCALE: NTS
DATE: February 2005
DRAWN/RVW: RTW/GEA
FIGURE 5

Appendix A

Test Boring Logs and Laboratory Data
Beach Area

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **30 Mar 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,323,672 ft. ±** Easting: **638,870 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **BE-01** Permanent: **BE-01**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **9.5 ft. WD**

Depth Drilled: **25.0 ft.**

Total Depth: **25.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Clear, -30 degrees, 5 mph winds**
						Ice	Ice							Sea ice, seasonal
2														
4														
6														
8														
10														Water Mudline
12		1	Nbn	NFS	5 5 3	SP	Poorly graded SAND	0	97	3				Dark gray, frozen, fine to medium sand
14														
16		2		NFS	2 1 2	SP	Poorly graded SAND	6	90	4				Dark gray-black, moist, fine to coarse sand
18														
20		3		F2	14 32 38	SW	Well-graded SAND with Gravel	23	75	2				Dark gray, moist, subrounded to rounded gravel, fine to coarse sand, 5 feet of heave
22														
24														
26														Bottom of Hole 25.0 ft. Groundwater Encountered While Drilling: at an elevation of ft. PID = (Cold/Hot) Photo Ionization Detector
28														
30														
32														

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **BE-01**

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section

EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **30 Mar 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,327,698 ft. ±** Easting: **645,063 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **BE-02** Permanent: **BE-02**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **9.0 ft. WD**

Depth Drilled: **24.0 ft.**

Total Depth: **24.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, -5 degrees, 20 mph winds
2														
4														
						ICE	ICE with Sand/Fines Inclusions							Sea ice, seasonal
6														
8														
													▼	Water
10														
12														
14														
16														Mudline
		1		NFS	7 15 37	SP	Poorly graded SAND	2	94	4				Dark gray, wet, fine to medium sand High blow count due to heave in auger
18														
20														
22														
		2				NR	No Recovery							
24														Bottom of Hole 24.0 ft. Groundwater Encountered While Drilling: at an elevation of ft. PID = (Cold/Hot) Photo Ionization Detector
26														
28														
30														
32														

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **BE-02**

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **31 Mar 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,324,365 ft. ±** Easting: **642,258 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **BE-03** Permanent: **BE-03**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **5.0 ft. WD**

Depth Drilled: **24.0 ft.**

Total Depth: **25.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, -10 degrees, 10 mph winds**
2 4						**Ice**	**Ice**							**Ice**
6 8 10 12 14 16														**Water**
18		1		**F3**	**2 2 4**	**SM**	**Silty SAND with Gravel**	**30**	**45**	**25**	**0.25**			**Dark gray, wet, subrounded to subangular gravel, fine to coarse sand, NP fines, strong sewer odor**
20 22		2		**F3**	**3 3 3**	**SM**	**Silty SAND**	**9**	**58**	**33**	**0.5**			**Dark gray, wet, subrounded to rounded gravel, fine to coarse sand, NP fines**
24		3		**NFS**	**2 3 3**	**SP**	**Poorly graded SAND**	**12**	**87**	**1**				**Dark gray, black, wet, fine to coarse sand**
26 28 30 32														**Bottom of Hole 25.5 ft.** **Groundwater Encountered While Drilling: at an elevation of ft.** **PID = (Cold/Hot) Photo Ionization Detector**

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **BE-03**

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **1 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,320,008 ft. ±** Easting: **638,941 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **BE-04** Permanent: **BE-04**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **6.0 ft. WD**

Depth Drilled: **22.0 ft.**

Total Depth: **23.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

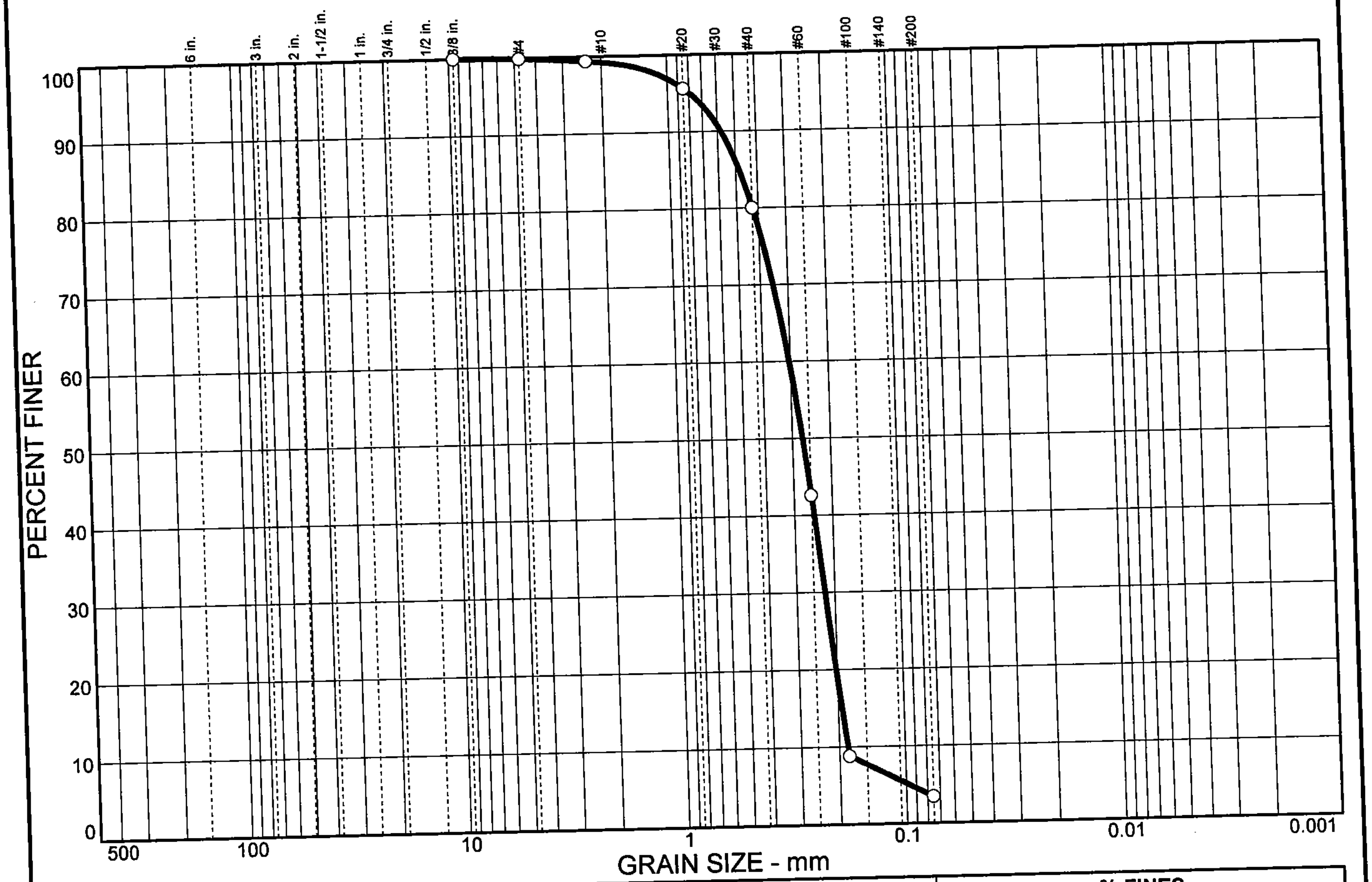
Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size			Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, -20 degrees
								%Gravel	%Sand	%Fines				
						Ice	Ice							Ice
6														Water
12		1	Nbn	F4	2 7 6	ML	SILT with Sand	0	29	71				Brown, frozen, fine sand, nonplastic (NP) to low plasicity fines, trace organic
18		2		F3	1 2 9	SM	Silty SAND	0	59	41				Brown, wet, fine sand, NP fines
22		3		F3	5 7 10	SM	Silty SAND	0	58	42				Brown, wet, fine sand, NP fines
24														Bottom of Hole 23.5 ft. Groundwater Encountered While Drilling: at an elevation of ft. PID = (Cold/Hot) Photo Ionization Detector

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.1	0.7	19.2	76.6	3.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
#4	99.9		
# 8	99.4		
# 20	95.6		
# 40	80.0		
# 60	42.6		
# 80	8.8		
# 200	3.4		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 0.484
D_{60}= 0.304
D_{50}= 0.270
D_{30}= 0.222
D_{15}= 0.193
D_{10}= 0.183
C_u= 1.66
C_c= 0.89

Classification

USCS= SP
AASHTO= A-3

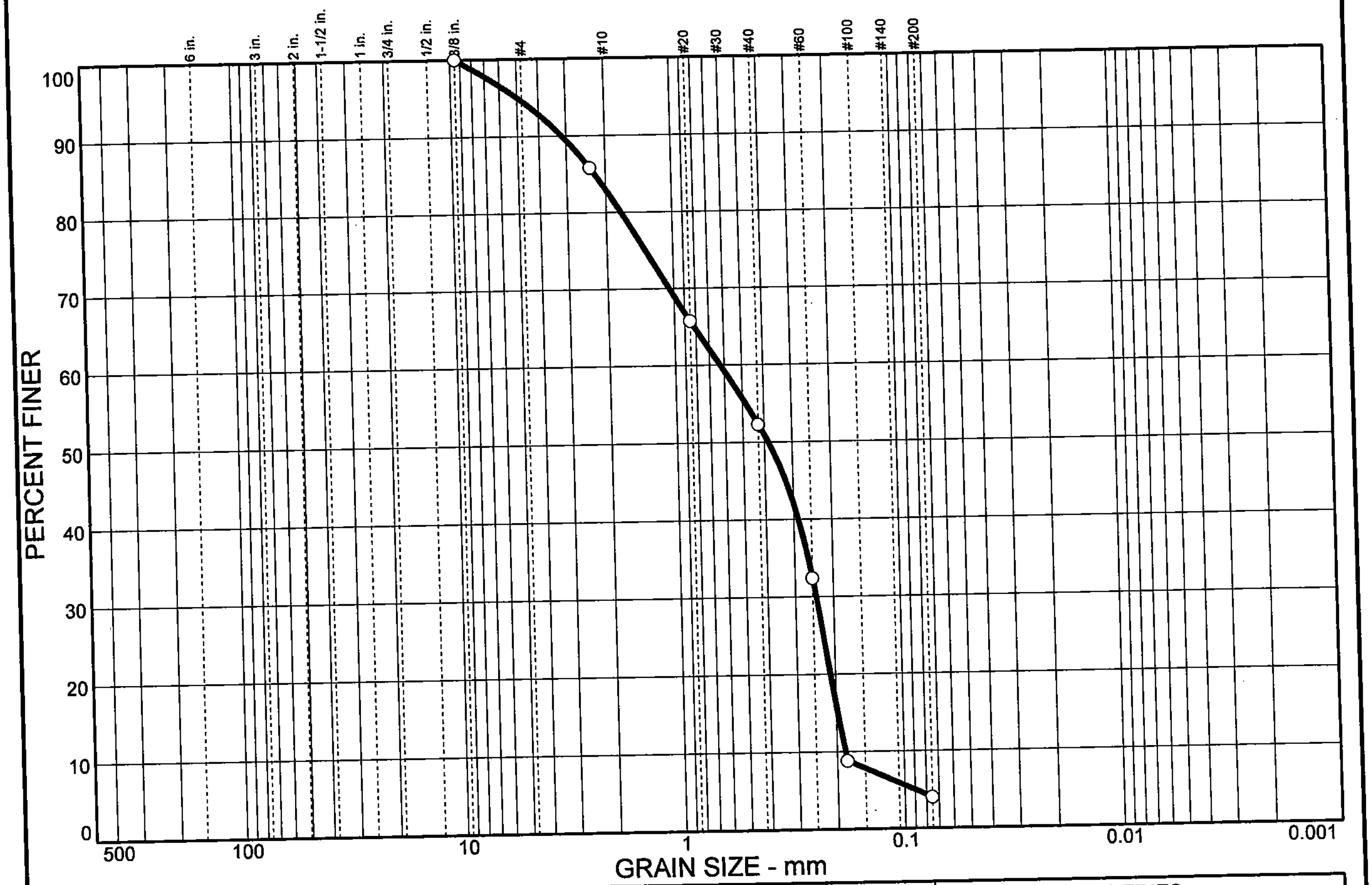
Remarks

Sample No.: 6006
Location: BE-01 #1
Source of Sample: Client Samples
Date:
Elev./Depth: 12 FT 3.6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	5.5	11.6	30.6	48.3	4.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 8	85.8		
# 20	65.7		
# 40	52.3		
# 60	32.4		
# 80	8.8		
# 200	4.0		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 2.25
D_{60}= 0.628
D_{50}= 0.384
D_{30}= 0.241
D_{15}= 0.197
D_{10}= 0.184
C_u= 3.42
C_c= 0.51

Classification

USCS= SP
AASHTO= A-3

Remarks

Sample No.: 6007
Location: BE-01 # 2

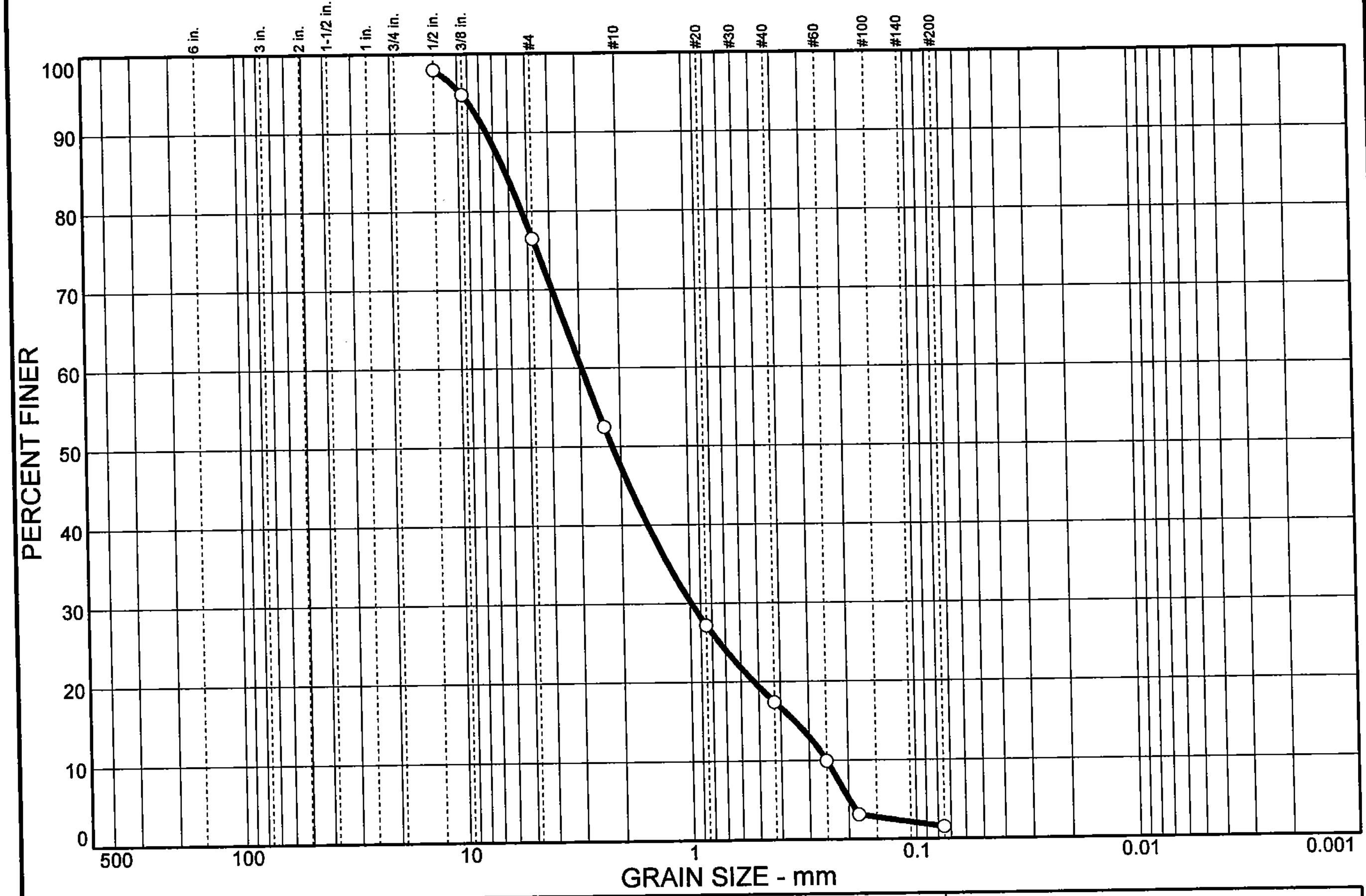
Source of Sample: Client Samples

Date:
Elev./Depth: 15 FT 4.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
			29.1	30.0	15.9	1.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	98.0		
3/8 in.	94.8		
# 4	76.5		
# 8	52.5		
# 20	27.2		
# 40	17.4		
# 60	9.9		
# 80	3.1		
# 200	1.5		

* (no specification provided)

Soil Description

Well-graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 6.21 D_{60}= 2.95 D_{50}= 2.18

D_{30}= 0.987 D_{15}= 0.347 D_{10}= 0.251

C_u= 11.75 C_c= 1.31

Classification

USCS= SW AASHTO= A-1-a

Remarks

Sample No.: 6008

Location: BE-01 #3

Source of Sample: Client Samples

Date:

Elev./Depth: 20 FT 6 m

Mappa TestLab

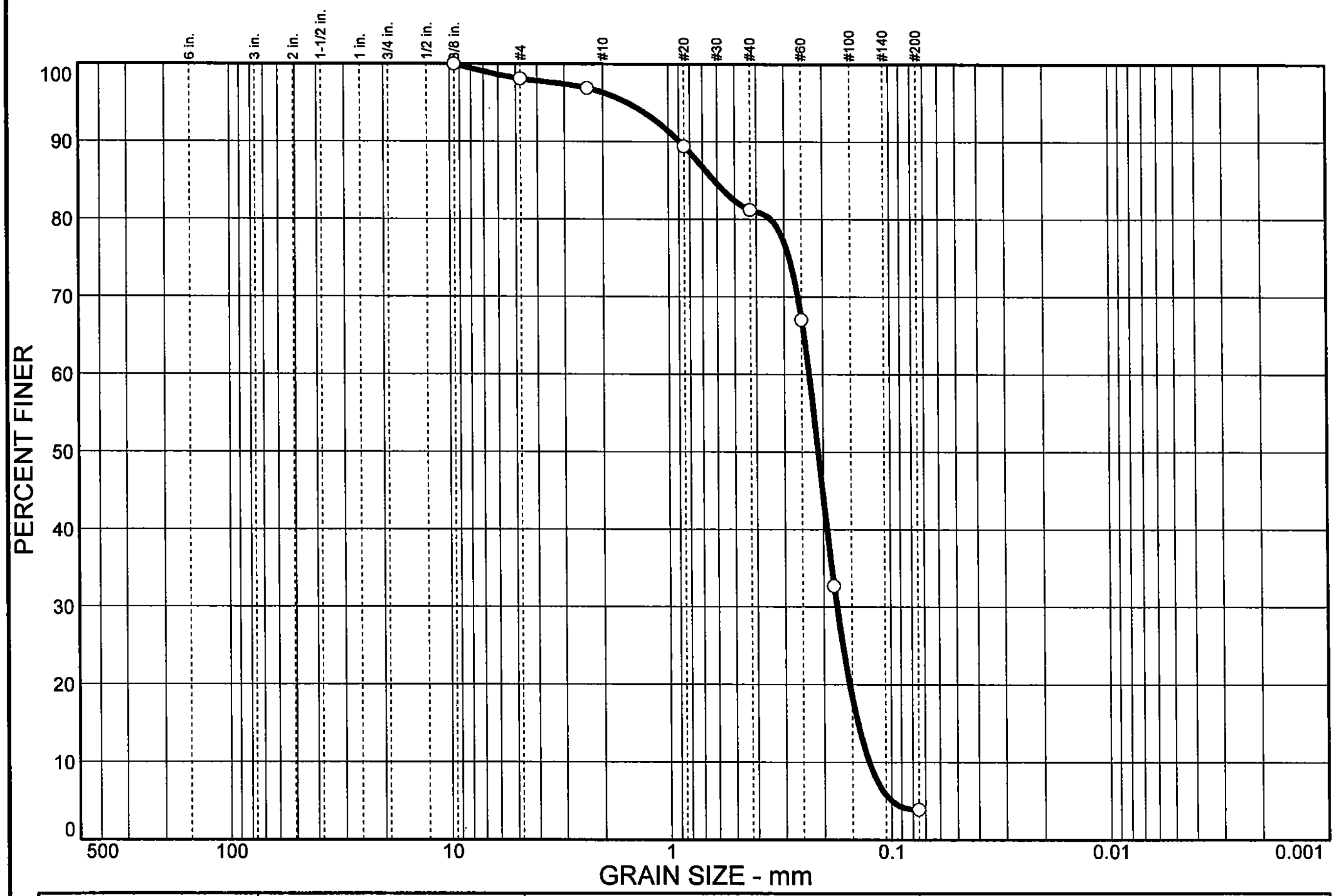
Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148

Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	1.9	1.7	15.2	77.3	3.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	98.1		
# 8	96.9		
# 20	89.4		
# 40	81.2		
# 60	67.0		
# 80	32.7		
# 200	3.9		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL=	LL=	PI=

Coefficients

D_{85}= 0.621	D_{60}= 0.232	D_{50}= 0.211
D_{30}= 0.175	D_{15}= 0.141	D_{10}= 0.126
C_u= 1.84	C_c= 1.05	

Classification

USCS= SP AASHTO= A-3

Remarks

Sample No.: 6009 **Source of Sample:** Client Samples **Date:**

Location: BE-02 # 1 **Elev./Depth:** 18 FT 5.4 m

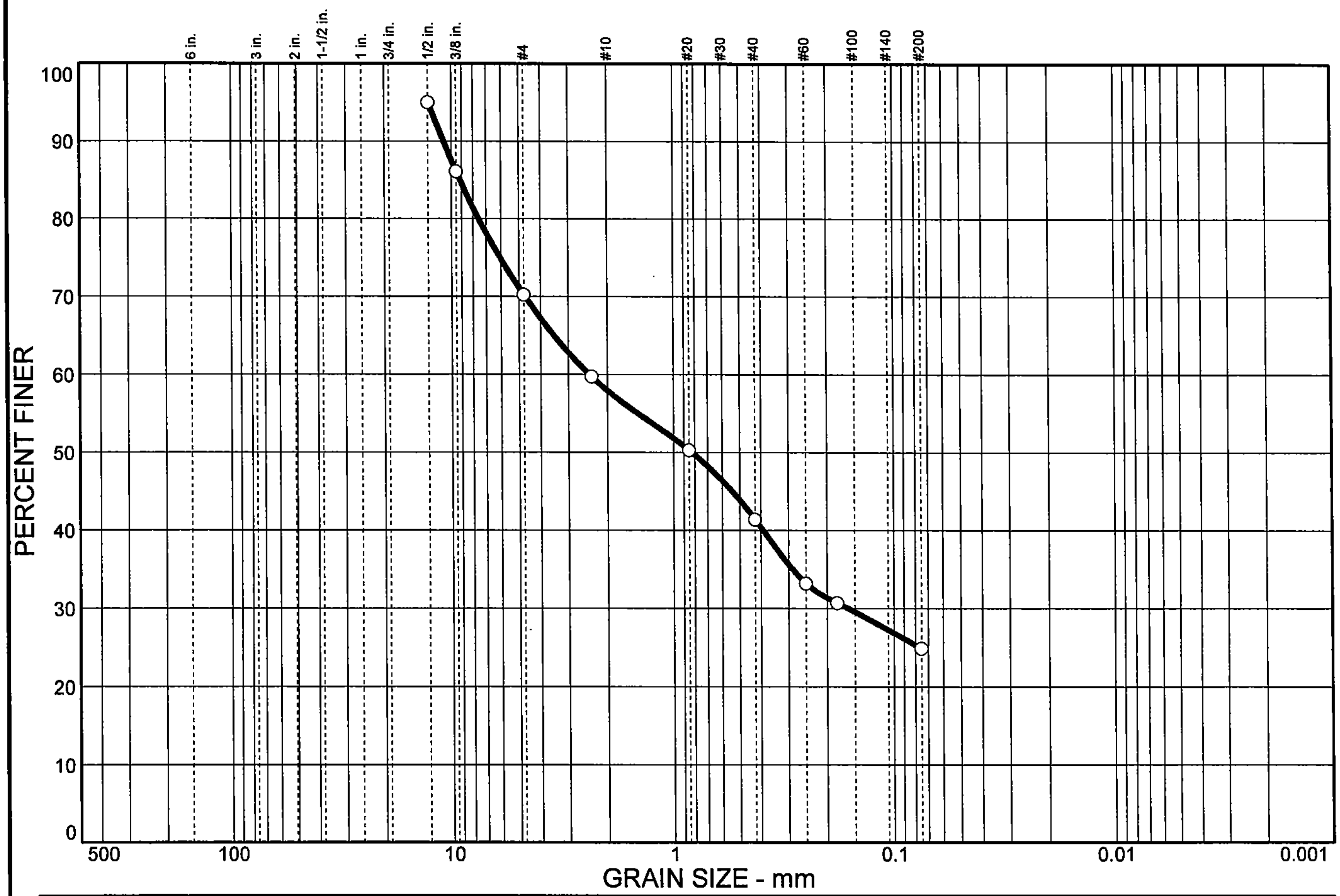
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
			12.3	16.5	16.5	24.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	95.0		
3/8 in.	86.1		
# 4	70.2		
# 8	59.7		
# 20	50.3		
# 40	41.4		
# 60	33.2		
# 80	30.7		
# 200	24.9		

* (no specification provided)

Soil Description

Silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 9.16 D_{60}= 2.42 D_{50}= 0.825

D_{30}= 0.161 D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-1-b

Remarks

Sample No.: 6010 **Source of Sample:** Client Samples **Date:**

Location: BE-03 #1 **Elev./Depth:** 17 FT 5.1 m

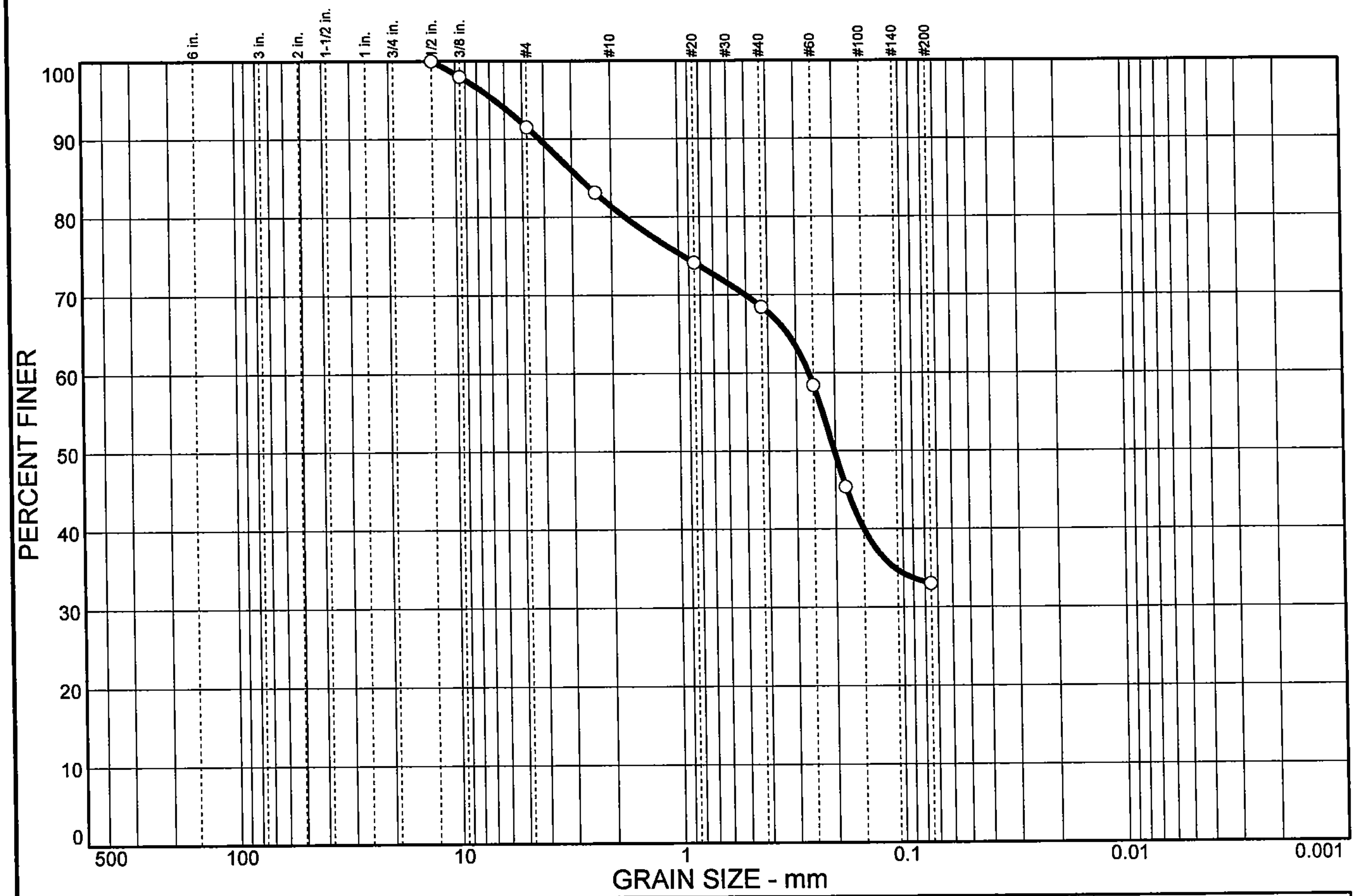
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	8.5	10.2	12.9	35.4	33.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	98.0		
# 4	91.5		
# 8	83.1		
# 20	74.1		
# 40	68.4		
# 60	58.4		
# 80	45.4		
# 200	33.0		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 2.78 D_{60}= 0.263 D_{50}= 0.202
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

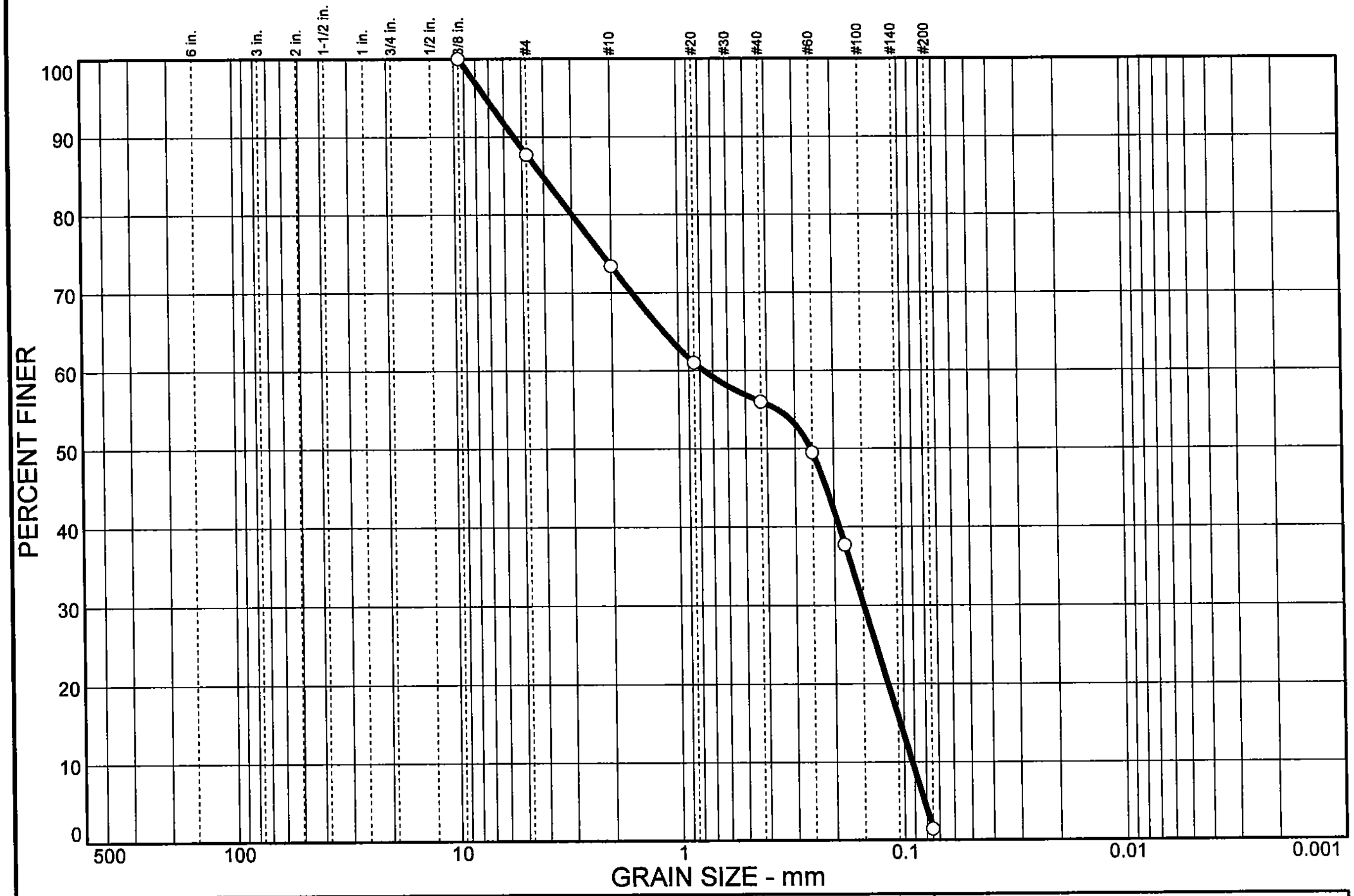
Remarks

Sample No.: 6011 **Source of Sample:** Client Samples **Date:**
Location: BE-03 #2 **Elev./Depth:** 19 FT 5.7 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	12.3	14.3	17.4	54.6	1.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	87.7		
# 10	73.4		
# 20	61.0		
# 40	56.0		
# 60	49.5		
# 80	37.7		
# 200	1.4		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 4.05 D_{60}= 0.769 D_{50}= 0.255
D_{30}= 0.149 D_{15}= 0.104 D_{10}= 0.0921
C_u= 8.34 C_c= 0.31

Classification

USCS= SP AASHTO= A-3

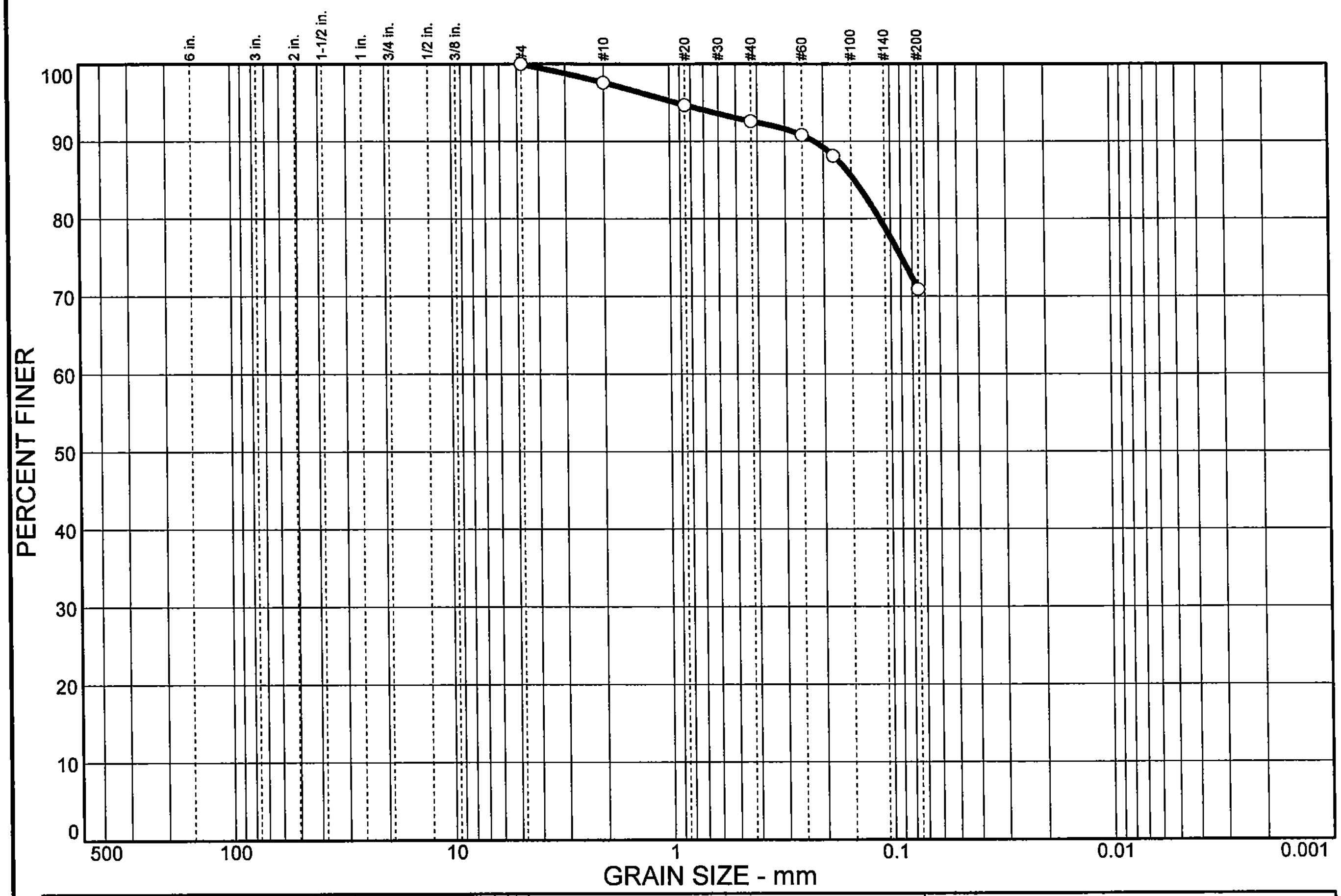
Remarks

Sample No.: 6012 **Source of Sample:** Client Samples **Date:**
Location: BE-03 #3 **Elev./Depth:** 24 FT 7.2 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	2.4	5.0	21.7	70.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
# 4	100.0		
# 10	97.6		
# 20	94.7		
# 40	92.6		
# 60	90.8		
# 80	88.1		
# 200	70.9		

* (no specification provided)

Soil Description

Silt with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.145 D_{60}= D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

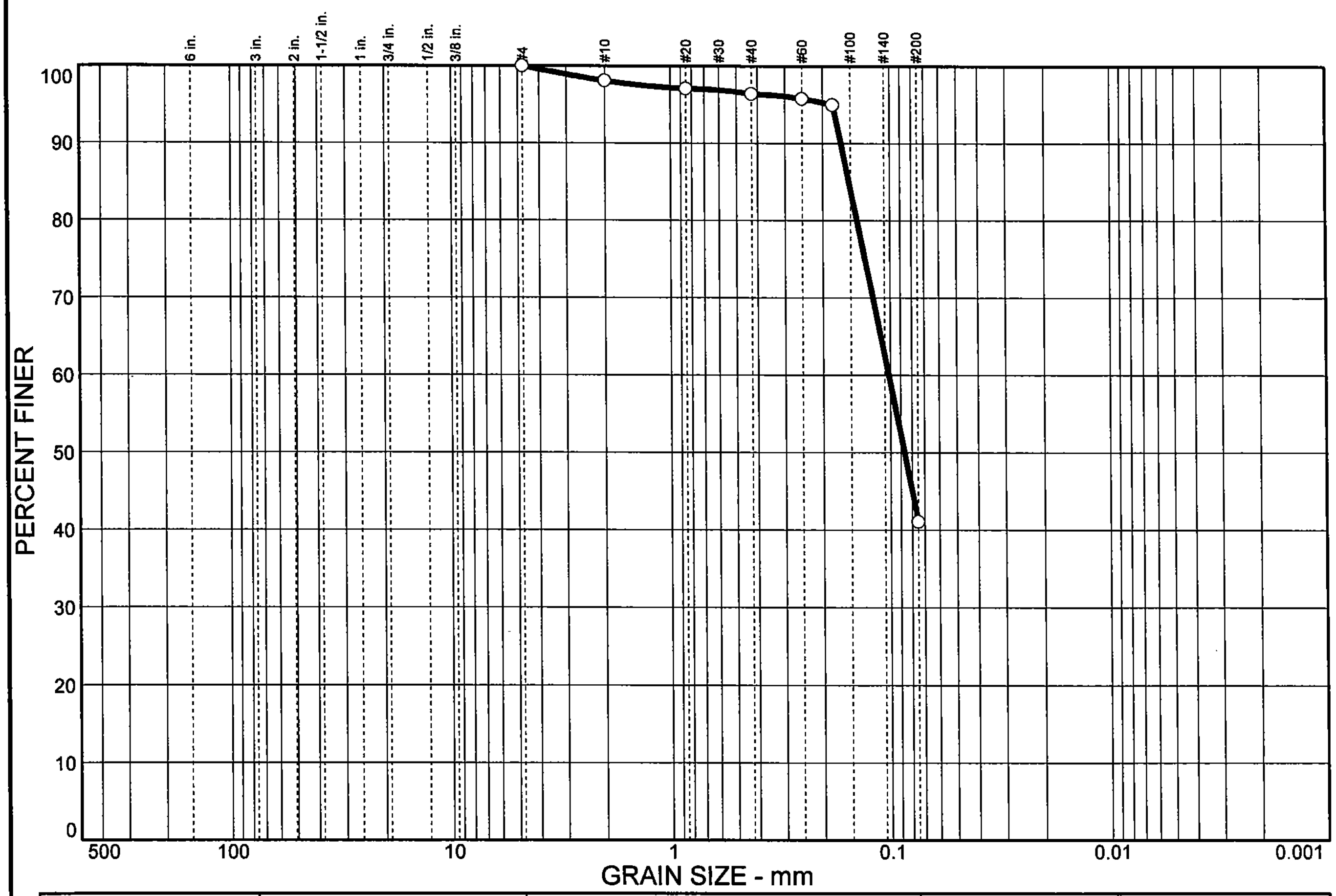
Remarks

Sample No.: 6013 **Source of Sample:** Client Samples **Date:**
Location: BE-04 #1 **Elev./Depth:** 12 FT 3.6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	1.9	1.7	55.3	41.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
# 4	100.0		
# 10	98.1		
# 20	97.1		
# 40	96.4		
# 60	95.8		
# 80	95.0		
# 200	41.1		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.153 D_{60}= 0.102 D_{50}= 0.0866

D_{30}= D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample No.: 6014 **Source of Sample:** Client Samples **Date:**

Location: BE-04 #2 **Elev./Depth:** 17 FT 5.1 m

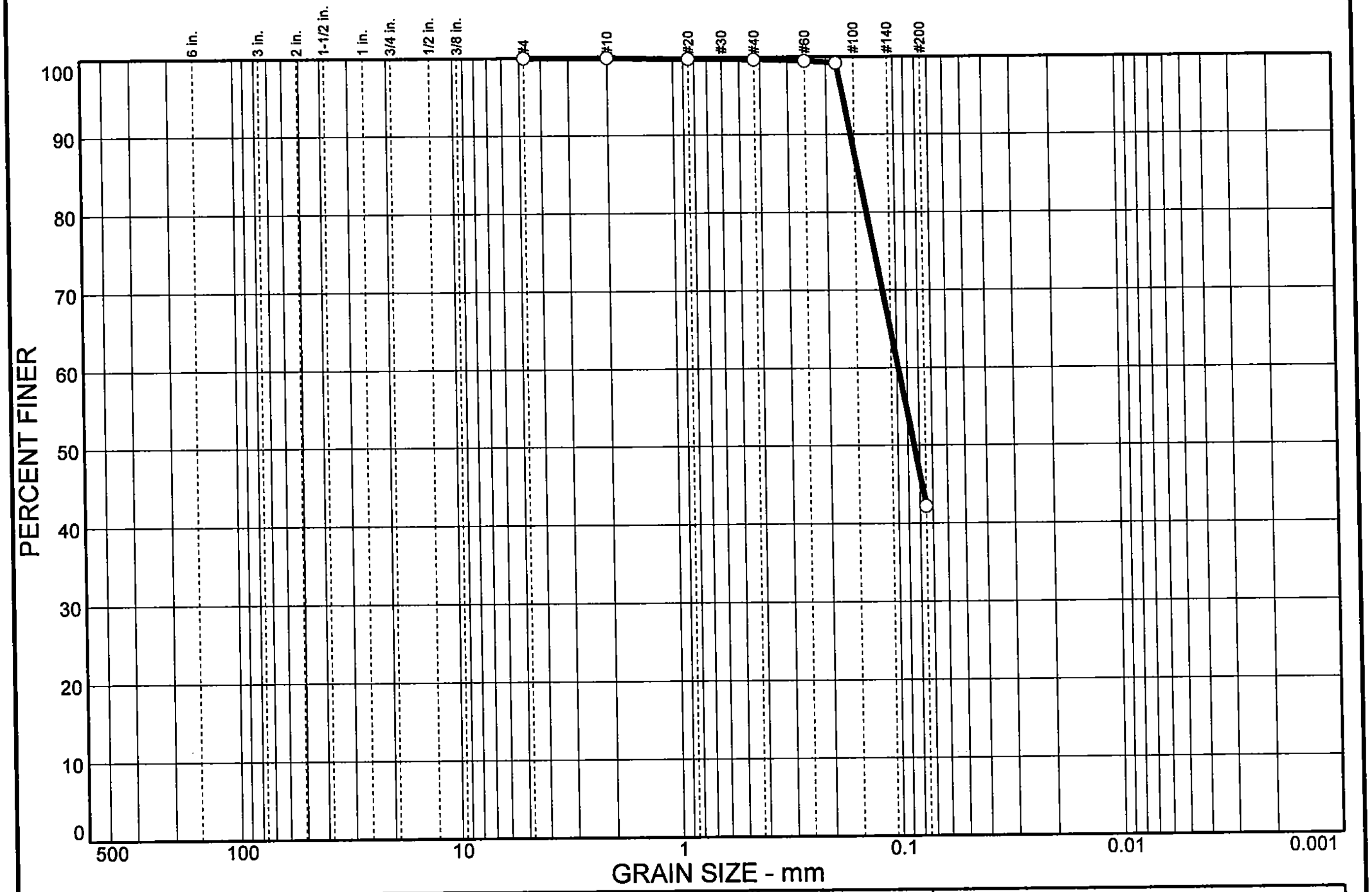
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.0	0.3	57.5	42.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
# 4	100.0		
# 10	100.0		
# 20	99.8		
# 40	99.7		
# 60	99.5		
# 80	99.2		
# 200	42.2		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.145 D_{60}= 0.0985 D_{50}= 0.0845
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample No.: 6015 **Source of Sample:** Client Samples **Date:**
Location: BE-04 #3 **Elev./Depth:** 22 FT 6.6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Appendix B

Test Boring Logs and Laboratory Data
Cooper Island

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 2

Date: **4 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,303,576 ft. ±**
Easting: **786,907 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-01**
Permanent: **CI-01**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **39.0 ft.**

Total Depth: **40.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, -15 degrees
		1		NFS	Grab	SP	Poorly graded SAND with Gravel	27	73		0.75			Brown, frozen, dry, rounded gravel, fine to coarse sand
4		2	Nf	PFS	17 61/ 4in.	SP	Poorly graded SAND with Gravel	20	78	2	0.75			Brown, frozen, dry, rounded gravel, fine to coarse sand
10		3	Nbn	S2	7 33 34	SP	Poorly graded SAND		96	4				Brown and gray, frozen, moist, fine sand
14		4		F4	2 9 9	ML	SILT							Gray, moist, fine sand, nonplastic (NP) to low plasticity fines
20		5		F4	2 5 9	ML	SILT							Gray to black, moist, fine sand, NP to low plasticity fines
24		6		F4	2 5 7	ML	SILT							Black, wet, NP to low-plasticity fines
30		7	Vx	F4	4 6 7	ML	SILT							Black, frozen, NP to low plasticity fines, ice crystals to 1/8"

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-01**

ALASKA DISTRICT
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EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 2 of 2

Date: **4 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,303,576 ft. ±** Easting: **786,907 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-01** Permanent: **CI-01**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **39.0 ft.**

Total Depth: **40.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, -15 degrees
34		8	Vx	F4	4 10 14	ML	SILT							Gray, frozen, NP fines, ice crystals to 1/8"
36														
38														
40		9	Vx	F4	3 7 11	CL	Lean CLAY							Gray, frozen, low plasticity fines, ice crystals to 1/8"
42														Bottom of Hole 40.5 ft. PID = (Cold/Hot) Photo Ionization Detector
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-01**

ALASKA DISTRICT
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ENGINEERING SERVICES

Soils and Geology Section

EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 2

Date: **5 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,304,872 ft. ±** Easting: **782,948 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-02** Permanent: **CI-02**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **13.0 ft. WD**

Depth Drilled: **39.0 ft.**

Total Depth: **40.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Cloudy, -10 degrees
		1		NFS	Grab	GP	**Poorly graded GRAVEL with Sand**	60	40		0.5			**Brown, frozen, dry, rounded gravel, medium to coarse sand**
2														
4														
		2	Nf	S2	5 60	SP	**Poorly graded SAND**	15	80	5	0.25			**Brown, frozen, rounded gravel, fine to coarse sand**
6														
8														
		3	Nf	F2	26 65/ 3in.	SP-SM	**Poorly graded SAND with Silt**	1	92	7				**Brown, frozen, fine to medium sand**
10														
12														
14														
		4		F4	5 4 5	ML	**Sandy SILT**							**Gray to black, wet, fine sand, nonplastic (NP) fines, water table at 13 feet**
16														
18														
		5		F4	4 7 8	ML	**SILT**							**Gray to black, wet, low plasticity fines**
20														
22														
24														
		6		F4	2 5 7	ML	**SILT**							**Black, wet, low plasticity fines**
26														
28														
		7		F4	3 7 7	ML	**SILT**							**Black, wet, low plasticity fines**
30														
32														

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-02**

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Soils and Geology Section

EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 2 of 2

Date: **5 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,304,872 ft. ±**
Easting: **782,948 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-02**

Permanent: **CI-02**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **13.0 ft. WD**

Depth Drilled: **39.0 ft.**

Total Depth: **40.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Cloudy, -10 degrees**
34		8		**F4**	**3 5 6**	**ML**	**SILT**							**Black and gray mottled, wet, low plasticity fines**
36														
38														
		9		**F4**	**3 4 8**	**ML**	**SILT**							**Gray and black mottled, wet, low plasticity fines**
40														
														Bottom of Hole 40.5 ft. **Groundwater Encountered While Drilling: at an elevation of ft.** **PID = (Cold/Hot) Photo Ionization Detector**
42														
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-02**

ALASKA DISTRICT
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ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **6 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,306,004 ft. ±** Easting: **778,095 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-03** Permanent: **CI-03**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **8.0 ft. WD**

Depth Drilled: **34.0 ft.**

Total Depth: **35.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Cloudy, -5 degrees
		1	Nf	NFS	Grab	SP	Poorly graded SAND with Gravel	40	60		1			Brown, frozen, dry, rounded gravel, fine to coarse sand
		2	Nf	NFS	26 60/ 3in.	SP	Poorly graded SAND with Gravel	16	83	1	0.5			Brown, frozen, rounded gravel, fine to medium sand
														▼ Water table at 11'
		3a	Nbn	F3	6 14	SM	Silty SAND	9	75	16				Brown to gray, frozen, fine sand
		3b	Nbn	F4	21	ML	SILT							Gray and black mottled, frozen, nonplastic (NP) to low plasticity fines
		4		NFS	7 16 20	SP	Poorly graded SAND							Brown, wet, fine sand, pieces of shell and organics
		5a		NFS	2 2	SP	Poorly graded SAND							Brown, wet, fine sand
		5b		NFS	3	ML	SILT							Gray, wet, NP fines
		6		F4	1 2 3	CL-ML	Silty CLAY							Dark gray, wet, low plasticity fines
		7		F4	2 3 6	ML	Sandy SILT							Gray, wet, fine sand, low plasticity fines

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **6 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,306,004 ft. ±** Easting: **778,095 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-03**

Permanent: **CI-03**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**

☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **8.0 ft. WD**

Depth Drilled: **34.0 ft.**

Total Depth: **35.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Cloudy, -5 degrees
34	▥	8		F4	2 5 7	ML	SILT							Dark gray, wet, low plasticity fines
36														Bottom of Hole 35.5 ft. Groundwater Encountered While Drilling: at an elevation of ft. PID = (Cold/Hot) Photo Ionization Detector
38														
40														
42														
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-03**

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EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **8 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,306,595 ft. ±** Easting: **775,776 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-04** Permanent: **CI-04**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **40.0 ft.**

Total Depth: **41.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Cloudy, 0 degrees, Windy
2 4		1	Nf	NFS	Grab	SP	Poorly graded SAND with Gravel	23	77		1			Brown, frozen to dry, rounded gravel, fine to medium sand, color change to gray at 2.5' - water table in summer?
6 8		2	Nf	NFS	70	SP	Poorly graded SAND with Gravel	37	62	1	2.5			Gray, frozen to dry, rounded gravel, medium to coarse sand
10 12 14		3	Nbn	F2	20 61	SP-SM	Poorly graded SAND with Silt		93	7				Gray, frozen, fine sand, nonplastic (NP) to low plasticity fines
16 18		4	Vx	F4	6 8 9	ML	SILT							Gray and black, low placticity fines, ice crystals to 1/8"
20 22 24		5	Vx & Vr	F4	3 6 8	ML	SILT							Gray and black, low plasticity fines, ice crystals to 1/8"
26 28		6	Vx & Vr	F4	2 8 12	CL-ML	Silty CLAY							Black, frozen, low plasticity fines, ice crystals to 1/8"
30 32		7	Vx	F4	3 13 20	CL-ML	Silty CLAY							Black, frozen, low plasticity fines, ice crystals to 1/8"

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-04**

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EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **8 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,306,595 ft. ±** Easting: **775,776 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-04** Permanent: **CI-04**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **40.0 ft.**

Total Depth: **41.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Cloudy, 0 degrees, Windy**
34														
36		8	**Nbn**	**F4**	**2** **5** **22**	**ML**	**SILT**							**Dark gray, frozen, low plasticiy fines**
38														
40		9	**Nbn**	**F4**	**36** **45**	**ML**	**Sandy SILT**							**Gray, frozen, fine sand, low plasticity fines**
42														**Bottom of Hole 41.0 ft.** **PID = (Cold/Hot) Photo Ionization Detector**
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-04**

ALASKA DISTRICT
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EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **9 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,305,661 ft. ±** Easting: **772,439 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-05** Permanent: **CI-05**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **40.0 ft.**

Total Depth: **40.8 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, 0 degrees
		1	Nf	NFS	Grab	SP	Poorly graded SAND with Gravel	20	79	1	0.5			Brown, frozen/ dry, rounded gravel, fine to coarse sand
														Color change to gray
		2	Nbn	F2	27 60/ 3in.	SP-SM	Poorly graded SAND with Silt and Gravel	8	83	9	0.375			Gray, frozen, rounded gravel, fine to medium sand
		3	Vx	F4	8 19 20	ML	SILT							Dark gray and black, frozen, nonplastic fines, ice crystals to 1/8 inch
		4		F4	1 3 4	ML	SILT							Dark gray, wet, low plasticity fines
		5		F4	3 4 7	ML	SILT							Dark gray, wet, low plasticity fines
		6	Vx	F4	8 8 10	CL-ML	Silty CLAY							Black, frozen, low plasticity fines, ice crystals to 1/8 inch
		7	Vx	F4	7 11 12	CL-ML	Silty CLAY							Black, frozen, low plasticity fines, ice crystals to 1/8 inch

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-05**

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **9 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,305,661 ft. ±** Easting: **772,439 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-05** Permanent: **CI-05**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**

☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **40.0 ft.**

Total Depth: **40.8 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Clear, 0 degrees**
34	▨													
36	▨	8	Vx	F4	39 26 48	CL-ML	**Silty CLAY**							**Gray and black, frozen, low plasticity fines, ice crystals to 1/8 inch**
38	▨													
40	▨	9	Vx	F4	40 50/ 3in.	CL-ML	**Silty CLAY**							**Gray and black, frozen, low plasticity fines, ice crystals to 1/8 inch**
42														**Bottom of Hole 40.8 ft.** **PID = (Cold/Hot) Photo Ionization Detector**
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-05**

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Date: **10 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,306,882 ft. ±** Easting: **770,851 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-06** Permanent: **CI-06**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **40.0 ft.**

Total Depth: **40.4 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Cloudy, 0 degrees, windy**
		1	Nf	NFS	Grab	SP	Poorly graded SAND with Gravel	20	80		0.75			Brown, frozen/ dry, rounded gravel, fine to coarse sand
2														
4														
6		2	Nbn	PFS	37 50/ 2in.	SP	Poorly graded SAND	10	88	2				Brown, frozen, rounded gravel, fine to medium sand
8														
10		3a	Nbn	NFS	17 15 14	SP	Poorly graded SAND with Gravel							Brown, frozen, rounded gravel, fine sand
		3b	Nbn	F4		ML	SILT							Gray, frozen, low plasticity fines
12														
14														
16		4	Nbn	F4	3 3 4	ML	SILT							Black, frozen, low plasticity fines
18														
20		5			2 3 4	NR	No Recovery							No recovery, same as sample four by cuttings
22														
24														
26		6	Vx	F4	4 5 9	CL-ML	Silty CLAY							Dark gray, frozen, low plasticity fines, 35% ice by volume, ice crystals to 1/4 inch
28														
30		7	Vx	F4	6 14 17	CL-ML	Silty CLAY							Dark gray, frozen, low plasticity fines, ice crystals to 1/8 inch
32														

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-06**

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Date: **10 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,306,882 ft. ±**
Easting: **770,851 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-06**

Permanent: **CI-06**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **40.0 ft.**

Total Depth: **40.4 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Cloudy, 0 degrees, windy**
34	▨													
36	▨	8	Vx & Vr	F4	5 13 16	CL-ML	**Silty CLAY**							**Dark gray, frozen, low plasticity fines, ice crystals to 1/8 inch**
38	▨													
40	▥	9	Nbn	F2	54/ 5in.	SM	**Silty SAND**							**Brown, frozen, fine sand, nonplastic fines** **Bottom of Hole 40.4 ft.** **PID = (Cold/Hot) Photo Ionization Detector**
42														
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-06**

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Date: **12 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,305,721 ft. ±** Easting: **768,612 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-07** Permanent: **CI-07**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **40.0 ft.**

Total Depth: **41.5 ft.**

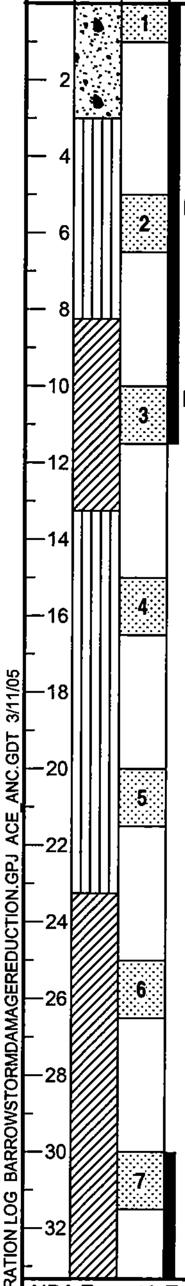
Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**



Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, 0 degrees, windy
1	Nf	NFS	Grab	SW	Well-graded SAND	14	83	3	0.375			Brown, frozen to dry, rounded gravel, fine to coarse sand
2	Nbn	F4	10 17 17	ML	SILT							Gray, frozen, fine sand as lenses to two inches, nonplastic fines
3	Nbn	F4	4 7 6	CL-ML	Silty CLAY							Gray, frozen, low plasticity fines
4		F4	2 3 4	ML	SILT							Gray and black, wet, low plasticity fines, trace organics
5		F4	2 3 4	ML	SILT							Gray and black, wet, low plasticity fines, trace organics
6		F4	3 4 7	CL-ML	Silty CLAY							Gray, wet, low plasticity fines
7	Vx	F4	8 12 16	CL-ML	Silty CLAY							Gray, frozen, low plasticity fines, ice crystals to 1/8 inch

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Date: 12 Apr 2004

Drilling Agency: ☐ Alaska District ☒ Other Denali Drilling

Elevation Datum: ☐ MSL ☐ other

Location: Northing: 6,305,721 ft. ± Easting: 768,612 ft. ±

Top of Hole Elevation:

Hole Number, Field: CI-07 **Permanent:** CI-07

Operator: Lyle Cain & Travis Coghill

Inspector: Gregory Carpenter

Type of Hole: ☒ other Auger
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: 40.0 ft.

Total Depth: 41.5 ft.

Hammer Weight: 340 lbs

Split Spoon I.D: 3 in.

Size and Type of Bit: 7 in. Hollow Stem Auger

Type of Equipment: CME-45

Type of Samples: Grab and Drive

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, 0 degrees, windy
34	▨													
36	▨	8	Vx	F4	5 20 17	CL-ML	Silty CLAY							Gray, frozen, low plasticity fines, ice crystals to 1/8 inch
38	▨													
40	▨	9	Vx	F4	28 19 19	CL-ML	Silty CLAY with sand							Gray, frozen, low plasticity fines, ice crystals to 1/8 inch
42														Bottom of Hole 41.5 ft. PID = (Cold/Hot) Photo Ionization Detector
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Hole Number: CI-07

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Date: **14 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,305,847 ft. ±** Easting: **767,203 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-08** Permanent: **CI-08**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **40.0 ft.**

Total Depth: **40.4 ft.**

Hammer Weight: **340 lbs**

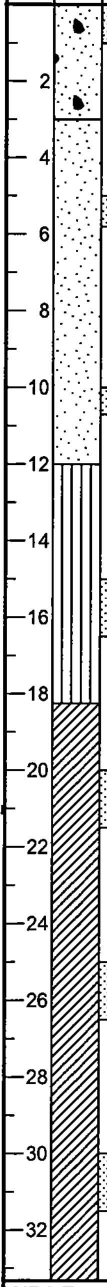
Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.) | Lithology



Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, 0 degrees
1	Nf	NFS	Grab	SP	Poorly graded SAND with Gravel	15	85		1			Brown, frozen to dry, rounded gravel, fine to coarse sand
2	Nbn	NFS	20 50/ 4in.	SP	Poorly graded SAND	1	97	2				Brown, frozen, fine sand, nonplastic (NP) fines
3	Nbn	NFS	24 50/ 3in.	SP	Poorly graded SAND		97	3				Brown, frozen, fine sand, NP fines
4	Vx	F4	5 6 10	ML	SILT							Gray, frozen, low plasticity fines, ice crystals to 1/16 inch thick
5		F4	3 3 4	CL-ML	Silty CLAY							Gray, wet, low plasticity fines
6		F4	4 5 5	CL-ML	Silty CLAY							Black and gray, wet, low plasticity fines
7		F4	4 7 10	CL-ML	Silty CLAY							Dark gray, wet, low plasticity fines

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Project: **Coastal Storm Damage Reduction**
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Date: **14 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,305,847 ft. ±** Easting: **767,203 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-08** Permanent: **CI-08**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **40.0 ft.**

Total Depth: **40.4 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Clear, 0 degrees**
34	▨													
36	▨	8	Vx	F4	5 11 43	CL-ML	**Silty CLAY**							**Dark gray and black, frozen, low plasticity fines, ice crystals to1/8 inch**
38														
40		9			60/5"	NR	**No Recovery**							**No recovery** **Bottom of Hole 40.4 ft.** **Groundwater Not Encountered** **PID = (Cold/Hot) Photo Ionization Detector**
42														
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Hole Number: **CI-08**

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Date: **15 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **7,906,214 ft. ±** Easting: **616,440 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-09** Permanent: **CI-09**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **40.0 ft.**

Total Depth: **41.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, -5 degrees, windy
		1	Nf	NFS	Grab	SP	**Poorly graded SAND**	13	86	1	1			**Brown, frozen/ dry, rounded gravel, fine to medium sand**
2														
4														
		2	Nbn	NFS	39 59	SP	**Poorly graded SAND**	7	91	2	0.375			**Brown, frozen, rounded gravel, fine to coarse sand**
6														
8														
10														
		3	Nbn & Vx	F2	13 18 28	SM	**Silty SAND**	2	64	34				**Gray, frozen, fine sand, low plasticity fines, ice crystals to 1/8 inch**
12														
14														
		4	Nbn & Vx	F4	9 17 23	CL-ML	**Silty CLAY**							**Gray and black, frozen, low plasticity fines, ice crystals to 1/8 inch**
16														
18														
20														
		5	Vx & Vr	F4	9 14 15	CL-ML	**Silty CLAY**							**Black, frozen, low plasticity fines, ice crystals to 1/8 inch, 25% ice by volume**
22														
24														
		6	Vx & Vr	F4	3 12 17	CL-ML	**Silty CLAY**							**Black, frozen, low plasticity fines, ice crystals to 1/8 inch**
26														
28														
30														
		7	Vx	F4	9 17 20	CL-ML	**Silty CLAY**							**Dark gray, frozen, low plasticity fines, ice crystals to 1/8 inch**
32														

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Date: **15 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **7,906,214 ft. ±** Easting: **616,440 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-09** Permanent: **CI-09**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **40.0 ft.**

Total Depth: **41.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Clear, -5 degrees, windy**
34	▨													
36	▨	8	Vx	F4	5 13 17	CL- ML	**Silty CLAY**							**Dark gray, frozen, low plasticity fines, ice crystals to 1/8 inch**
38	▨													
40	▨	9	Vx	F4	7 9 13	CL- ML	**Silty CLAY**							**Dark gray, frozen, low plasticity fines, ice crystals to 1/4 inch**
42														**Bottom of Hole 41.5 ft.** **Groundwater Not Encountered** **PID = (Cold/Hot) Photo Ionization Detector**
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Hole Number: **CI-09**

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Date: **15 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,306,443 ft. ±** Easting: **766,192 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-10** Permanent: **CI-10**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **40.0 ft.**

Total Depth: **41.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, 0 degrees, windy
		1	Nf	NFS	Grab	SP	Poorly graded SAND with Gravel	23	77		1			Brown, frozen to dry, rounded gravel, fine to coarse sand
2														
4														
6		2	Nf	NFS	3 8 50/ 4in.	SW	Well-graded SAND with Gravel	48	51	1	0.5			Brown, frozen, dry, rounded gravel, fine to coarse sand
8														
10		3	Nbn	NFS	24 50/ 2in.	SP	Poorly graded SAND		98	2				Brown, frozen, fine sand
12														
14														
16		4		F2	11 13 12	SP-SM	Poorly graded SAND with Silt	1	93	6				Brown, wet, fine sand
18														
20		5		F4	3 5 4	CL-ML	Silty CLAY							Gray, wet, low plasticity fines
22														
24														
26		6		F4	2 3 4	CL-ML	Silty CLAY							Dark gray, wet, low plasticity fines
28														
30		7		F4	3 3 3	CL-ML	Silty CLAY							Dark gray, wet, low plasticity fines
32														

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Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-10**

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Date: **15 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,306,443 ft. ±** Easting: **766,192 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **CI-10** Permanent: **CI-10**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **40.0 ft.**

Total Depth: **41.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Clear, 0 degrees, windy**
34														
36		8		F2	4 5 4	SM	Silty SAND							Gray, wet, fine sand, non plastic fines
38														
40		9		NFS	5 5 5	SP	Poorly graded SAND							Gray, wet, fine sand
42														Bottom of Hole 41.5 ft. Groundwater Not Encountered PID = (Cold/Hot) Photo Ionization Detector
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

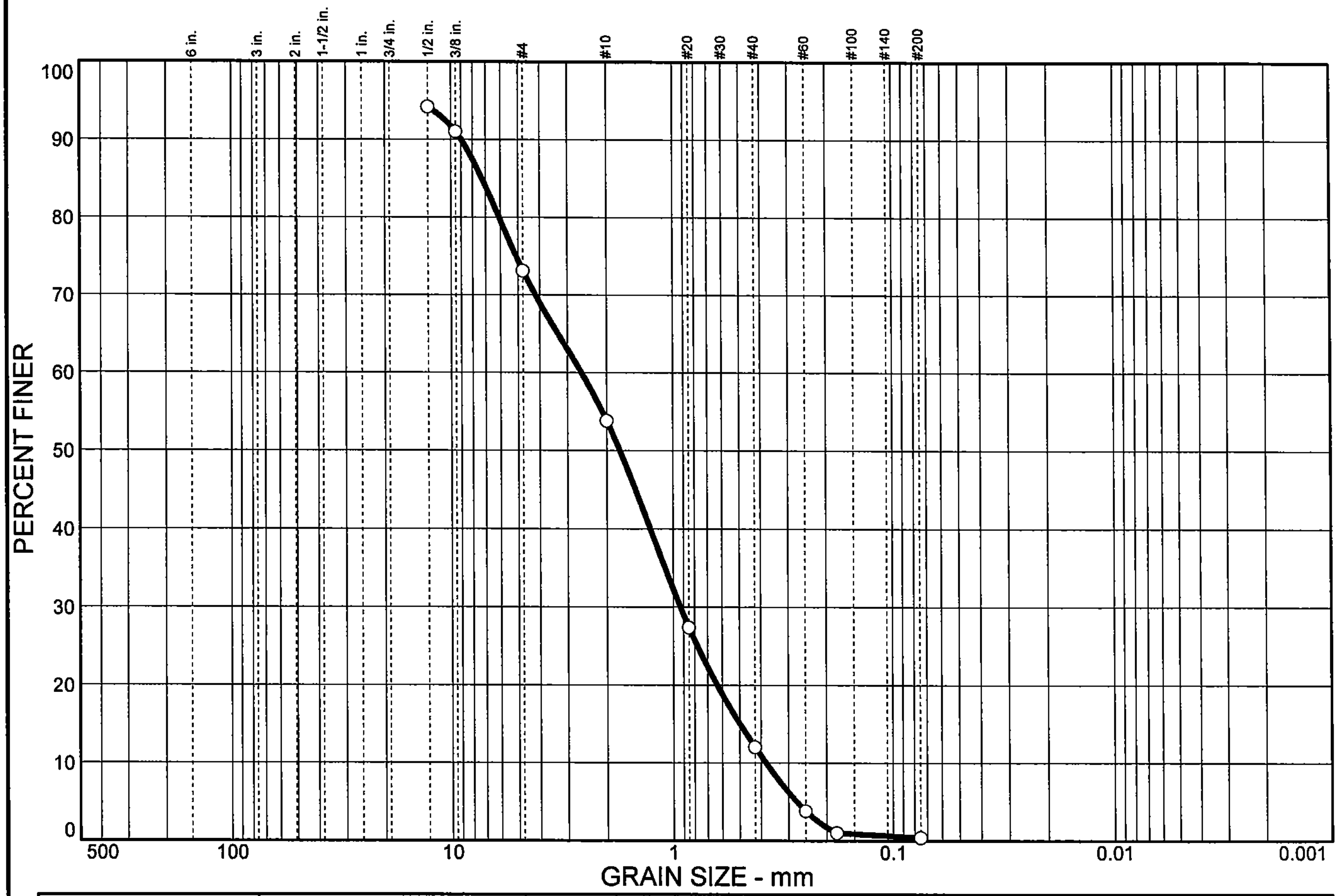
EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **CI-10**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
			19.3	41.8	11.6	0.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	94.2		
3/8 in.	91.0		
# 4	73.1		
# 10	53.8		
# 20	27.4		
# 40	12.0		
# 60	3.8		
# 80	1.0		
# 200	0.4		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 7.27 D_{60}= 2.60 D_{50}= 1.75

D_{30}= 0.929 D_{15}= 0.499 D_{10}= 0.380

C_u= 6.85 C_c= 0.87

Classification

USCS= SP AASHTO= A-1-b

Remarks

Sample No.: 6016 **Source of Sample:** Client Samples **Date:**

Location: CI-01 #1 **Elev./Depth:** 0 FT 0 m

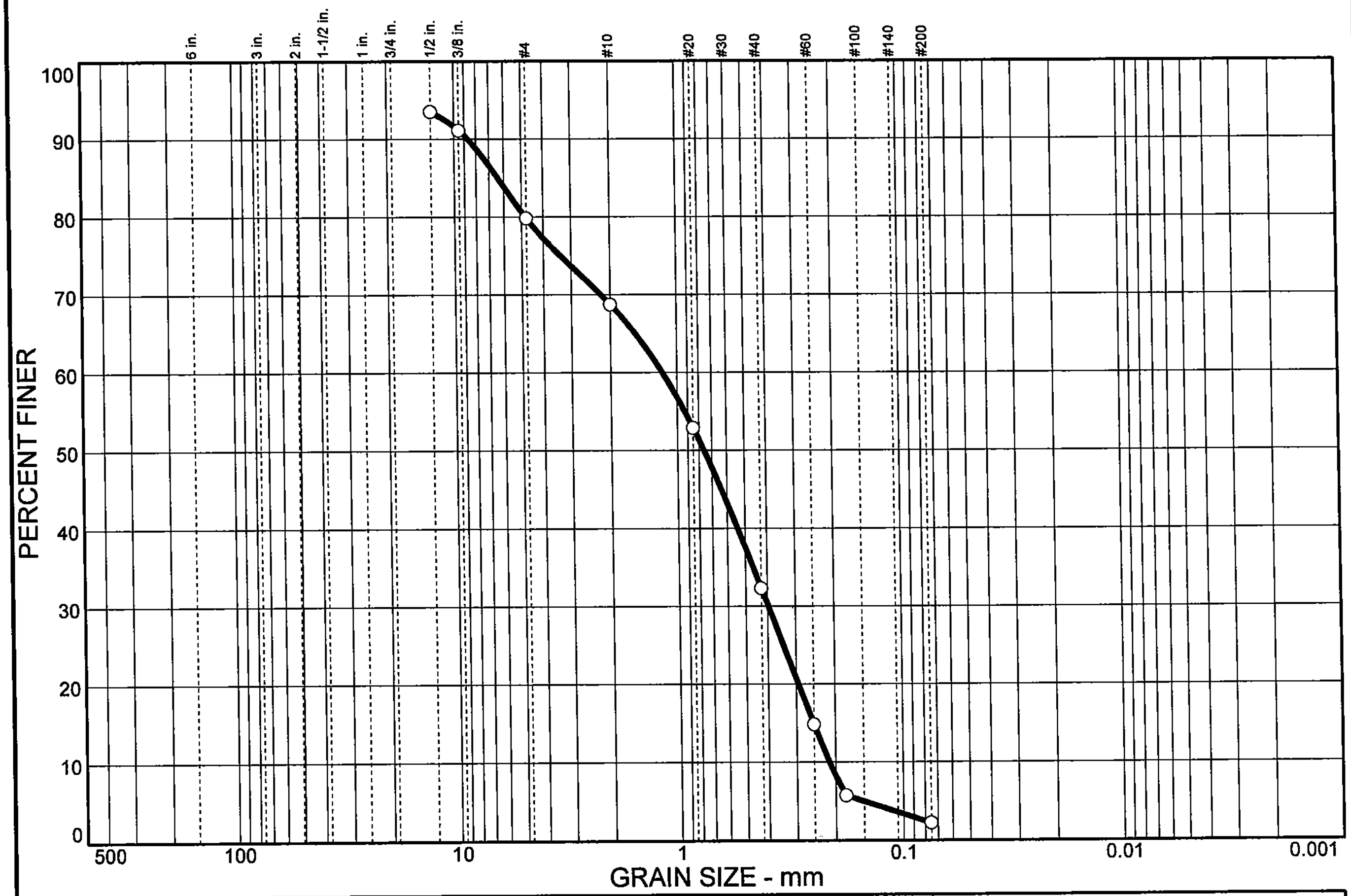
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
			11.1	36.4	30.1	2.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	93.5		
3/8 in.	91.1		
# 4	79.8		
# 10	68.7		
# 20	52.9		
# 40	32.3		
# 60	14.8		
# 80	5.7		
# 200	2.2		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 6.40 D_{60}= 1.17 D_{50}= 0.760
D_{30}= 0.396 D_{15}= 0.252 D_{10}= 0.214
C_u= 5.47 C_c= 0.63

Classification

USCS= SP AASHTO= A-1-b

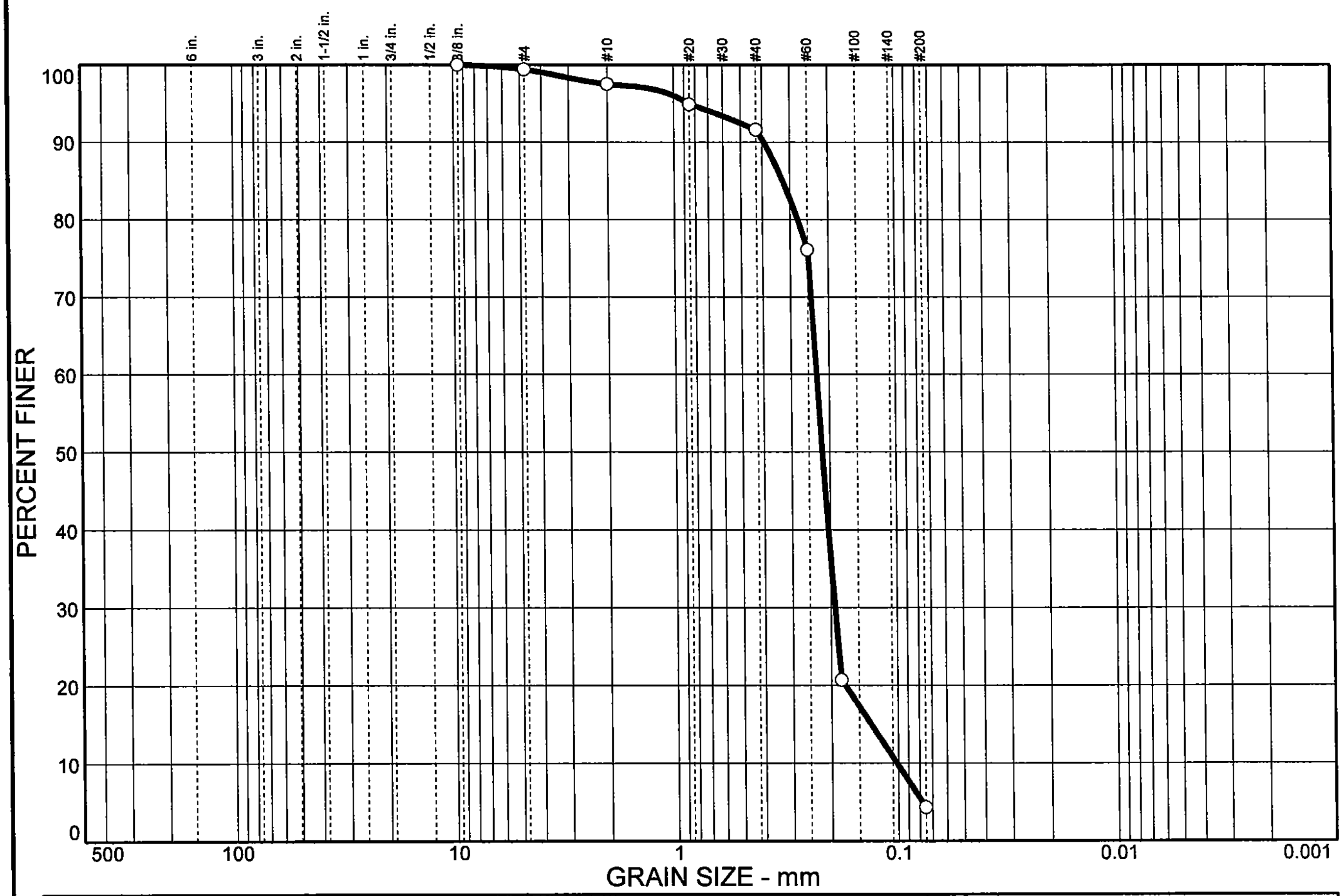
Remarks

Sample No.: 6017
Location: CI-01 #2
Source of Sample: Client Samples
Date:
Elev./Depth: 4 FT 1.2 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.6	1.9	5.9	87.3	4.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	99.4		
# 10	97.5		
# 20	94.9		
# 40	91.6		
# 60	76.1		
# 80	20.7		
# 200	4.3		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.323 D_{60}= 0.229 D_{50}= 0.217

D_{30}= 0.192 D_{15}= 0.133 D_{10}= 0.102

C_u= 2.25 C_c= 1.59

Classification

USCS= SP AASHTO= A-3

Remarks

Sample No.: 6018 **Source of Sample:** Client Samples **Date:**

Location: CI-01 #3 **Elev./Depth:** 9 FT 2.7 m

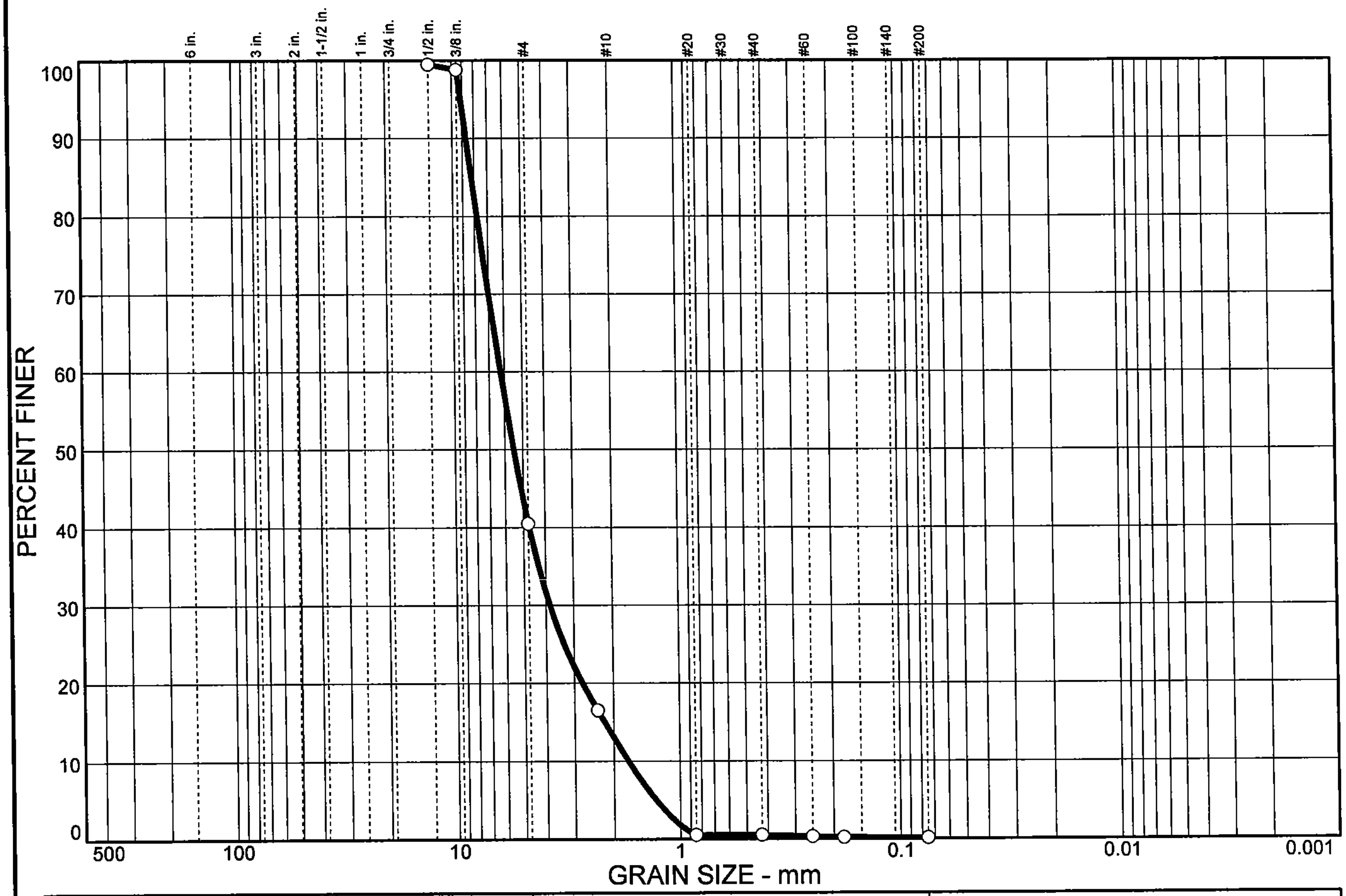
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
			27.5	12.5	0.4	0.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	99.5		
3/8 in.	98.8		
# 4	40.5		
# 8	16.5		
# 20	0.5		
# 40	0.5		
# 60	0.3		
# 80	0.2		
# 200	0.1		

* (no specification provided)

Soil Description

Poorly graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 8.24 D_{60}= 6.23 D_{50}= 5.48
D_{30}= 3.84 D_{15}= 2.20 D_{10}= 1.72
C_u= 3.62 C_c= 1.37

Classification

USCS= GP AASHTO= A-1-a

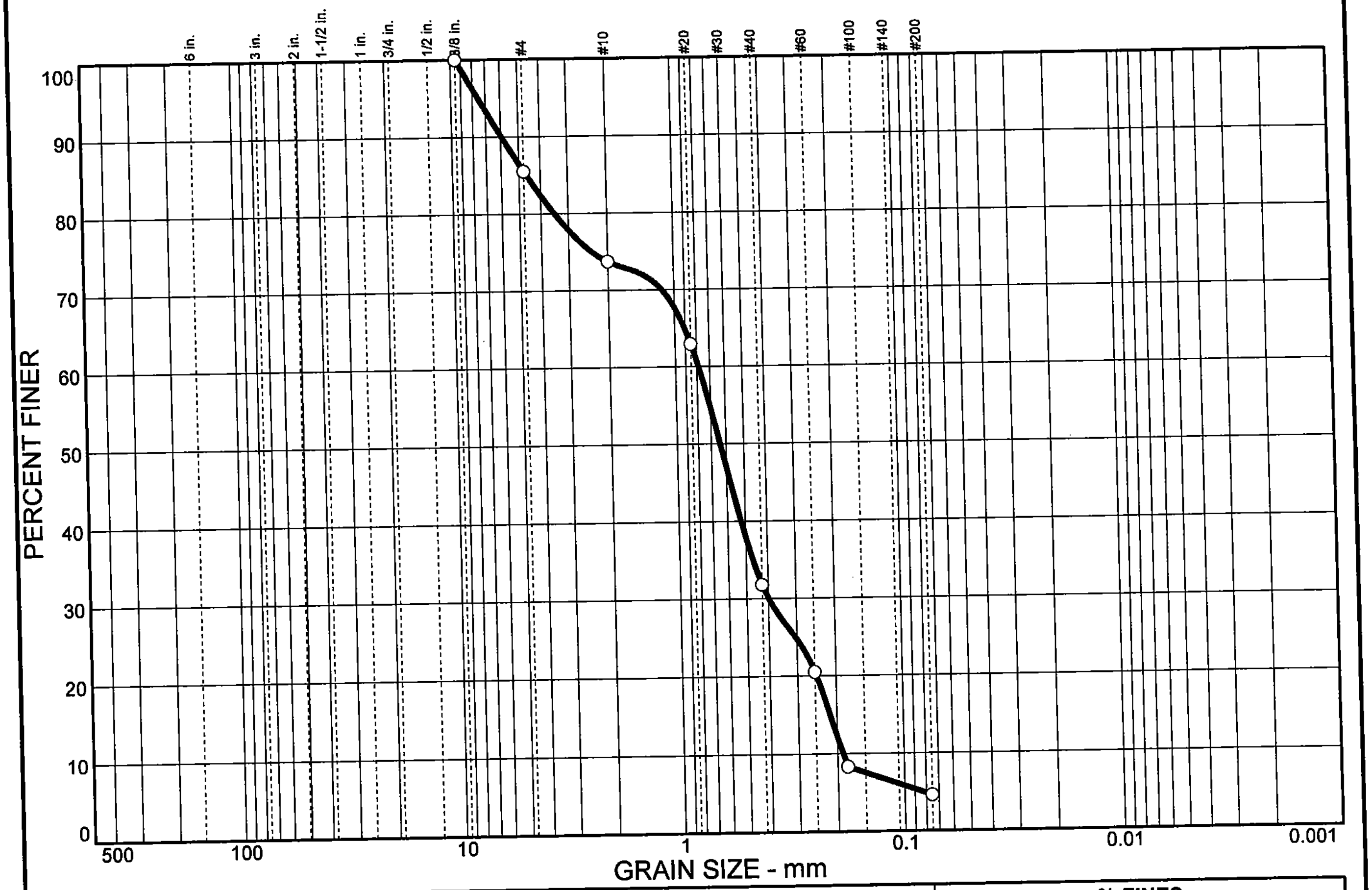
Remarks

Sample No.: 6019 **Source of Sample:** Client Samples **Date:**
Location: CI-02 #1 **Elev./Depth:** 0 FT 0 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	14.5	11.8	41.9	27.2	4.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	85.5		
# 10	73.7		
# 20	62.9		
# 40	31.8		
# 60	20.5		
# 80	8.3		
# 200	4.6		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 4.63 D_{60}= 0.789 D_{50}= 0.639

D_{30}= 0.398 D_{15}= 0.215 D_{10}= 0.189

C_u= 4.17 C_c= 1.06

Classification

USCS= SP AASHTO= A-1-b

Remarks

Sample No.: 6020 **Source of Sample:** Client Samples **Date:**

Location: CI-02 #2 **Elev./Depth:** 4 FT 1.2 m

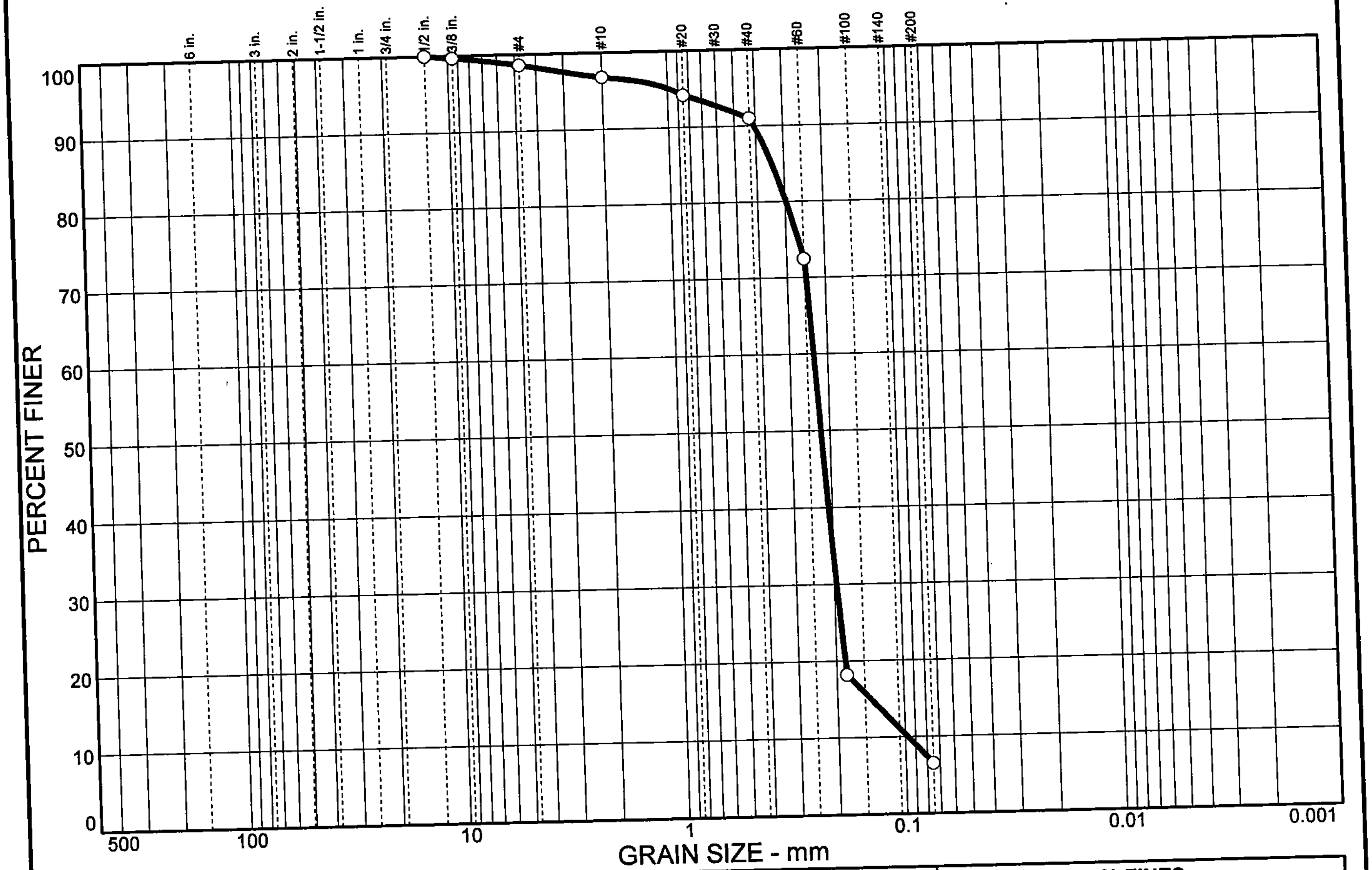
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	1.4	1.8	5.8	84.5	6.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	99.7		
# 4	98.6		
# 10	96.8		
# 20	94.2		
# 40	91.0		
# 60	72.4		
# 80	18.2		
# 200	6.5		

* (no specification provided)

Soil Description

Poorly graded sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.341 D_{60}= 0.233 D_{50}= 0.221

D_{30}= 0.196 D_{15}= 0.142 D_{10}= 0.0975

C_u= 2.40 C_c= 1.69

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Sample No.: 6021

Location: CI-02 #3

Source of Sample: Client Samples

Date:

Elev./Depth: 9 FT 2.7 m

Mappa TestLab

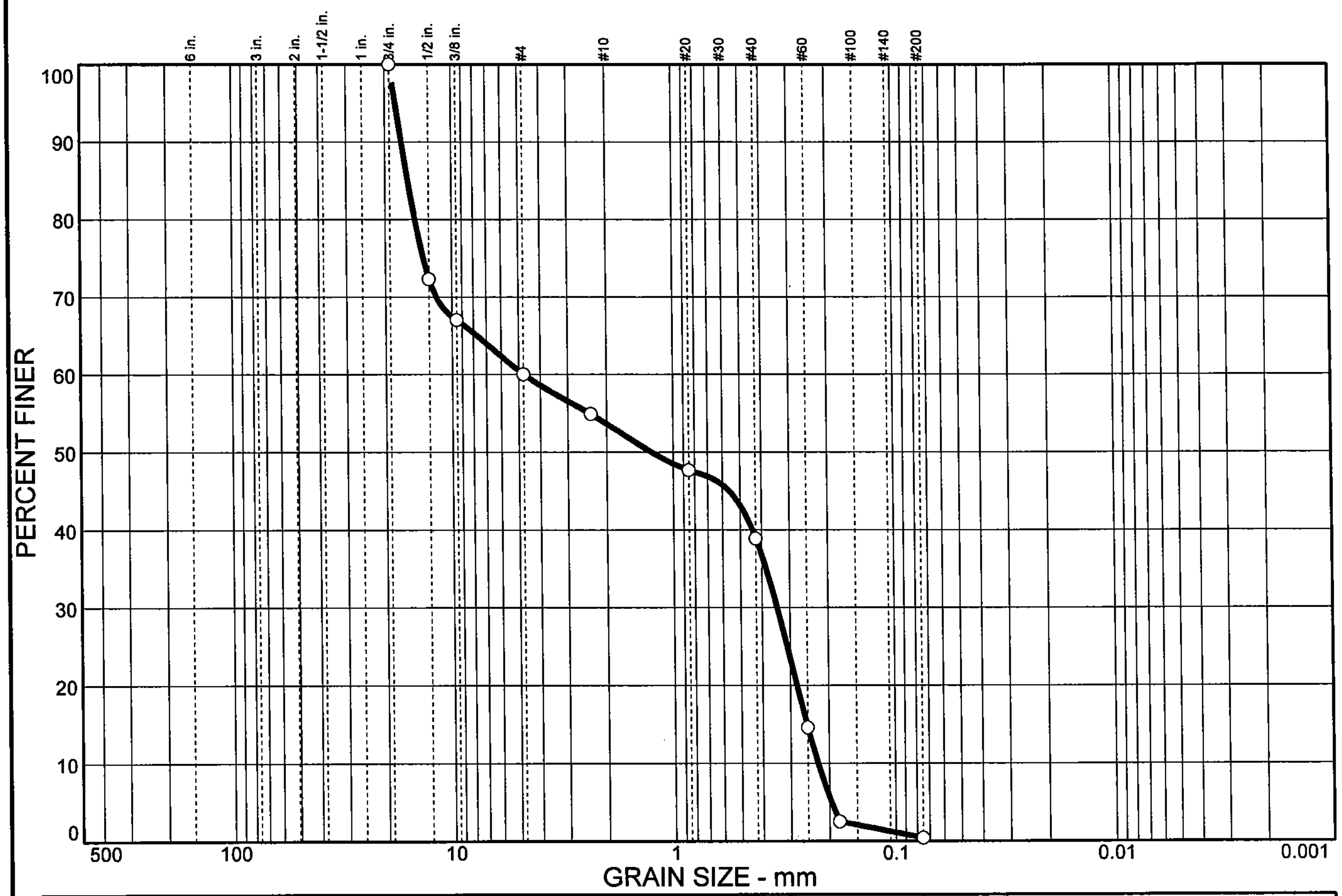
Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148

Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	40.0	6.4	14.7	38.5	0.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	72.3		
3/8 in.	67.0		
# 4	60.0		
# 8	54.9		
# 20	47.7		
# 40	38.9		
# 60	14.6		
# 80	2.5		
# 200	0.4		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 15.8 D_{60}= 4.75 D_{50}= 1.25
D_{30}= 0.343 D_{15}= 0.252 D_{10}= 0.225
C_u= 21.12 C_c= 0.11

Classification

USCS= SP AASHTO= A-1-b

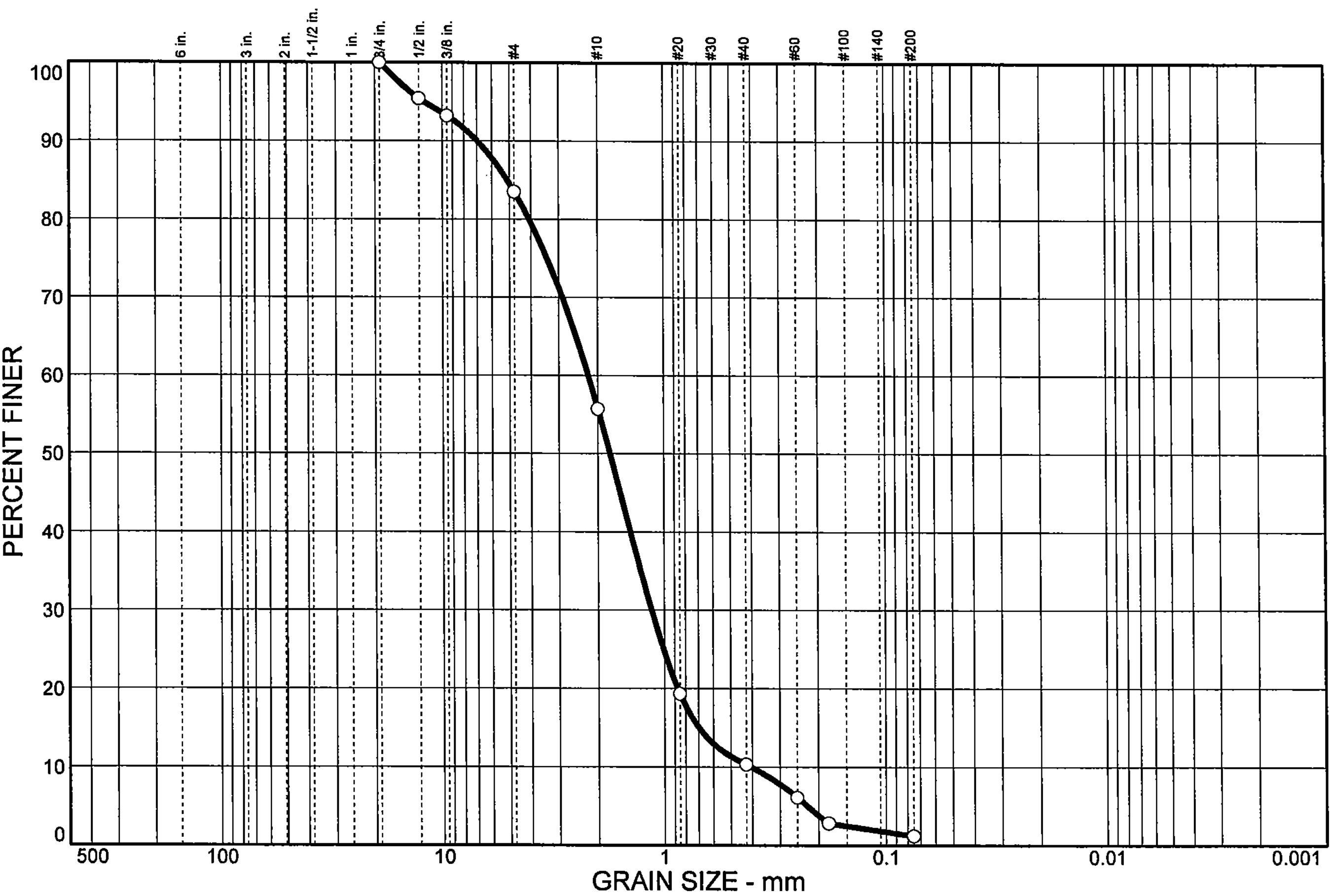
Remarks

Sample No.: 6022 **Source of Sample:** Client Samples **Date:**
Location: CI-03 #1 **Elev./Depth:** 0 FT 0 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	16.5	27.8	45.4	9.1	1.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	95.4		
3/8 in.	93.2		
# 4	83.5		
# 10	55.7		
# 20	19.3		
# 40	10.3		
# 60	6.1		
# 80	2.8		
# 200	1.2		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 5.12 D_{60}= 2.21 D_{50}= 1.76
D_{30}= 1.14 D_{15}= 0.699 D_{10}= 0.405
C_u= 5.46 C_c= 1.46

Classification

USCS= SP AASHTO= A-1-b

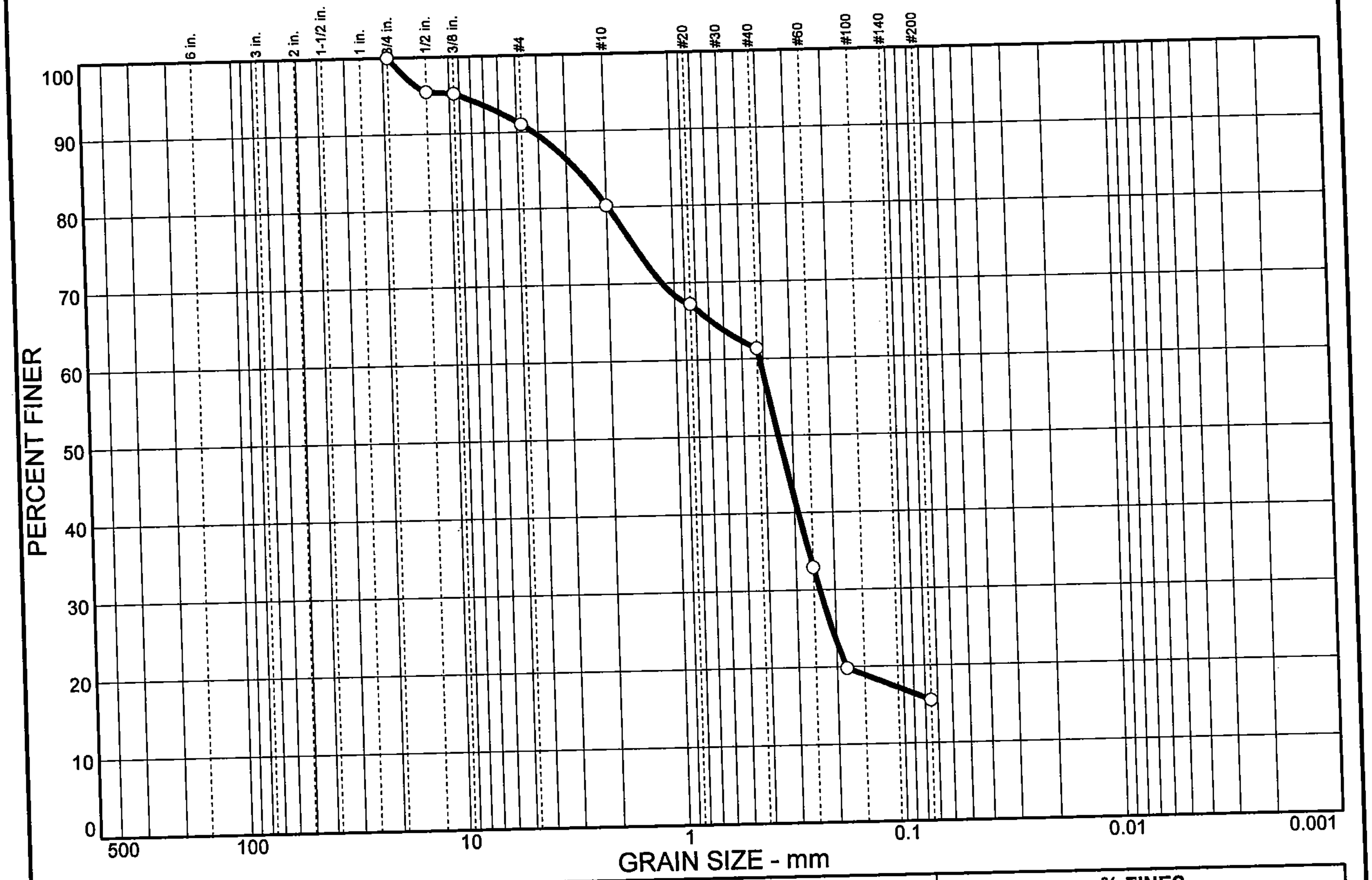
Remarks

Sample No.: 6023 **Source of Sample:** Client Samples **Date:**
Location: CI-03 #2 **Elev./Depth:** 4 FT 1.2 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	9.0	10.8	18.9	45.8	15.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	95.5		
3/8 in.	95.2		
# 4	91.0		
# 10	80.2		
# 20	67.2		
# 40	61.3		
# 60	32.9		
# 80	19.8		
# 200	15.5		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 2.71
D_{60}= 0.416
D_{50}= 0.348
D_{30}= 0.235
D_{15}=
D_{10}=
C_u=
C_c=

Classification

USCS= SM
AASHTO= A-2-4(0)

Remarks

Sample No.: 6024
Location: CI-03 # 3

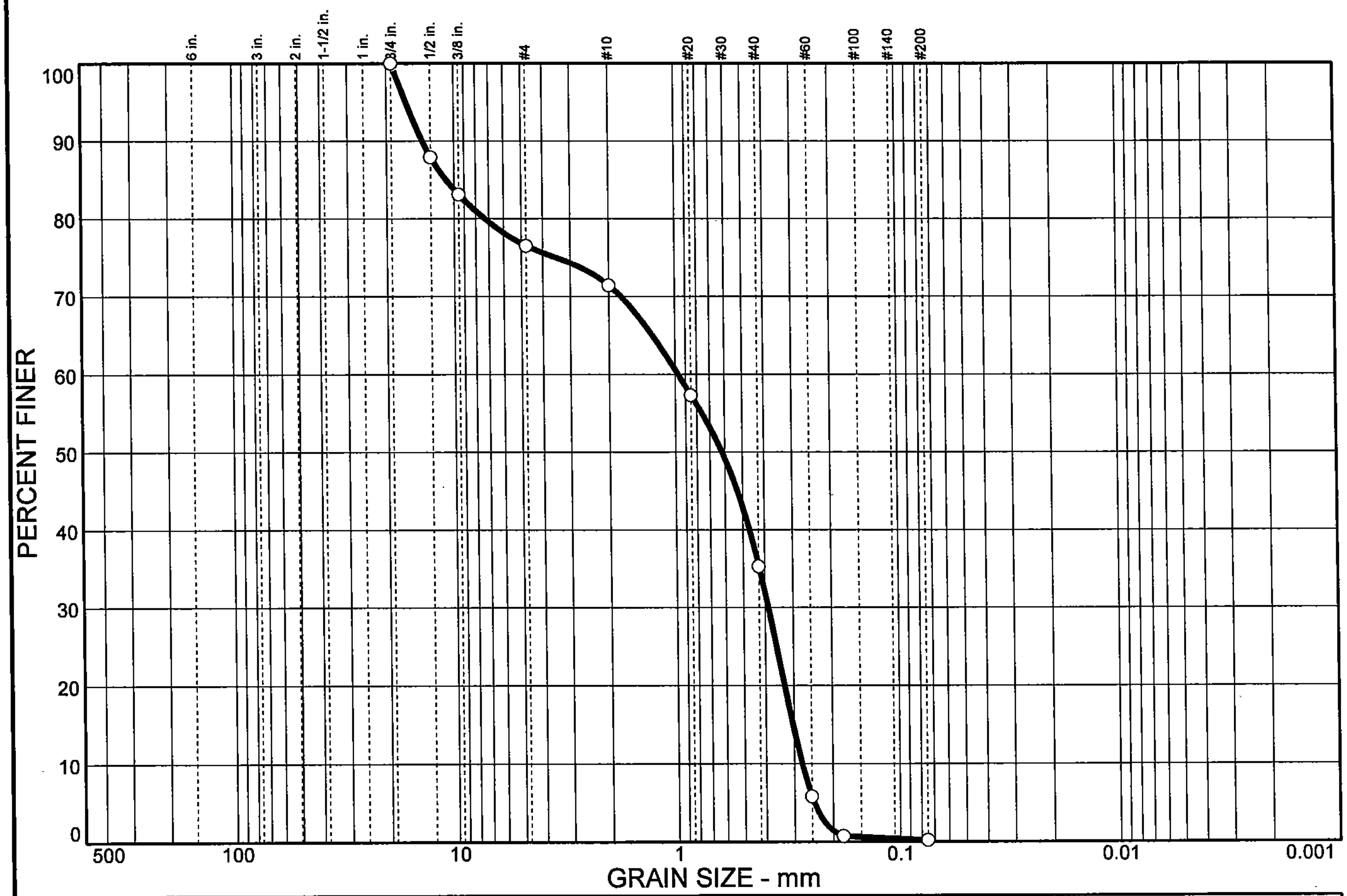
Source of Sample: Client Samples

Date:
Elev./Depth: 9 FT 2.7 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	23.5	5.1	36.1	35.1	0.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	87.9		
3/8 in.	83.1		
# 4	76.5		
# 10	71.4		
# 20	57.3		
# 40	35.3		
# 60	5.8		
# 80	0.7		
# 200	0.2		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 10.9 D_{60}= 0.973 D_{50}= 0.618
D_{30}= 0.387 D_{15}= 0.303 D_{10}= 0.276
C_u= 3.52 C_c= 0.56

Classification

USCS= SP AASHTO= A-1-b

Remarks

Sample No.: 6025
Location: CI-04 #1

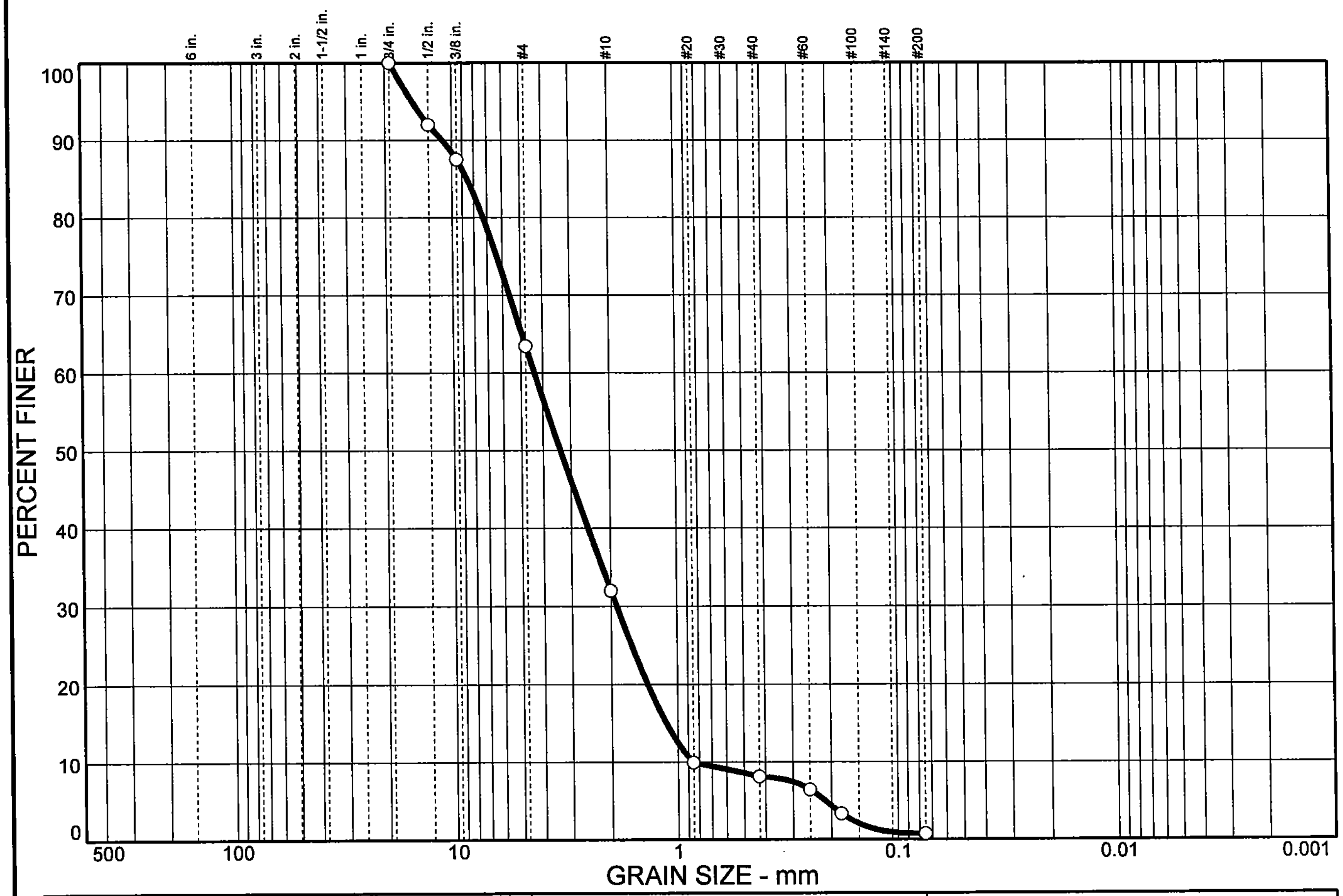
Source of Sample: Client Samples

Date:
Elev./Depth: 0 FT 0 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	36.6	31.4	23.9	7.4	0.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	92.0		
3/8 in.	87.5		
# 4	63.4		
# 10	32.0		
# 20	9.9		
# 40	8.1		
# 60	6.4		
# 80	3.3		
# 200	0.7		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 8.57 D_{60}= 4.36 D_{50}= 3.35
D_{30}= 1.88 D_{15}= 1.13 D_{10}= 0.857
C_u= 5.09 C_c= 0.95

Classification

USCS= SP AASHTO= A-1-a

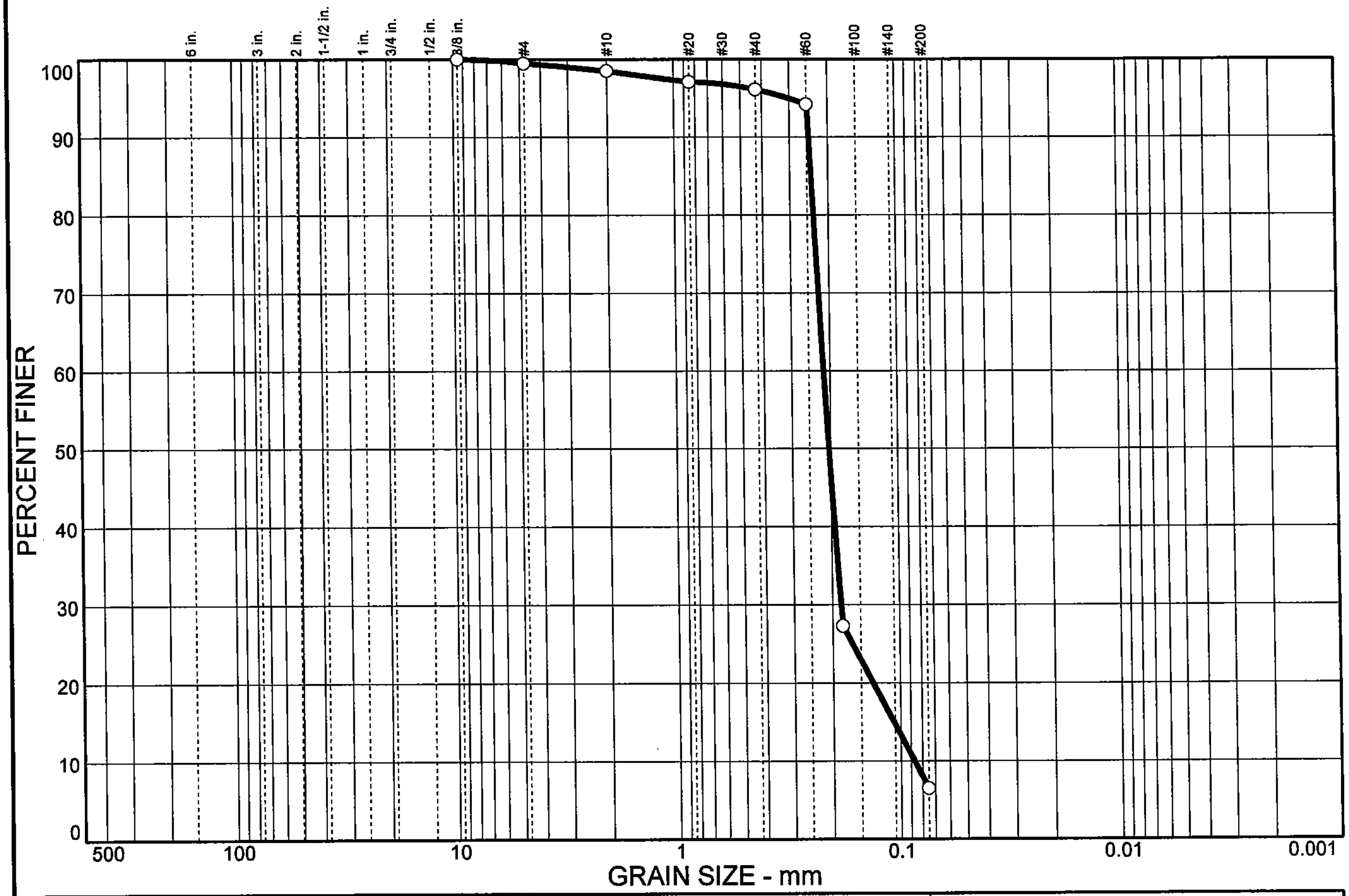
Remarks

Sample No.: 6026 **Source of Sample:** Client Samples **Date:**
Location: CI-04 #2 **Elev./Depth:** 5 FT 1.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.5	1.0	2.4	89.6	6.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	99.5		
# 10	98.5		
# 20	97.1		
# 40	96.1		
# 60	94.2		
# 80	27.3		
# 200	6.5		

* (no specification provided)

Soil Description

Poorly graded sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.240 D_{60}= 0.214 D_{50}= 0.204
D_{30}= 0.183 D_{15}= 0.107 D_{10}= 0.0868
C_u= 2.47 C_c= 1.80

Classification

USCS= SP-SM AASHTO= A-3

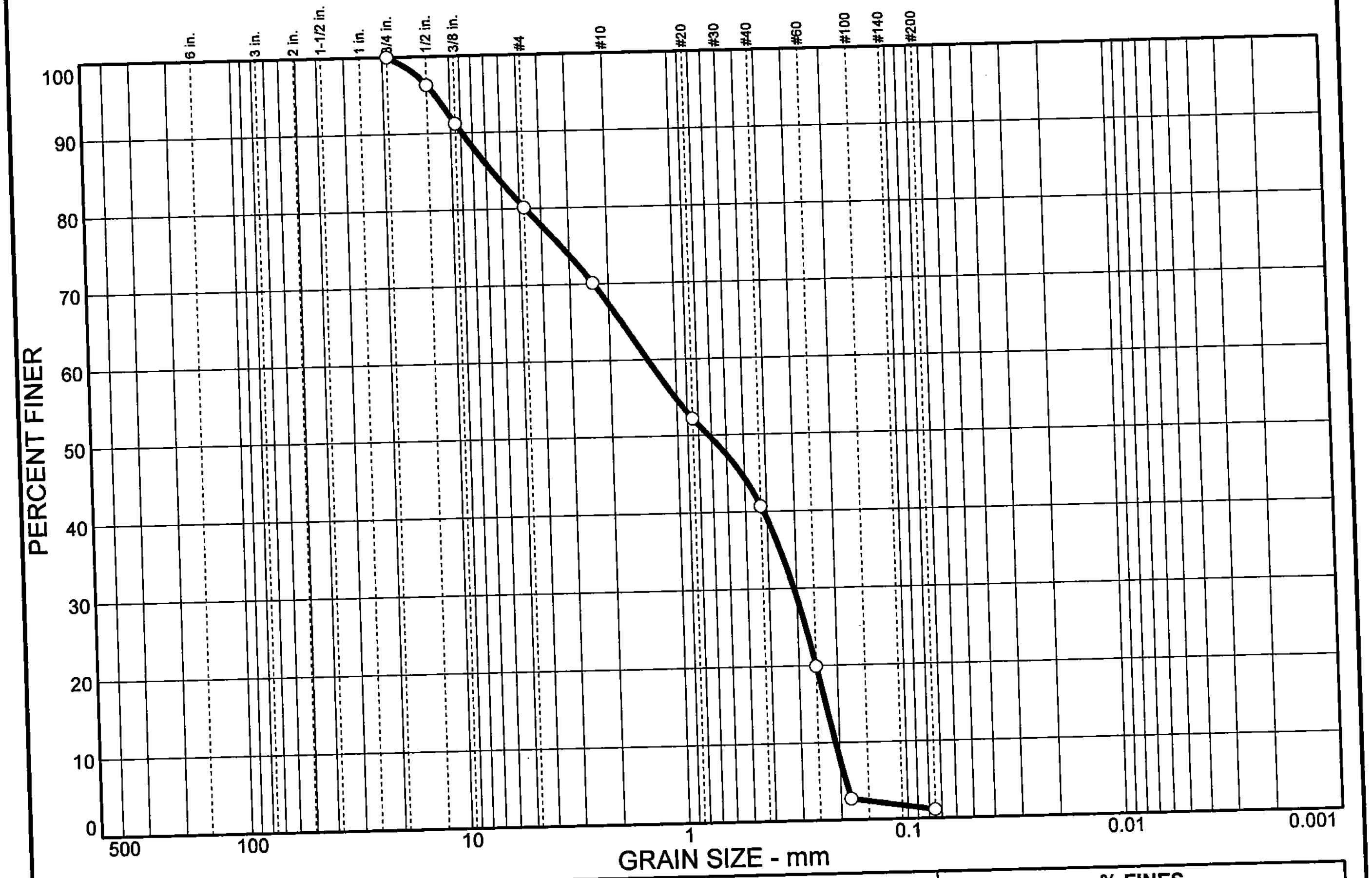
Remarks

Sample No.: 6027
Location: CI-04 #3
Source of Sample: Client Samples
Date:
Elev./Depth: 10 FT 3 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	19.9	12.8	26.6	39.6	1.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	96.3		
3/8 in.	91.2		
# 4	80.1		
# 8	70.1		
# 20	52.2		
# 40	40.7		
# 60	19.9		
# 80	2.7		
# 200	1.1		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 6.63 D_{60}= 1.35 D_{50}= 0.724
D_{30}= 0.309 D_{15}= 0.229 D_{10}= 0.209
C_u= 6.45 C_c= 0.34

Classification

USCS= SP AASHTO= A-1-b

Remarks

Sample No.: 6028
Location: CI-05 #1

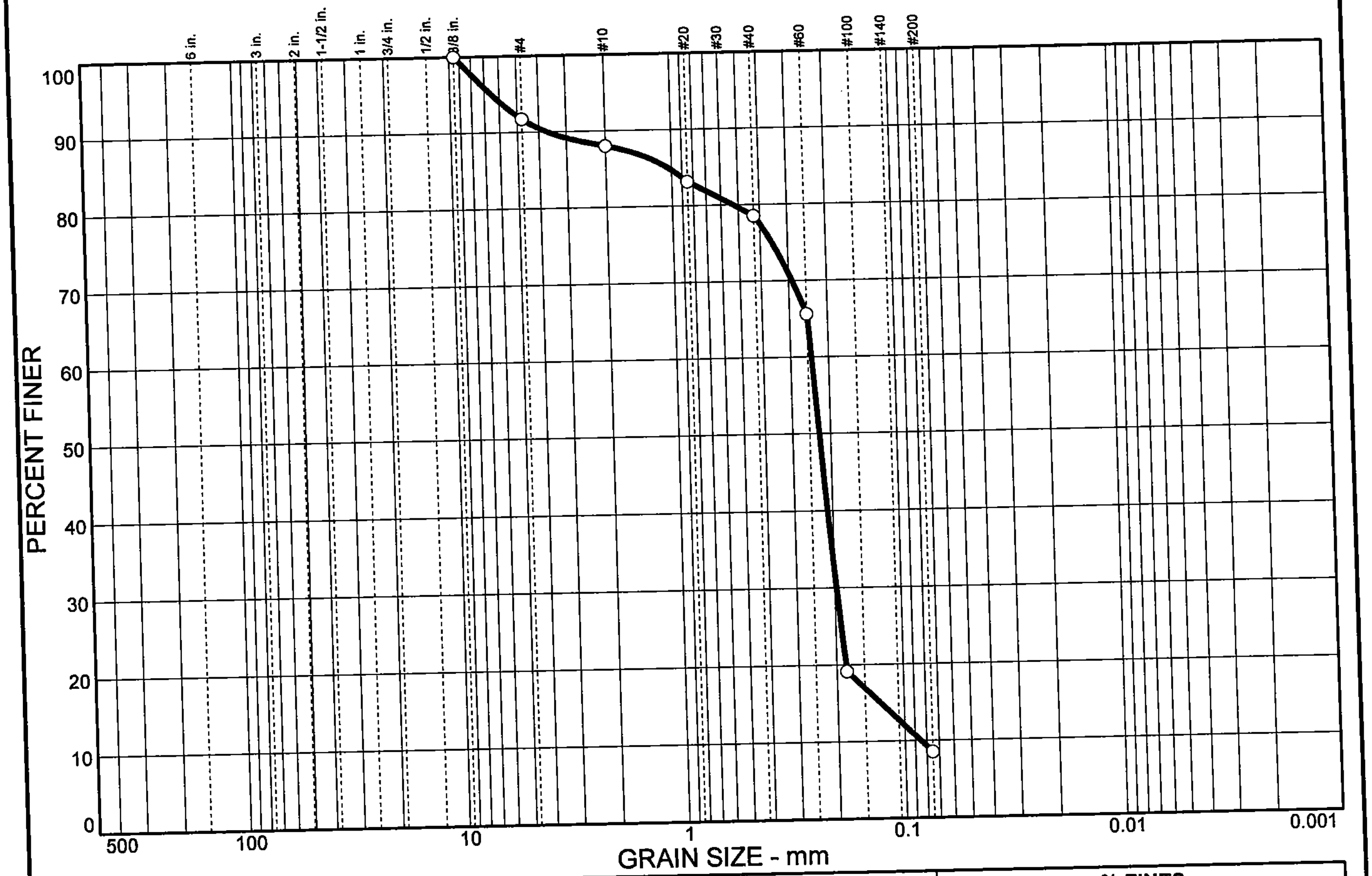
Source of Sample: Client Samples

Date:
Elev./Depth: 0 FT 0 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	8.3	3.7	9.5	70.0	8.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	91.7		
# 10	88.0		
# 20	83.1		
# 40	78.5		
# 60	65.6		
# 80	19.1		
# 200	8.5		

* (no specification provided)

Soil Description

Poorly graded sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 1.04 D_{60}= 0.241 D_{50}= 0.226
D_{30}= 0.197 D_{15}= 0.128 D_{10}= 0.0849
C_u= 2.84 C_c= 1.90

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Sample No.: 6029
Location: CI-05 #2
Source of Sample: Client Samples
Date:
Elev./Depth: 5 FT 1.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	19.8	22.9	32.8	23.9	0.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	93.0		
3/8 in.	89.2		
# 4	80.2		
# 8	62.6		
# 20	34.1		
# 40	24.5		
# 60	7.3		
# 80	1.6		
# 200	0.6		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 6.60 D_{60}= 2.17 D_{50}= 1.59
D_{30}= 0.590 D_{15}= 0.317 D_{10}= 0.274
C_u= 7.93 C_c= 0.59

Classification

USCS= SP AASHTO= A-1-b

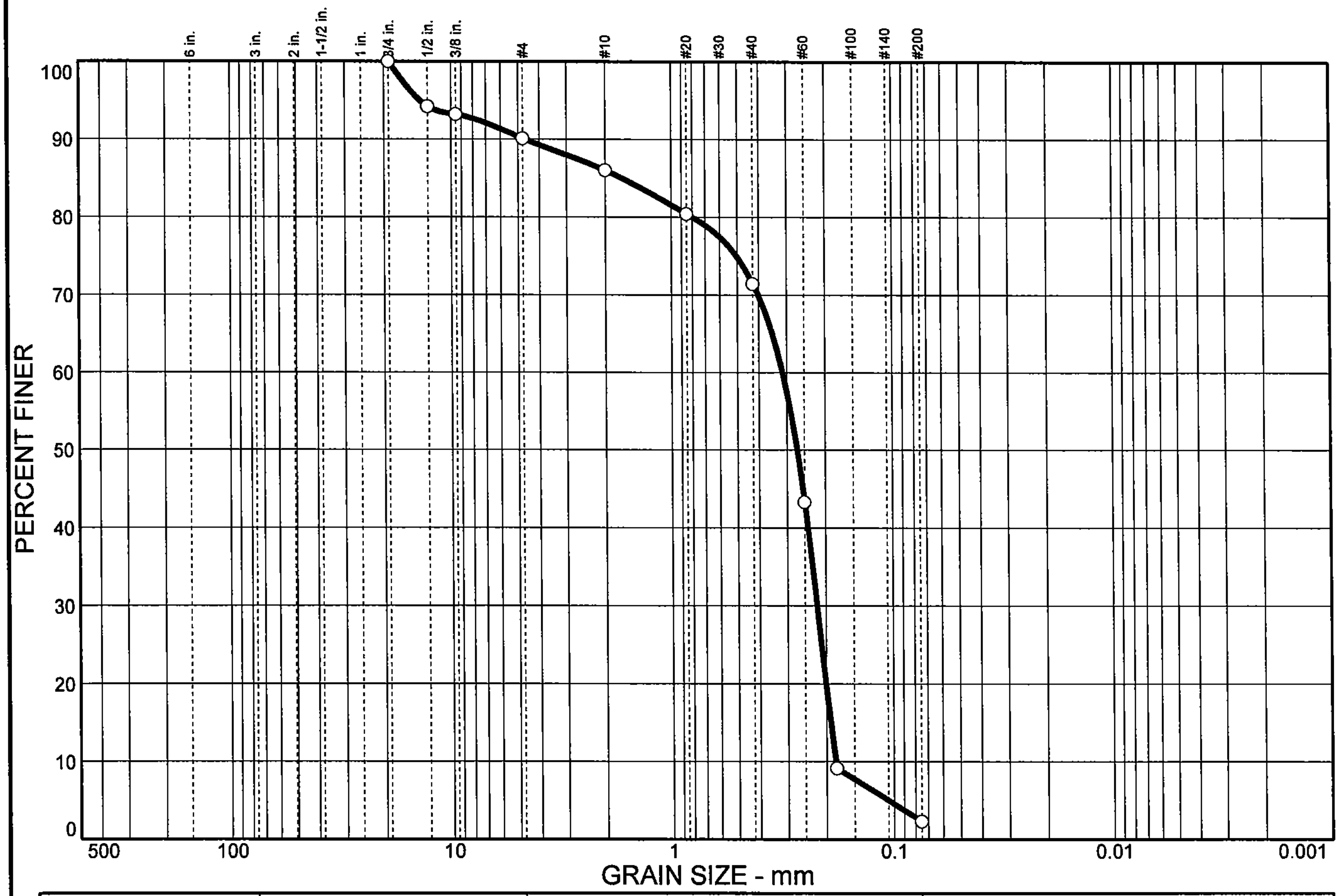
Remarks

Sample No.: 6030 **Source of Sample:** Client Samples **Date:**
Location: CI-06 #1 **Elev./Depth:** 0 FT 0 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	9.9	4.1	14.6	69.1	2.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	94.2		
3/8 in.	93.2		
# 4	90.1		
# 10	86.0		
# 20	80.4		
# 40	71.4		
# 60	43.3		
# 80	9.1		
# 200	2.3		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 1.68 D_{60}= 0.314 D_{50}= 0.270
D_{30}= 0.220 D_{15}= 0.192 D_{10}= 0.182
C_u= 1.72 C_c= 0.85

Classification

USCS= SP AASHTO= A-3

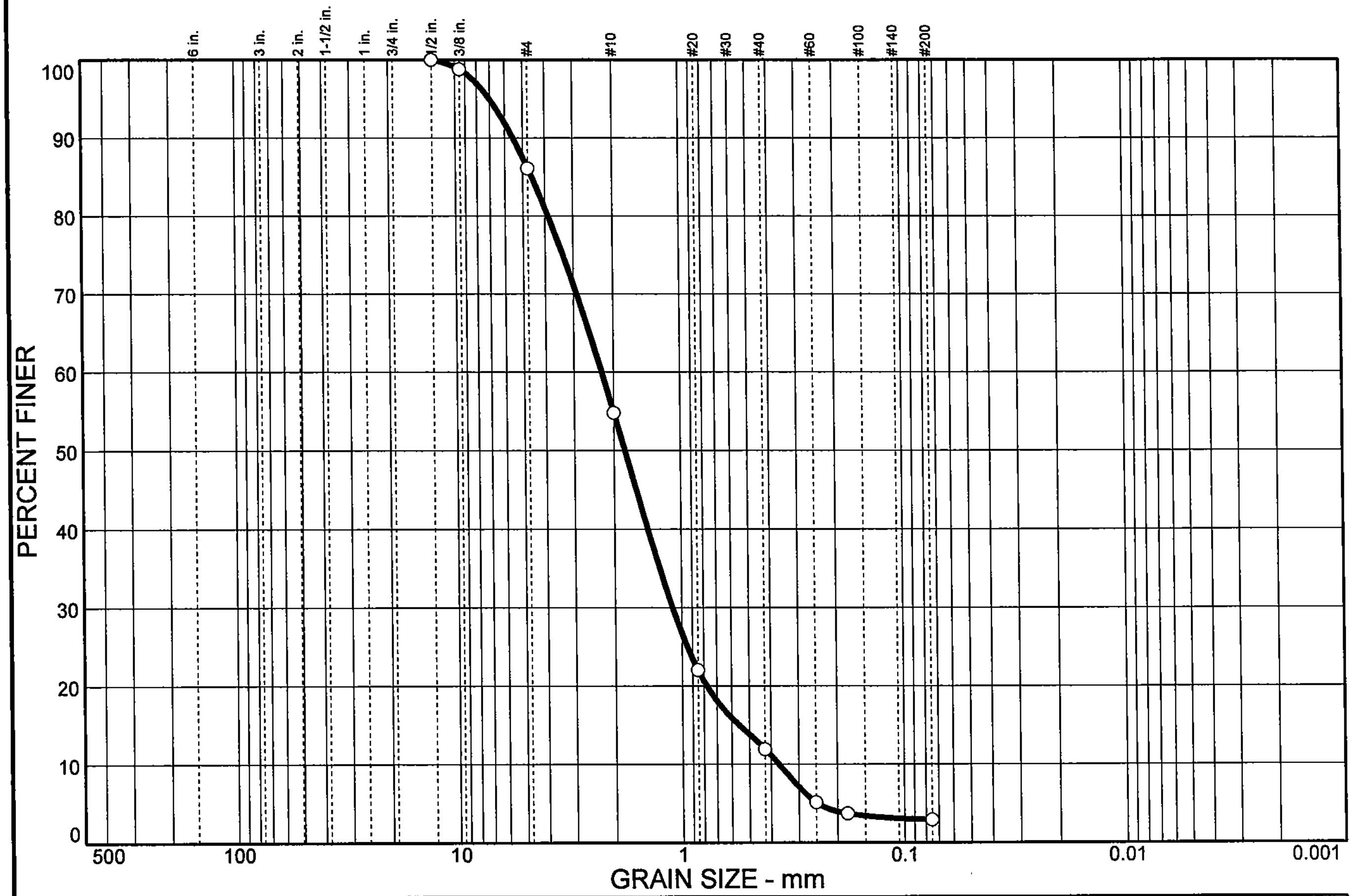
Remarks

Sample No.: 6031 **Source of Sample:** Client Samples **Date:**
Location: CI-06 #2 **Elev./Depth:** 5 FT 1.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	13.9	31.3	42.9	9.0	2.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	98.8		
# 4	86.1		
# 10	54.8		
# 20	22.0		
# 40	11.9		
# 60	5.1		
# 80	3.7		
# 200	2.9		

* (no specification provided)

Soil Description

Well-graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 4.57 D_{60}= 2.26 D_{50}= 1.79
D_{30}= 1.10 D_{15}= 0.557 D_{10}= 0.370
C_u= 6.12 C_c= 1.45

Classification

USCS= SW AASHTO= A-1-b

Remarks

Sample No.: 6032
Location: CI-07 #1

Source of Sample: Client Samples

Date:
Elev./Depth: 0 FT 0 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	15.3	16.7	33.2	34.8	0.0	0.0

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	96.2		
3/8 in.	92.9		
# 4	84.7		
# 8	71.9		
# 20	49.6		
# 40	34.8		
# 60	6.7		
# 80	0.9		
# 200	0.0		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 4.85
D_{60}= 1.44
D_{50}= 0.874
D_{30}= 0.386
D_{15}= 0.298
D_{10}= 0.271
C_u= 5.30
C_c= 0.38

Classification

USCS= SP
AASHTO= A-1-b

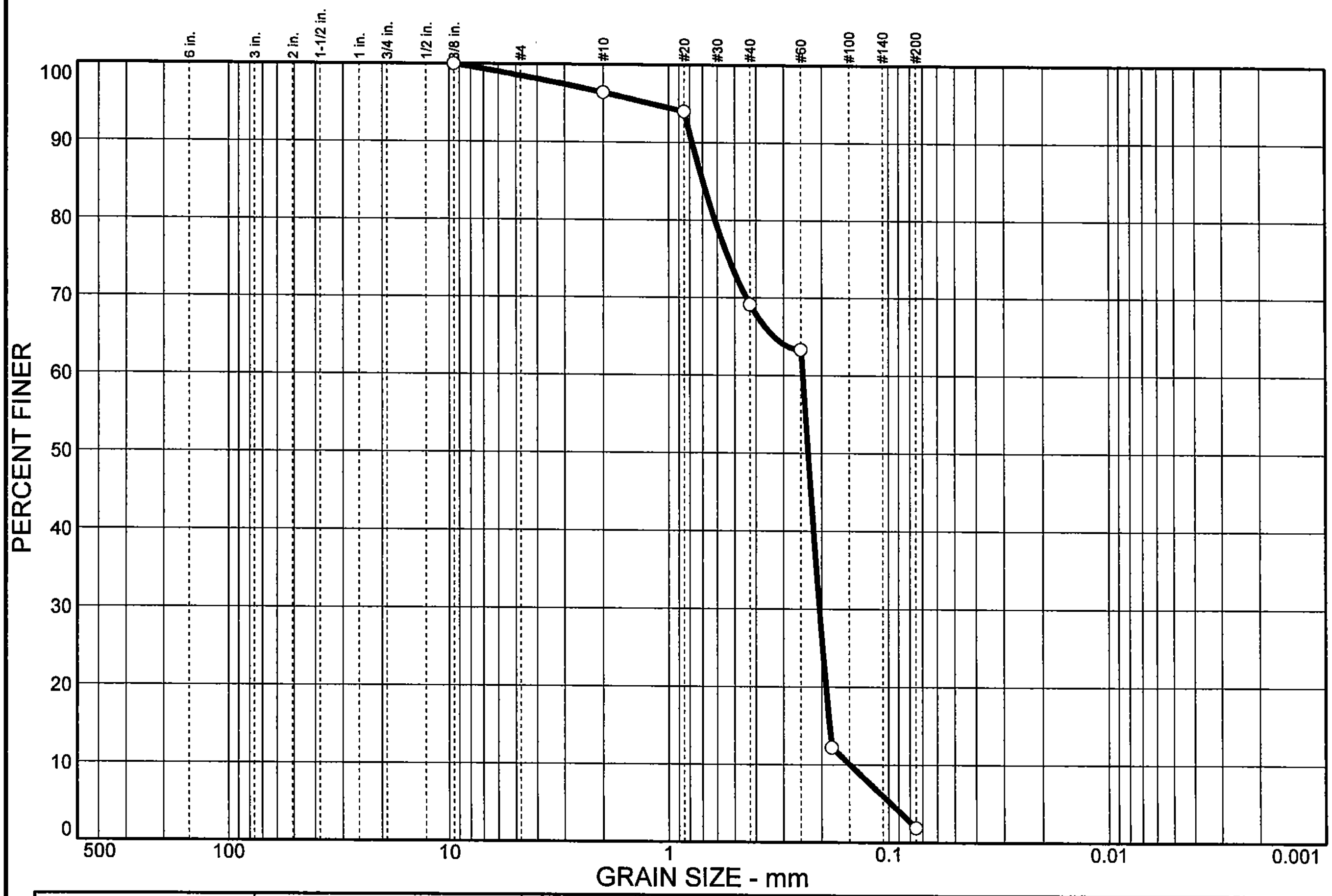
Remarks

Sample No.: 6033
Location: CI-08 #1
Source of Sample: Client Samples
Date:
Elev./Depth: 0 FT 0 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	1.5	2.1	27.3	67.2	1.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 10	96.4		
# 20	94.0		
# 40	69.1		
# 60	63.3		
# 80	12.2		
# 200	1.9		

* (no specification provided)

Soil Description

Poorly graded sand with silt ad

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 0.699
D_{60}= 0.245
D_{50}= 0.232
D_{30}= 0.205
D_{15}= 0.184
D_{10}= 0.149
C_u= 1.64
C_c= 1.15

Classification

USCS= SP
AASHTO= A-3

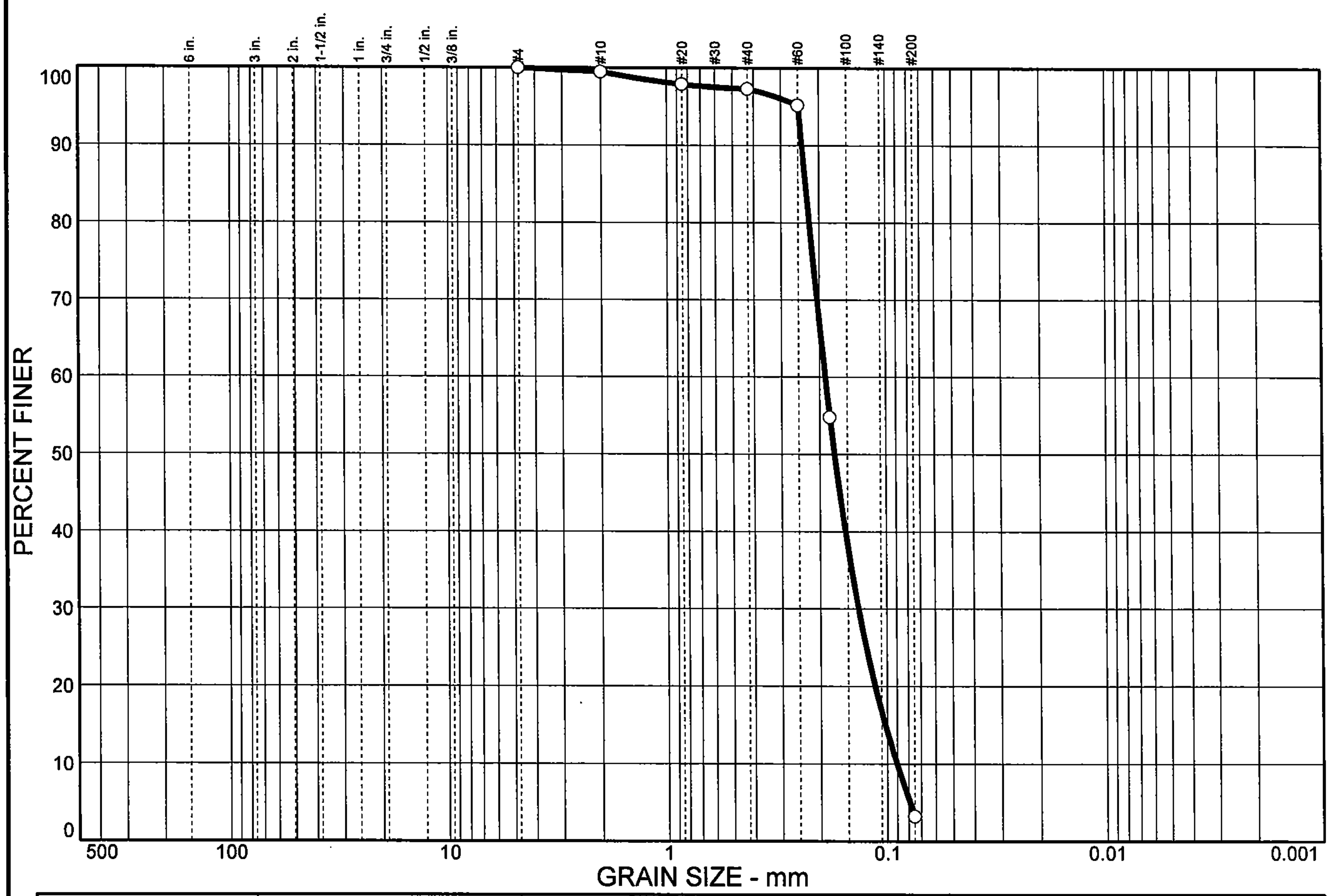
Remarks

Sample No.: 6034
Location: CI-08 #2
Source of Sample: Client Samples
Date:
Elev./Depth: 5 FT 1.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.5	2.2	94.1	3.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
# 4	100.0		
# 10	99.5		
# 20	97.9		
# 40	97.3		
# 60	95.2		
# 80	54.8		
# 200	3.2		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.231 D_{60}= 0.189 D_{50}= 0.172
D_{30}= 0.134 D_{15}= 0.102 D_{10}= 0.0903
C_u= 2.09 C_c= 1.06

Classification

USCS= SP AASHTO= A-3

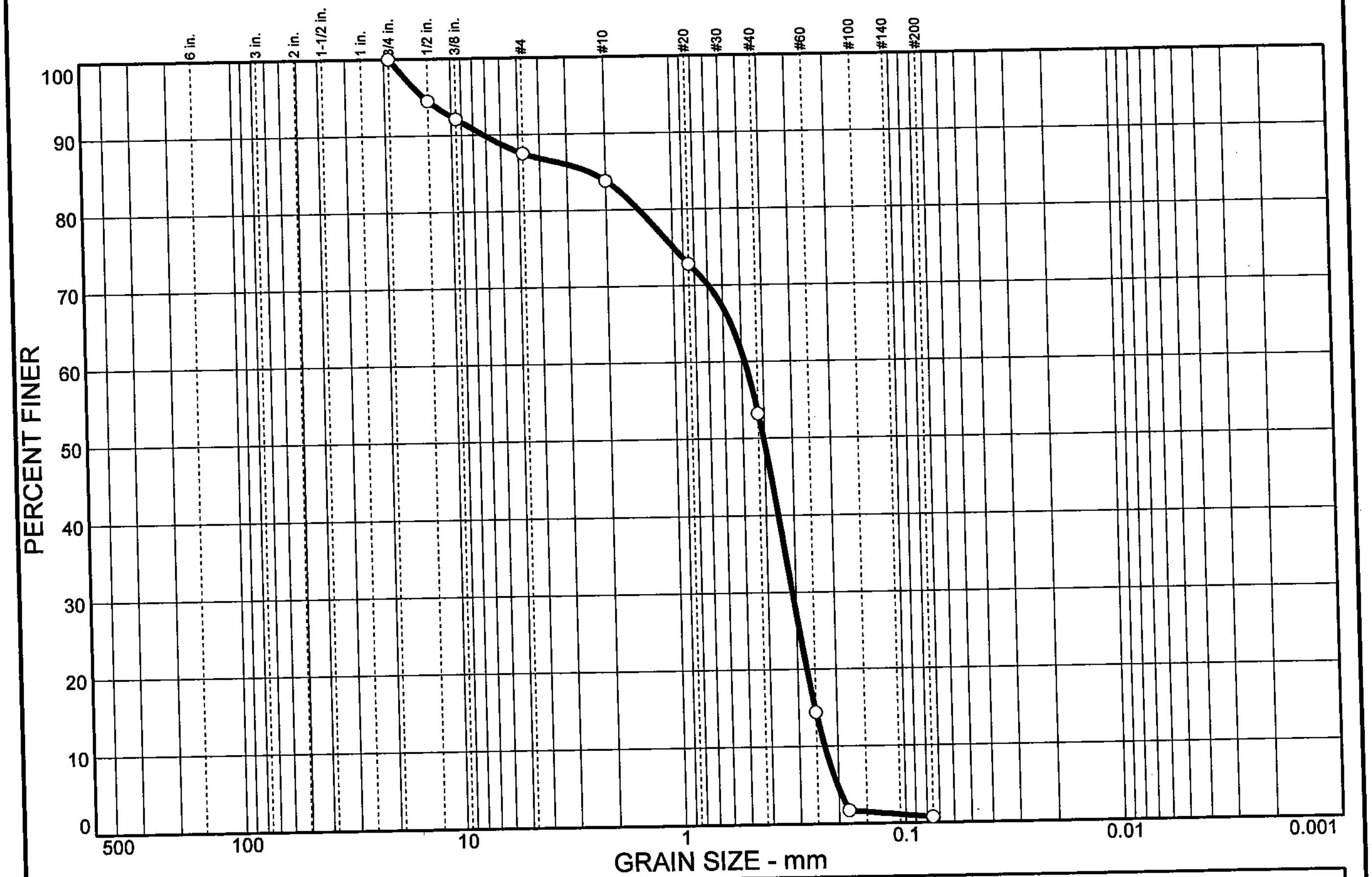
Remarks

Sample No.: 6035 **Source of Sample:** Client Samples **Date:**
Location: CI-08 #3 **Elev./Depth:** 10 FT 3 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	12.5	3.7	30.6	52.5	0.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	94.5		
3/8 in.	92.1		
# 4	87.5		
# 10	83.8		
# 20	72.8		
# 40	53.2		
# 60	14.4		
# 80	1.7		
# 200	0.7		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 2.38 D_{60}= 0.484 D_{50}= 0.404
D_{30}= 0.311 D_{15}= 0.253 D_{10}= 0.230
C_u= 2.10 C_c= 0.87

Classification

USCS= SP AASHTO= A-3

Remarks

Sample No.: 6036
Location: CI-09 #1

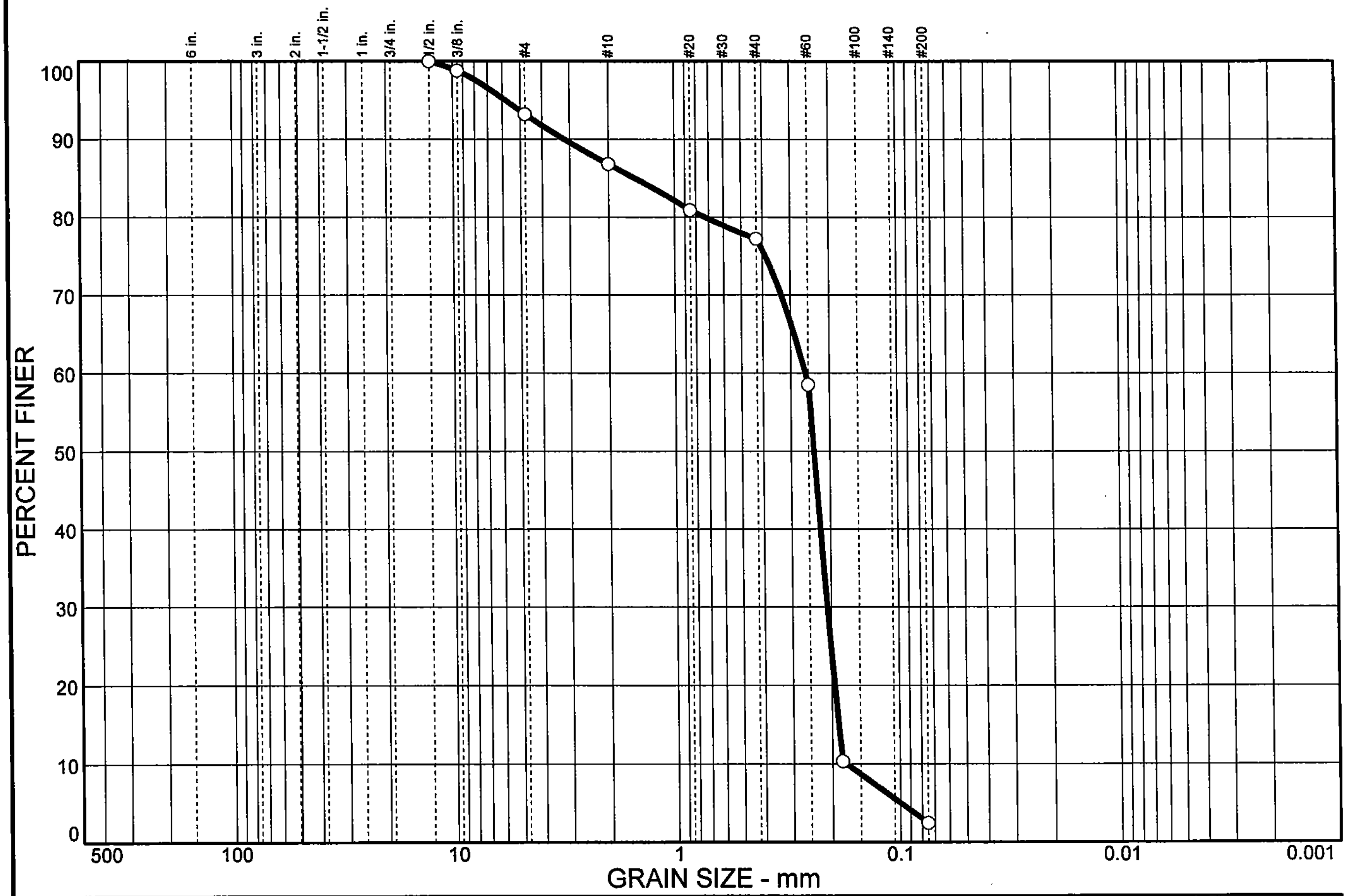
Source of Sample: Client Samples

Date:
Elev./Depth: 0 FT 0 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	6.8	6.4	9.6	74.8	2.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	98.8		
# 4	93.2		
# 10	86.8		
# 20	80.9		
# 40	77.2		
# 60	58.5		
# 80	10.3		
# 200	2.4		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 1.52 D_{60}= 0.258 D_{50}= 0.237
D_{30}= 0.209 D_{15}= 0.187 D_{10}= 0.174
C_u= 1.48 C_c= 0.97

Classification

USCS= SP AASHTO= A-3

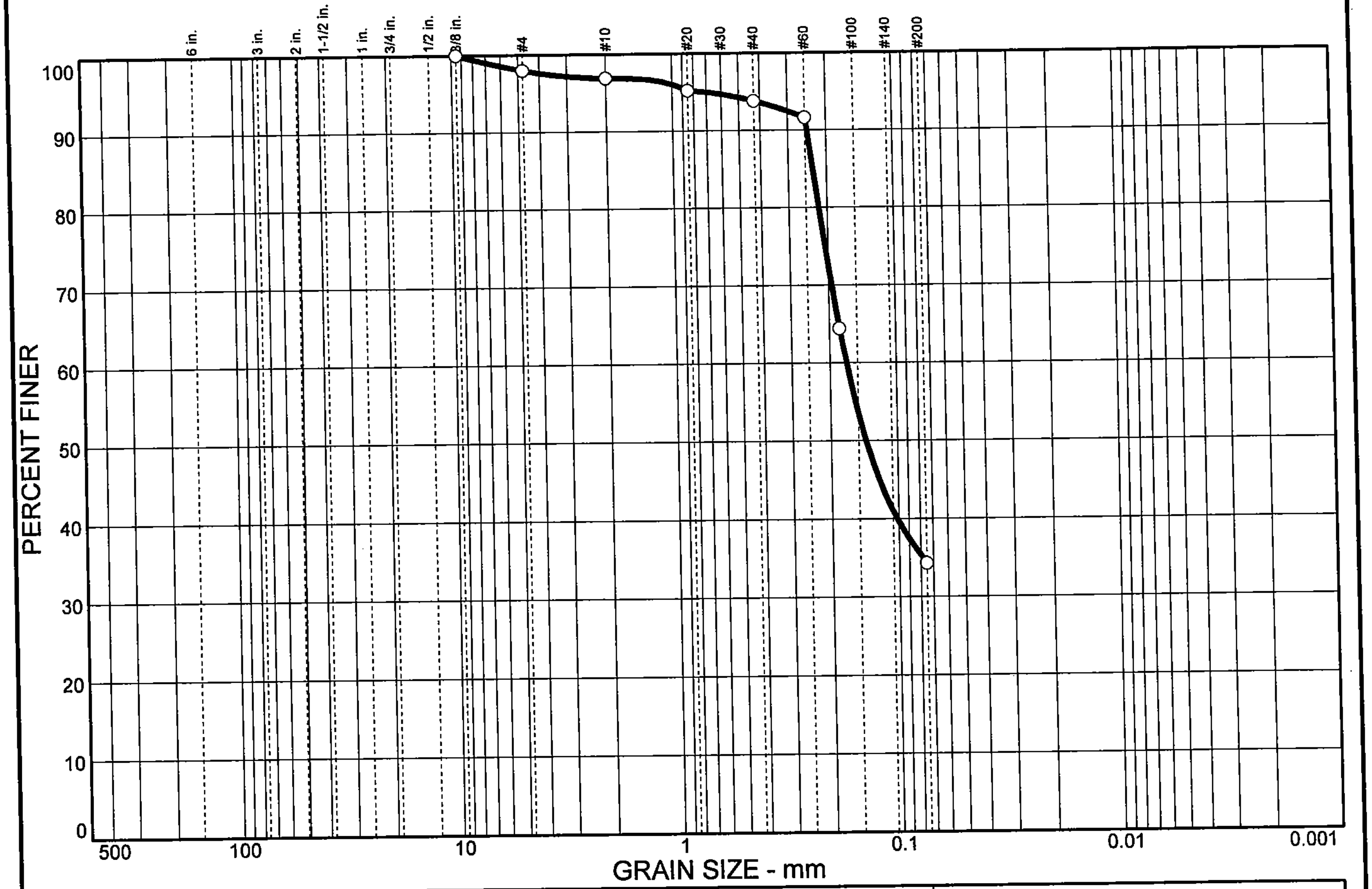
Remarks

Sample No.: 6037
Location: CI-09 #2
Source of Sample: Client Samples
Date:
Elev./Depth: 5 FT 1.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	2.0	1.1	3.1	59.5	34.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	98.0		
# 10	96.9		
# 20	95.2		
# 40	93.8		
# 60	91.6		
# 80	64.4		
# 200	34.3		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.232 D_{60}= 0.168 D_{50}= 0.139
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6038
Location: CI-09 #3

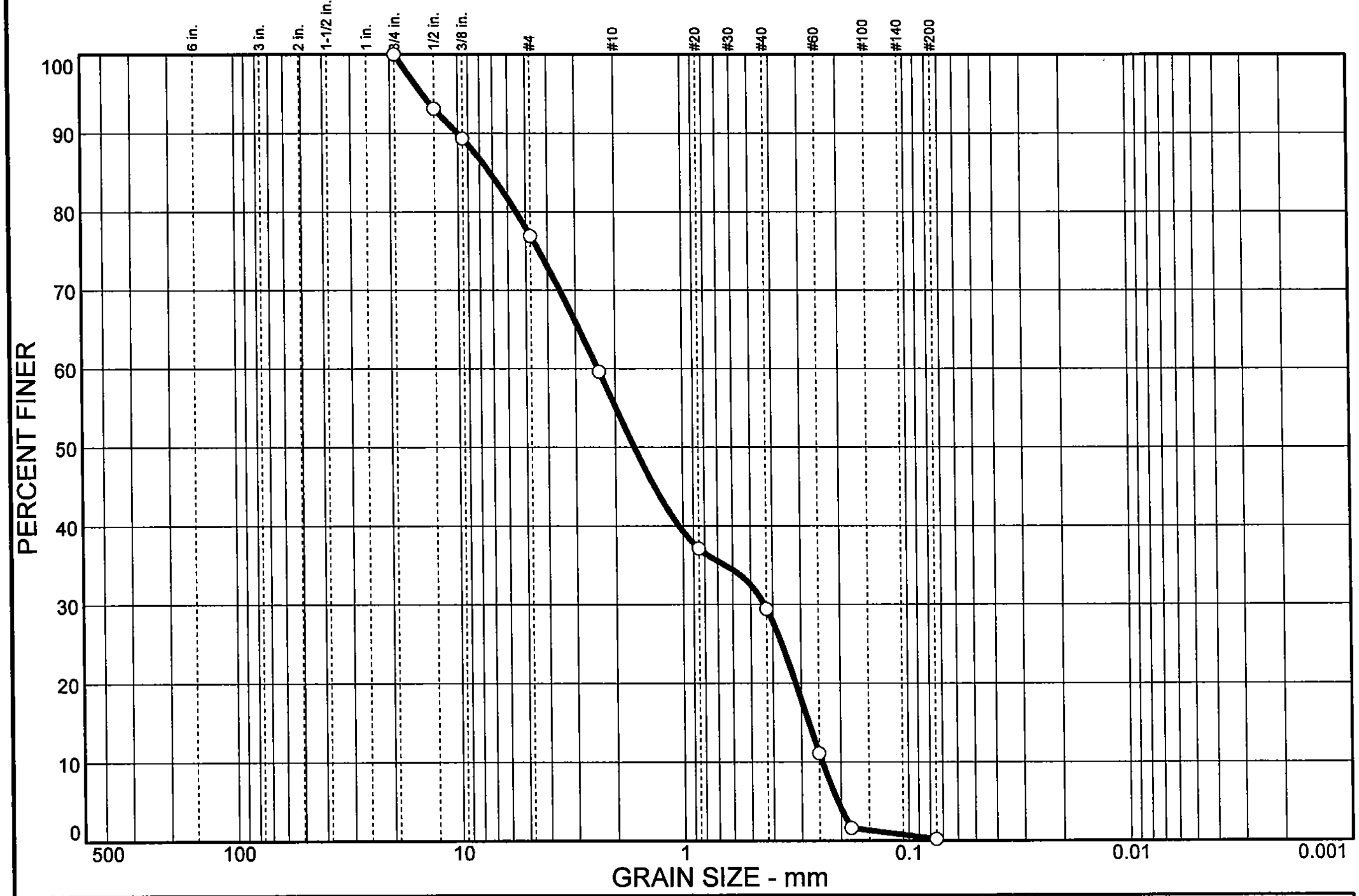
Source of Sample: Client Samples

Date:
Elev./Depth: 10 FT 3 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	23.1	21.8	25.7	29.2	0.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	93.1		
3/8 in.	89.3		
# 4	76.9		
# 8	59.6		
# 20	37.1		
# 40	29.4		
# 60	11.1		
# 80	1.6		
# 200	0.2		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 7.20 D_{60}= 2.40 D_{50}= 1.65
D_{30}= 0.436 D_{15}= 0.278 D_{10}= 0.242
C_u= 9.89 C_c= 0.33

Classification

USCS= SP AASHTO= A-1-b

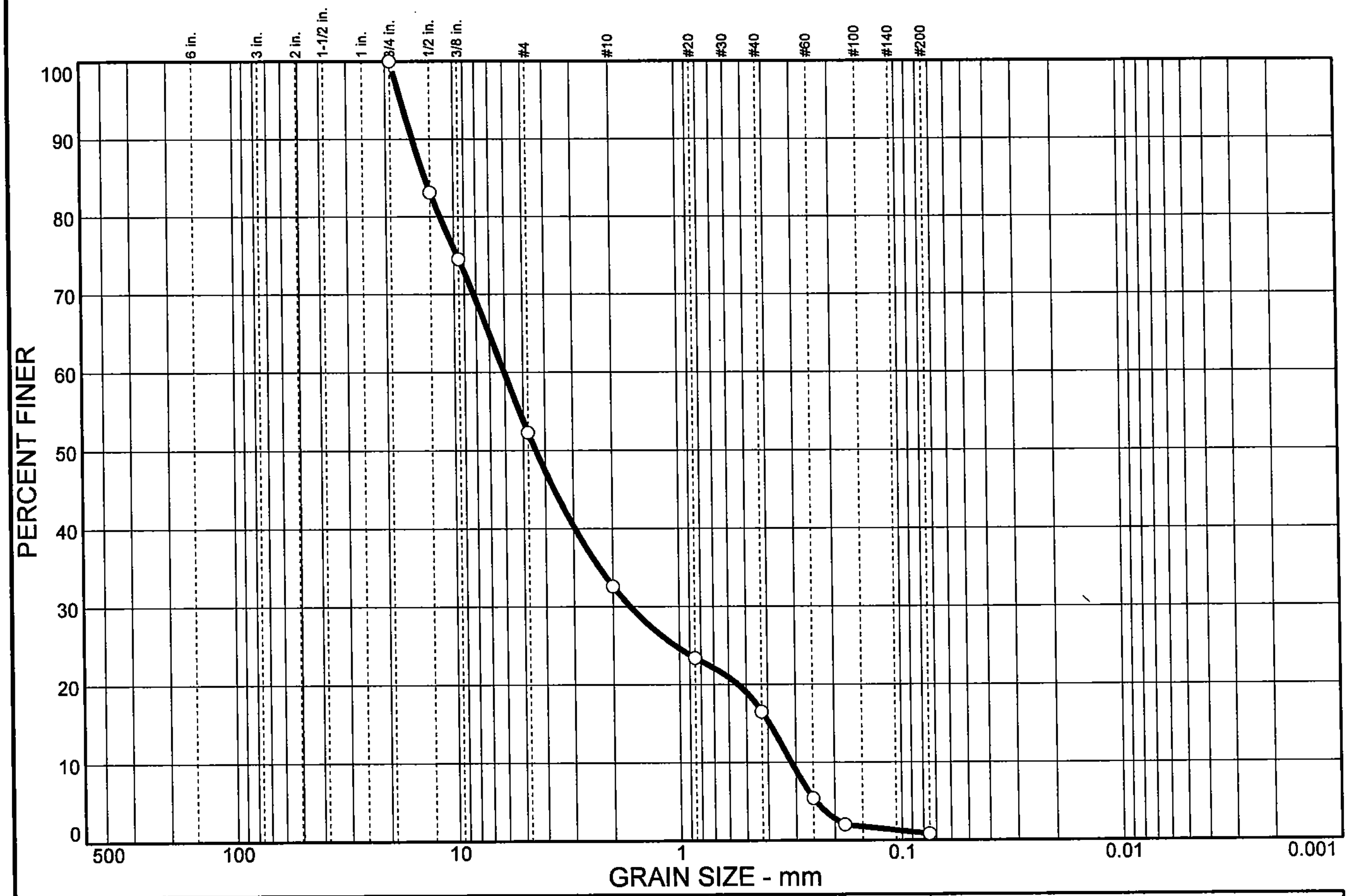
Remarks

Sample No.: 6039 **Source of Sample:** Client Samples **Date:**
Location: CI-10 #1 **Elev./Depth:** 0 FT 0 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	47.7	19.7	16.1	15.7	0.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	83.1		
3/8 in.	74.5		
# 4	52.3		
# 10	32.6		
# 20	23.4		
# 40	16.5		
# 60	5.4		
# 80	2.0		
# 200	0.8		

* (no specification provided)

Soil Description

Well-graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 13.4 D_{60}= 6.05 D_{50}= 4.39
D_{30}= 1.67 D_{15}= 0.393 D_{10}= 0.314
C_u= 19.26 C_c= 1.47

Classification

USCS= SW AASHTO= A-1-a

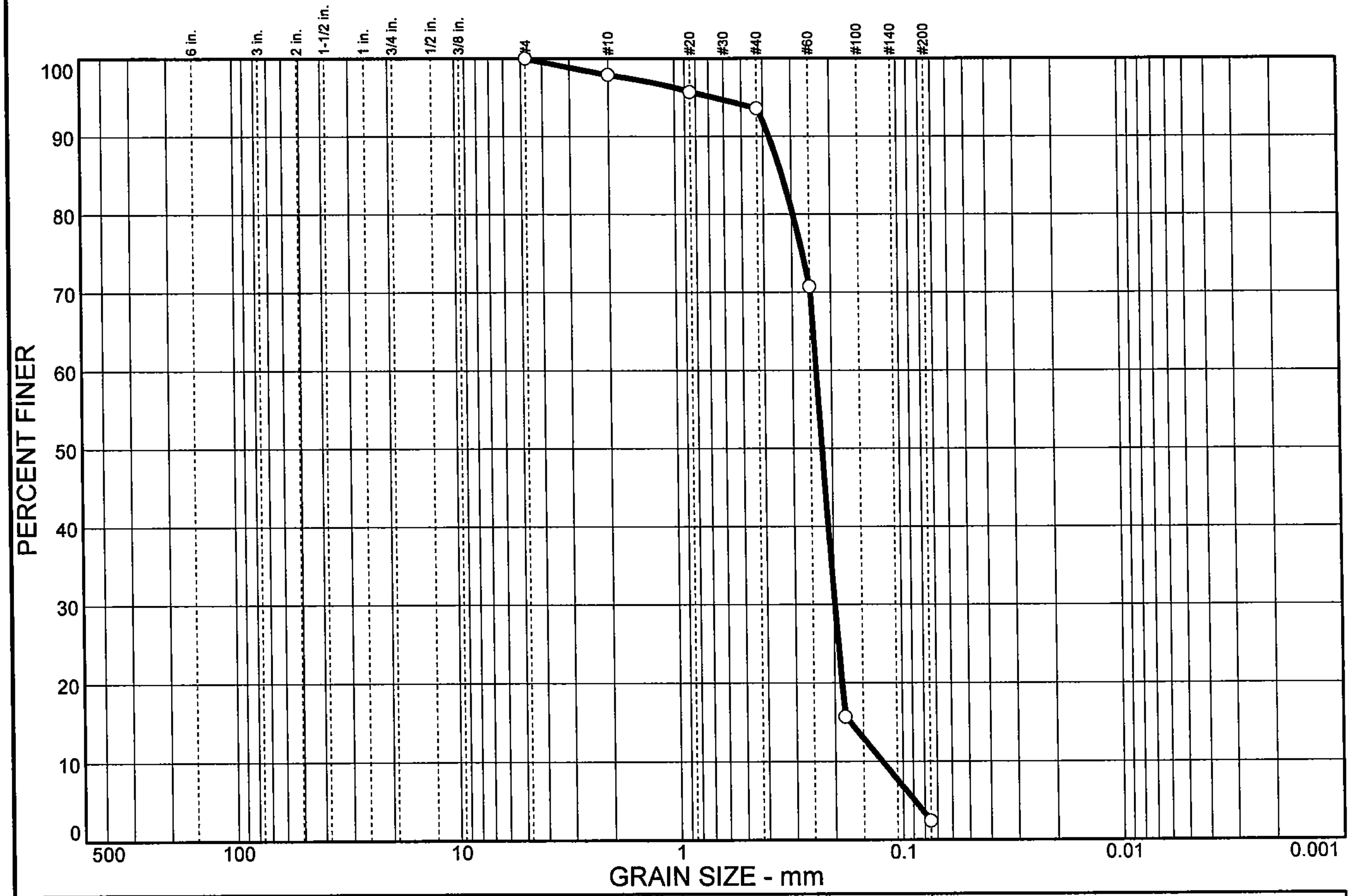
Remarks

Sample No.: 6040 **Source of Sample:** Client Samples **Date:**
Location: CI-10 #2 **Elev./Depth:** 5 FT 1.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	2.1	4.3	91.2	2.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
# 4	100.0		
# 10	97.9		
# 20	95.7		
# 40	93.6		
# 60	70.7		
# 80	15.7		
# 200	2.4		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.330 D_{60}= 0.236 D_{50}= 0.223

D_{30}= 0.199 D_{15}= 0.172 D_{10}= 0.124

C_u= 1.91 C_c= 1.35

Classification

USCS= SP AASHTO= A-3

Remarks

Sample No.: 6041 **Source of Sample:** Client Samples **Date:**

Location: CI-10 #3 **Elev./Depth:** 10 FT 3 m

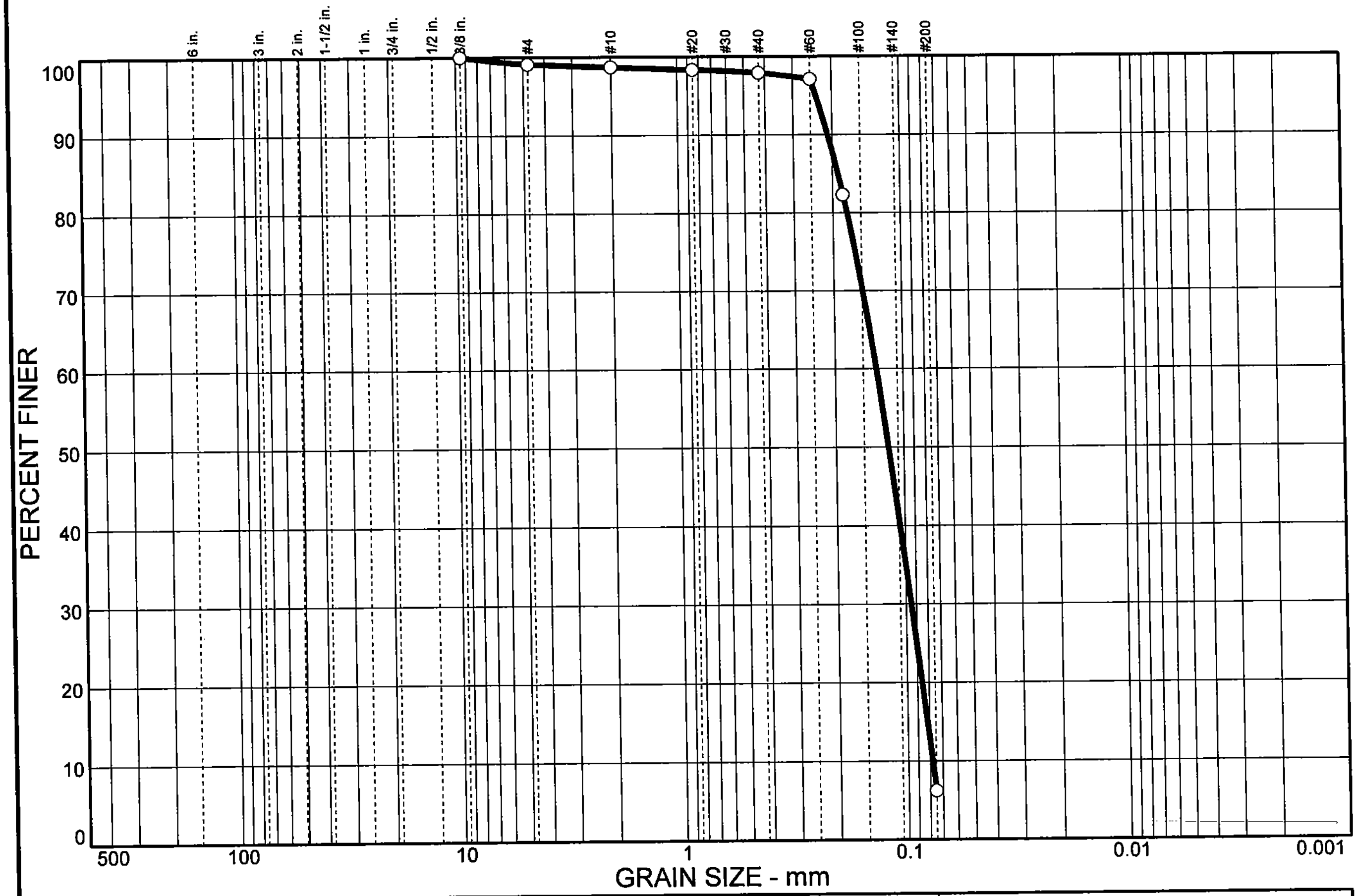
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.9	0.4	0.8	91.7	6.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	99.1		
# 10	98.7		
# 20	98.3		
# 40	97.9		
# 60	97.1		
# 80	82.3		
# 200	6.2		

* (no specification provided)

Soil Description

Poorly graded sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.189 D_{60}= 0.131 D_{50}= 0.117
D_{30}= 0.0949 D_{15}= 0.0818 D_{10}= 0.0778
C_u= 1.69 C_c= 0.88

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Sample No.: 6042
Location: CI-10 #4

Source of Sample: Client Samples

Date:
Elev./Depth: 15 FT 4.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Appendix C

Test Boring Logs and Laboratory Data
BIA Prospect

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **1 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,316,855 ft. ±**
Easting: **641,136 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-01**

Permanent: **BIA-01**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D.: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Foggy, -15 degrees, 5 mph winds
		1	Ice		5 13 21	ICE	ICE with Sand/Fines Inclusions							No sample collected, clear, ice, planar ice crystals larger than 2 inches with white interstitial ice
2														
4														
6		2	Vr	F4	5 15 28	SM	Silty SAND				0.25			Gray/ brown, frozen, subrounded gravel, fine to coarse sand, nonplastic (NP) fines, estimated 45% clear ice crystals less than .5 inch with interstitial ice.
8														gravel present in cuttings
10		3	Nbe	S2	19 44 50/ 4in.	SP-SM	Poorly graded SAND with Silt and Gravel	23	70	7	0.5			Brown, frozen, subrounded gravel, fine to coarse sand
12														
14														
16		4	Vr	S1	29 33 54	SP-SM	Poorly graded SAND with Silt and Gravel				0.25			Light brown, frozen, subrounded gravel, fine to coarse sand, Estimated 30% clear and cloudy ice crystals randomly distributed
18														
20		5	Vx	F4	30 40 52	SM	Silty SAND	1	74	25				Brown and gray, frozen, fine to coarse sand, NP fines, estimated 5% ice, 0.5-inch clusters of small cloudy ice crystals
22														
24														
26		6	Vr	F1	18 26 26	ML	SILT							Gray, frozen, NP fines, randomly oriented-clusters and veins of small white ice crystals, estimated 15% ice
28														
30		7	Vs	F4	11 17 24	ML	SILT							Gray, frozen, NP fines, estimated 10% ice, horizontally stratified 1/16 inch veins of small cloudy ice crystals
32														Bottom of Hole 31.5 ft. PID = (Cold/Hot) Photo Ionization Detector

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-01**

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **4 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,313,928 ft. ±** Easting: **641,593 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-02** Permanent: **BIA-02**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size			Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, -10 degrees, 15 mph winds**
								%Gravel	%Sand	%Fines				
2 4		1	Ice	F4	6 11 17	ICE	ICE with Sand/Fines Inclusions							No sample collected, Ice (large planer clear ice crystals with white interstitial ice)
6 8		2	Vx	F4	7 15 50/ 5in.	ML	SILT							1st foot of sample is ice as above, last 6 inches is gray, frozen, fine sand, non plastic (NP) fines, estimated 10% ice, sampler was overstuffed 50 blows is not accurate
10 12		3	Vr	F4	48 41 45	SM	Silty SAND with Gravel				0.25			Gray and brown, subrounded gravel, fine to coarse sand, Estimated 10% visible small white ice crystals in random formations greater than .5 inch thick
14 16		4	Nbe	F3	35 50/5in.	SM	Silty SAND	3	74	23	0.375			Gray, frozen, fine to medium sand, cuttings from 16 feet down are black and slightly plastic when thawed
18 20 22		5	Vx	F4	12 23 36	CL-ML	Silty CLAY							Dark gray, very fine to fine sand, fines are slightly plastic when thawed, Estimated 20% visible ice (uniformly distributed small cloudy-clear granuler ice crystals)
24 26 28		6	Vx	F4	15 29 34	CL-ML	Silty CLAY							Dark gray, frozen, fines are slightly to low plasticity when thatwed, small clear-white granular ice crystals throughout, estimated 30% visible ice
30		7	Vx	F4	10 15 20	CL-ML	Silty CLAY							Dark gray, frozen, fines are slightly to low plasticity when thawed, small clear-white granular ice crystals throughout, estimated 30% visible ice
32														Bottom of Hole 31.5 ft. PID = (Cold/Hot) Photo Ionization Detector

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-02**

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **5 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,313,857 ft. ±** Easting: **640,961 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-03** Permanent: **BIA-03**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks
														Sunny, 0 degrees, 5 mph winds
		1	Vr	F3	8 48 50/ 5in.	SM	Silty SAND		54	46	0.125			Gray and brown, frozen, subrounded gravel, fine to coarse sand, estimated 20% visible ice, uniformly distributed small white crystalls
		2	Vr	F3	20 50/ 4in.	SM	Silty SAND	3	67	30				Gray and brown, frozen, fine to medium sand, estimated 20% visible ice, less than 1 inch clusters of small granular white ice
		3	Nbe	F3	45 50/ 2in.	SM	Silty SAND							Brown, frozen, subrounded gravel, fine to medium sand
														Gravel in cuttings at 12'
		4	Vr	F4	14 28 38	ML	Sandy SILT				0.25			Gray, frozen, subrounded gravel, fine to coarse sand, estimated 10% visible ice, less than 0.5 inch random orientated veins and clusters of white small granular ice crystals
		5	Vx	F4	15 21 27	ML	SILT with Sand				0.125			Dark gray, frozen, subrounded gravel, fine sand, estimated 5% visible ice, small white individual ice crystals
		6	Vx	F4	12 22 20	ML	SILT							Dark gray, frozen, thawed cuttings have low plascicity, estimated 20% visible ice, small cloudy flat ice crystals
		7	Vx	F4	12 12 11	ML	SILT							Dark gray, frozen, thawed cuttings have low plascicity fines, estimated 20% visible ice, small cloudy flat ice crystals
														Bottom of Hole 31.5 ft. PID = (Cold/Hot) Photo Ionization Detector

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

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Date: **7 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,310,478 ft. ±** Easting: **641,008 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-04** Permanent: **BIA-04**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Partly cloudy, 0 degrees, 20 mph winds**
						ML	**SILT**							
2														
		1	Ice		5 28 40	ICE + silt	**Ice with silt inclusions**							**80% ice with 20% silt, silt is gray, ice is large clear crystals with white interstitial ice**
4														
		2	Ice		17 27 48	ICE + silt	**Ice with silt inclusions**							**80% ice with 20% silt, silt is gray, ice is large clear crystals with white interstitial ice**
6														
8														
10														
		3	Vr	F2	22 41 50/ 5in.	SM	**Silty SAND**	4	77	19	0.25			**Brown and gray, frozen, subrounded gravel, fine sand, small white ice crystals throughout, estimated 20% visible ice**
12														
14														
		4	Vs	F4	29 49 50/ 5in.	ML	**SILT**				0.25			**Gray, frozen, subrounded gravel, fine to coarse sand, estimated 5% visible ice, less than 1/8 inch thick bands of cloudy flakey ice crystals**
16														
18														
20														
		5	Vs	F4	18 25 32	ML	**SILT**							**Dark gray, frozen, estimated 3% visible ice, 1/8 inch horizontally stratified white ice veins**
22														
24														
		6	Vr	F4	14 18 19	ML	**SILT**							**Dark gray, frozen, estimated 20% small, clear - cloudy, flakey ice crystals throughout, cuttings have low plasticity fines**
26														
28														
30														
		7	Vr	F4	14 37 27	ML	**SILT**							**Dark gray, frozen, estimated 20% small, clear - cloudy, flakey ice crystals throughout**
32														**Bottom of Hole 31.5 ft.** **PID = (Cold/Hot) Photo Ionization Detector**

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Hole Number: **BIA-04**

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Date: **9 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,301,067 ft. ±**
Easting: **640,133 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-05**

Permanent: **BIA-05**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks
														Sunny, 0 degrees, 10 mph winds
2														
4														
6		1	Vr	F3	25 45 50/ 4in.	SM	Silty SAND	1	66	33	0.25			Brown and gray, frozen, subrounded gravel, fine to medium sand, nonplastic (NP) fines, 20% ice by volume, small white ice crystals throughout
8														
10		2	Vx	F3	30 50 54	SM	Silty SAND	1	55	44	0.25			Gray and brown, frozen, subrounded gravel, fine sand, NP fines, 5% ice by volume, individual inclusions to 0.5 inch of small white ice crystals
12														
14														
16		3	Vx	F2	19 42 42	SM	Silty SAND							Gray, frozen, fine sand, NP fines, 10% ice by volume, 0.5 inch inclusions and veins of small white to clear ice crystals
18														
20		4	Vx	F3	21 47 44	SM	Silty SAND							Gray and brown, frozen, fine sand, NP fines, 3% ice by volume, 1/16-inch horizontal veins of small white ice crystals
22														
24														
26		5	Vx	F3	22 38 41	SM	Silty SAND				0.25			Gray and brown, frozen, subrounded gravel, fine to coarse sand, NP fines, 3% ice by volume
		6	Vr	F3	30	SM	Silty SAND							Dark gray, frozen, fine sand, NP fines, 2% ice by volume, 1/8 inch randomly oriented veins of white ice
28														
30		7	Nbe	F3	27 45 30	SM	Silty SAND				0.25			Dark gray, frozen, subrounded gravel, fine to coarse sand, NP fines
32														Bottom of Hole 31.5 ft. Groundwater Not Encountered PID = (Cold/Hot) Photo Ionization Detector

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-05**

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Date: **9 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,301,447 ft. ±** Easting: **637,886 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-06**

Permanent: **BIA-06**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, 5 degrees, 10 mph winds**
						ML	SILT							Brown silt cuttings
		1	Ice		9 16 18	ICE	ICE with Sand/Fines Inclusions							Clear ice, large flat clear ice crystals with white intersticial ice
		2	Vx	F3	50 50/ 3in.	SM	Silty SAND		80	20	0.25			Gray and brown, frozen, subrounded gravel, fine sand, nonplastic (NP) fines, estimate 3% ice, small .5-inch white ice crystals
		3	Nbe	NFS	50 50/ 3in.	SP	Poorly graded SAND	5	93	2	0.5			Gray and brown, frozen, subrounded gravel, fine sand
		4	Nbn	F3	43 50 46	SM	Silty SAND	7	76	17				Gray and brown, frozen, fine to coarse sand, NP fines
		5	Nbe	F4	45 50/ 2in.	ML	Sandy SILT							Dark gray, frozen, fine sand, low plasticity fines
		6	Nbe	F4	30 38 44	ML	Sandy SILT							Dark gray, frozen, fine sand, NP fines
														Bottom of Hole 31.5 ft. Groundwater Not Encountered PID = (Cold/Hot) Photo Ionization Detector

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-06**

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Date: **10 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,301,276 ft. ±**
Easting: **643,097 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-07**

Permanent: **BIA-07**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **30.0 ft.**

Total Depth: **30.4 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks
														Sunny, 5 degrees, 20 mph winds
2														
4														
6		1	**Vr**	**F4**	**21 40 50/ 5in.**	**SM**	**Silty SAND with Gravel**				**0.5**			**Olive gray, frozen, subrounded gravel, fine to coarse sand, nonplastic (NP) fines, estimate 30% ice, .5 inch clusters of hard white ice crystals**
8														
10		2	**Vr**	**F3**	**22 34 40**	**SM**	**Silty SAND with Gravel**	**18**	**52**	**30**	**0.5**			**Olive gray, frozen, subrounded gravel, fine to coarse sand, NP fines, uniform large cloudy ice crystals throughout, estimate 40% ice**
12														
14														**Switched to auger core at 14.5'**
16		3	**Vr**	**F4**	**GRAB**	**SM**	**Silty SAND**				**0.5**			**Gray, frozen, subrounded gravel, fine sand, NP fines, estimate 5% ice, 1/16-inch viens of clear ice**
18		4	**Vs**	**PFS**	**GRAB**	**SP**	**Poorly graded SAND with Gravel**	**30**	**68**	**2**	**1.25**			**Gray and brown, frozen, subrounded gravel, fine sand, NP fines, estimate 10% ice, 1-inch thick layers of clear hard ice**
20		5	**Nbe**	**S2**	**GRAB**	**SP**	**Poorly graded SAND**				**2**			**Gray, frozen, rounded gravel, fine sand**
22														
24														
26		6	**Nbe**	**S2**	**50/ 1in.**	**SP**	**Poorly graded SAND**							**Gray, frozen, fine sand, NP fines**
28														
30		7	**Nbe**	**F3**	**50/ 5in.**	**SM**	**Silty SAND**							**Dark gray, frozen, fine sand, NP fines**
32														**Bottom of Hole 30.4 ft.** **Groundwater Not Encountered** **PID = (Cold/Hot) Photo Ionization Detector**

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-07**

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Date: **12 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,301,091 ft. ±** Easting: **645,540 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-08**

Permanent: **BIA-08**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **30.0 ft.**

Total Depth: **30.4 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, 5 degrees, 30 mph winds**
2														
4														
6		1	Nbe	F2	38 50/ 4in.	SP-SM	**Poorly graded SAND with Silt**							**Gray, frozen, fine sand, nonplastic (NP) fines**
8														
10		2	Vx	F2	32 44 52	SM	**Silty SAND with Gravel**	18	58	24	0.25			**Gray, frozen, subrounded to rounded gravel, fine sand, NP fines, .5 inch thick clusters of small white ice crystals**
12														
14														
16		3	Ice + Vx	F3	53 44 35	SM	**Silty SAND**		51	49				**Gray and brown, frozen, fine sand, NP fines, one 4-inch thick band of flat clear large ice crystals with silt and white interstitial ice**
18														
20		4	Vx	F3	24 35 45	SM	**Silty SAND**	2	54	44	0.5			**Dark gray, frozen, subrounded gravel, fine sand, NP fines, individual clusters of white ice crystals less than 0.5 inch thick**
22														
24														
26		5	Nbe	S2	50/ 4in.	SP	**Poorly graded SAND**							**Gray, frozen, fine sand**
28														
30		6	Nbe	NFS	50/ 4in.	SP	**Poorly graded SAND**							**Not enough sample to collect data**
32														**Bottom of Hole 30.4 ft.** **Groundwater Not Encountered** **PID = (Cold/Hot) Photo Ionization Detector**

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Date: **13 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,298,400 ft. ±** Easting: **640,254 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-09**

Permanent: **BIA-09**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D.: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size			Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, 10 degrees, 10 mph winds**
								%Gravel	%Sand	%Fines				
6		1	Ice	F4	22 28 43	SM	Silty SAND with Gravel				0.5			Gray and brown, frozen, angular to subrounded gravel, fine to coarse sand, NP fines, estimate 30% organics by volume, estimate 60% ice by volume, clear ice crystals less than .5 inch thick with white interstical ice
10		2	Ice	F4	17 28 41	ML	Sandy SILT							Gray, frozen, fine sand, NP fines, estimate 65% ice by volume, large clear planar ice crystals with white interstital ice
16		3	Vx	F3	21 32 35	SM	Silty SAND	4	58	38	0.25			Gray and brown, frozen, subrounded to rounded gravel, fine sand, NP fines, small white ice crystals less than .25 inch thick, 10% ice by volume
18														gravel in cuttings at 18 feet
20		4	Nbe	F3	23 29 26	SM	Silty SAND with Gravel	13	56	31	0.5			Gray and brown, frozen, subrounded to rounded gravel, fine and coarse sand (mostly fine), NP fines
24														gravel in cuttings to 25 feet, no more than 30% gravel, lots of fines
26		5	Vr	F3	23 23 27	SM	Silty SAND				0.25			Gray, frozen, subrounded to rounded gravel, fine sand, NP fines, randomly oriented veins of small white ice crystals less than .125 inch thick
30		6	Nbe	S2	24 25 53	SP-SM	Poorly graded SAND with Silt and Gravel	37	52	11	0.5			Dark gray, frozen, subrounded to rounded gravel, fine and coarse sand, NP fines
32														Bottom of Hole 31.5 ft. Groundwater Not Encountered PID = (Cold/Hot) Photo Ionization Detector

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Date: **14 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,290,706 ft. ±** Easting: **635,797 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-10**

Permanent: **BIA-10**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**

☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **30.0 ft.**

Total Depth: **30.3 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, 5 degrees, 20 mph winds**
						PT	**PEAT**							**Brown, frozen, silty peat**
2														
4														
6		1	**Vr**	**F4**	**23 23 53**	**OL**	**Organic SILT**							**Brown and gray, frozen, organic fines, estimate 60% organics by volume, estimate 40 % ice by volume**
8														
10		2	**Vr**	**F4**	**20 30 35**	**OL**	**Organic SILT**							**Brown and gray, frozen, organic fines, estimate 60% organics by volume, estimate 40 % ice by volume**
12														
14														
16		3	**Nbe**	**F4**	**21 34 34**	**ML**	**Sandy SILT**	**2**	**47**	**51**	**0.25**			**Brown, frozen, subrounded to rounded gravel, fine sand, NP fines**
18														
20		4	**Nbn**	**S2**	**40 50/ 5in.**	**SP-SM**	**Poorly graded SAND with Silt**							**Gray and brown, frozen, fine sand, nonplastic (NP) fines**
22														
24														
26		5	**Vx**	**F2**	**30 30 50/ 3in.**	**SM**	**Silty SAND**		**83**	**17**	**0.5**			**Gray and brown, frozen, subrounded gravel, fine and coarse sand, individual clusters of clear ice crystals less than .5 inch thick with white interstitial ice**
28														
30		6	**Nbe**	**F2**	**50/ 3in.**	**SM**	**Silty SAND**							**Gray and brown, frozen, fine sand, NP fines, low recovery**
32														**Bottom of Hole 30.3 ft. Groundwater Not Encountered PID = (Cold/Hot) Photo Ionization Detector**

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Project: **Coastal Storm Damage Reduction** **Barrow, Alaska**		Page 1 of 1 Date: **14 Apr 2004**
Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**		Elevation Datum: ☐ MSL ☐ other
Location: Northing: **6,293,316 ft. ±** Easting: **640,159 ft. ±**		Top of Hole Elevation:

Hole Number, Field: **TB-11**	Permanent: **BIA-11**	Operator: **Lyle Cain & Travis Coghill**	Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **30.0 ft.**

Total Depth: **30.5 ft.**

Hammer Weight:	Split Spoon I.D:	Size and Type of Bit:	Type of Equipment:	Type of Samples:
340 lbs	**3 in.**	**7 in. Hollow Stem Auger**	**CME-45**	**Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, 10 degrees, 15 mph winds**
2														
4														
6		1	**Vr**	**F4**	**22 30 25**	**ML**	**Sandy SILT**							**Gray, frozen, fine sand, nonplastic (NP) fines, estimate 30% ice by volume, small white and clear ice crystals throughout**
8														
10		2	**Vr**	**F3**	**9 9 14**	**SM**	**Silty SAND with Gravel**	**10**	**66**	**24**	**0.25**			**Light brown, frozen, subrounded gravel, fine sand, NP fines, estimate 30 % ice by volume, small white and clear ice crystals throughout**
12														
14														
16		3	**Vr**	**F4**	**33 45 50/ 4in.**	**ML**	**Sandy SILT**							**Gray, frozen, fine sand, NP fines, estimate 40% ice by volume, small clear ice crystals throughout with white interstitial ice**
18														
20		4	**Vx**	**F3**	**50/ 5in.**	**SM**	**Silty SAND**							**Gray and brown, frozen, fine sand, NP fines, estimate 10% ice by volume, individual small white ice crystals less than .5 inch thick**
22														
24														
26		5	**Nbe**	**F2**	**50/ 4in.**	**SM**	**Silty SAND**							**Gray, frozen, fine sand, NP fines**
28														
30		6	**Nbe**	**F2**	**85**	**SM**	**Silty SAND**							**Dark gray, frozen, fine sand, NP fines**
32															**Bottom of Hole 30.5 ft.** **Groundwater Not Encountered** **PID = (Cold/Hot) Photo Ionization Detector**

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-11**

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EXPLORATION LOG

Project:	**Coastal Storm Damage Reduction** **Barrow, Alaska**
Page 1 of 1	Date: **18 Apr 2004**
Drilling Agency:	☐ Alaska District ☒ Other **Denali Drilling**
Elevation Datum:	☐ MSL ☐ other
Location:	Northing: **6,294,807 ft. ±** Easting: **643,484 ft. ±**
Top of Hole Elevation:	
Hole Number, Field:	**TB-12**
Permanent:	**BIA-12**
Operator:	**Lyle Cain & Travis Coghill**
Inspector:	**Aaron Banks**
Type of Hole:	☒ other **Auger** ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer
Depth to Groundwater:	**NE**
Depth Drilled:	**30.0 ft.**
Total Depth:	**30.3 ft.**
Hammer Weight:	**340 lbs**
Split Spoon I.D:	**3 in.**
Size and Type of Bit:	**7 in. Hollow Stem Auger**
Type of Equipment:	**CME-45**
Type of Samples:	**Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, 10 degrees, 10 mph winds**
		1	Ice		7 20 20	Ice	Ice							No sample collected, large clear ice crystals with white interstitial ice
		2	Ice		10 13 15	Ice	Ice							No sample collected, large clear ice crystals with white interstitial ice
		3	Ice		10 18 34	Ice	Ice							No sample collected, large clear ice crystals with white interstitial ice
		4	Ice	F2	31 50/ 5in.	SM	Silty SAND							Light brown, frozen, fine sand, nonplastic (NP) fines, estimate 40% ice by volume, large cloudy ice crystals with white interstitial ice, the ice soil interface is approximately 20.7 feet below the surface
		5	Nbe	F2	50/ 4in.	SM	Silty SAND							Gray and brown, frozen, fine sand, NP fines
		6	Nbe	F2	50/ 3in.	SM	Silty SAND							Gray and frozen, fine sand, NP fines

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32

Bottom of Hole 30.3 ft.
Groundwater Not Encountered
PID = (Cold/Hot) Photo Ionization Detector

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **18 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,288,499 ft. ±** Easting: **640,373 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-13** Permanent: **BIA-13**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, 10 degrees, 10 mph winds**
2 4						PT	PEAT							Brown, frozen
6 8		1	Ice		11 14 20	Ice	Ice							Large clear ice crystals with white interstital ice, no soil color
10 12 14		2	Nbe	F2	11 26 34/ 3in.	SM	Silty SAND							Gray and brown, frozen, trace of gravel less than .25 inch, fine sand, nonplastic (NP) fines
16 18		3	Vx	F3	50 50 50/ 3in.	SM	Silty SAND	1	61	38	0.5		1	Gray and brown, frozen, subrounded to rounded gravel, fine sand, NP fines, estimate 5% ice by volume, individual clusters of small white ice crystals less than 1/2 inch wide
20 22 24		4	Nbe	NFS	50/ 3in.	SP	Poorly graded SAND	4	93	3	0.25		0	Light brown, frozen, rounded gravel, fine to medium sand, NP fines
26 28		5	Vx	F4	52 42 50/ 3in.	SP ML	Poorly graded SAND Sandy SILT							Dark gray and brown, fine sand, NP fines, estimate 2% ice by volume, small individual white ice crystals, first 3 inches of sample not retained (same as sample 4)
30		6	Vx	F4	30 42 54	ML	Sandy SILT							Dark gray, frozen, fine sand, estimated 2% visible ice, individual, .125 inch thick veins of small white ice crystals
32														Bottom of Hole 31.5 ft. Groundwater Not Encountered PID = (Cold/Hot) Photo Ionization Detector

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-13**

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **19 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,282,490 ft. ±** Easting: **638,855 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-14**

Permanent: **BIA-14**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Cloudy, 12 degrees, 10 mph winds
						ICE	ICE with Sand/Fines Inclusions							Ground ice and snow
2						PT	PEAT							Brown, frozen
4 6		1	Vx & Nbe	F3	48 50/ 5in.	SM	Silty SAND							Gray and brown, frozen, fine sand, nonplastic (NP) fines
8 10 12		2	Vx	F4	30 40 34	ML	Sandy SILT							Dark gray, frozen, fine sand, NP fines, 5% ice by volume, small ice crystals
14 16		3	Nbe	F4	26 50/ 5in.	ML	Sandy SILT							Dark gray, frozen, fine sand, NP fines
18 20 22		4	Nbe	F2	50/ 5in.	SP-SM	Poorly graded SAND with Silt	1	92	7				Light brown and gray, frozen, fine sand, NP fines
24 26 28		5	Nbn	F4	33 48 50	ML	Sandy SILT							Dark gray, frozen, fine sand, NP fines
30		6	Nbn	F4	12 16 22	ML	SILT							Dark gray, frozen, NP fines
32														Bottom of Hole 31.5 ft. PID = (Cold/Hot) Photo Ionization Detector

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-14**

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **20 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,282,420 ft. ±** Easting: **642,146 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-15**

Permanent: **BIA-15**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**

☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks
														Sunny, -5 degrees, 10 mph winds
2														
4														
6		1	Vr	F4	24 33 50	ML-OL	**Sandy SILT-Organic SILT mix**							**Gray and brown, frozen, fine sand, nonplastic (NP) fines, small white ice crystals on fresh sufaces, estimated 10% visible ice, estimated 10% organics by volume**
8														
10		2	Nbn	F3	14 50 50/5in.	SM	**Silty SAND**	4	65	31	0.75			**Gray and brown, frozen, subrounded to rounded gravel, fine to medium sand, NP fines**
12														
14														
16		3	Vx	F3	16 30 30	SM	**Silty SAND**							**Gray and brown, frozen, fine to coarse sand, NP fines, estimated 2% visible ice, individual inclusions of small white to clear ice crystals less then .5 inch thick**
18														
20		4	Nbe	F4	33 50/ 5in.	ML	**Sandy SILT**		49	51	0.5			**Gray and brown, frozen, subrounded to rounded gravel, fine to coarse sand, NP fines**
22														
24														
26		5	Nbn	F4	10 10 14	ML	**SILT**							**Dark gray, frozen, NP fines**
28														
30		6	Nbn	F4	17 17 16	ML	**SILT**							**Dark gray, frozen, NP fines**
32														**Bottom of Hole 31.5 ft.** **PID = (Cold/Hot) Photo Ionization Detector**

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **20 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,300,276 ft. ±** Easting: **639,972 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-16** Permanent: **BIA-16**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **40.0 ft.**

Total Depth: **41.0 ft.**

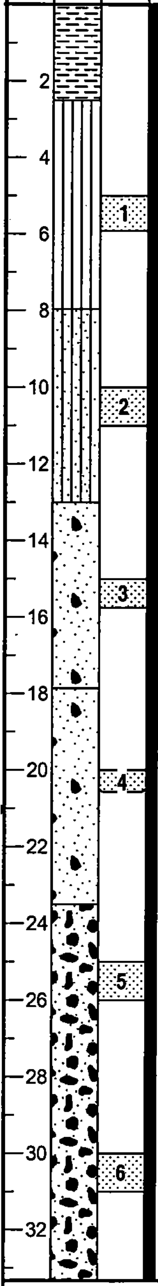
Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**



Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Sunny, 5 degrees
						OL	Organic SILT							Dark brown, frozen
		1	Nbe	F4	14 50/ 5in.	ML	SILT							Brown, frozen, nonplastic (NP) to low plasticity fines, 25% ice by volume
		2	Vr	F4	21 55	ML	Sandy SILT				0.25			Brown, frozen, rounded gravel, fine sand, NP fines, 30% ice by volume
		3	Vx	NFS	22 50/ 3in.	SP	Poorly graded SAND	8	90	2	0.25			Brown, frozen, rounded gravel, fine to coarse sand, 20% ice by volume
		4	Vx	NFS	50	SP	Poorly graded SAND with Gravel	49	50	1	0.375			Brown, frozen, rounded gravel, fine to coarse sand
		5		NFS	GRAB	GP	Poorly graded GRAVEL with Sand	67	31	2	0.75			Brown, frozen, rounded gravel, fine to coarse sand
		6		NFS	GRAB	GP	Poorly graded GRAVEL with Sand	72	26	2	0.75			Brown, frozen, rounded gravel, fine to coarse sand

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-16**

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **20 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,300,276 ft. ±** Easting: **639,972 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-16** Permanent: **BIA-16**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **40.0 ft.**

Total Depth: **41.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, 5 degrees**
34														
		7		**NFS**	**GRAB**	**GP**	**Poorly graded GRAVEL with Sand**	**63**	**35**	**2**	**0.5**			**Brown, frozen, rounded gravel, fine to coarse sand**
36														
38														
40		8		**F2**	**GRAB**	**SM**	**Silty SAND**							**Gray, frozen, fine sand, NP fines**
42														**Bottom of Hole 41.0 ft.** **PID = (Cold/Hot) Photo Ionization Detector**
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-16**

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **20 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,806 ft. ±** Easting: **640,062 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-17** Permanent: **BIA-17**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **40.0 ft.**

Total Depth: **40.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, 5 degrees
2						OL	Organic SILT							Dark brown, frozen, nonplastic (NP) fines
4 6 8		1	Vx & Vr	F4	7 14 35	ML	SILT							Brown, frozen, NP fines, 40% ice by volume
10 12		2	Vx	F4	29 60	ML	SILT				0.375			Brown, frozen, rounded gravel, fine sand, NP fines, 25% ice by volume
14 16 18		3	Nbe	F3	30 50/ 3in.	SM	Silty SAND with Gravel	20	59	21	0.375			Brown, frozen, rounded gravel, fine to coarse sand, NP to low plasticity fines
20 22		4	Nbe	F3	12 39 55	SM	Silty SAND with Gravel				0.375			Brown, frozen, rounded gravel, fine sand, NP fines
24 26 28		5		F4		ML	Sandy SILT	12	33	55	0.375			Brown, frozen, rounded gravel, fine to coarse sand, NP fines
30 32		6		S2		SP	Poorly graded SAND with Gravel	42	53	5	0.375			Brown, frozen, rounded gravel, fine to coarse sand, NP fines, pieces of coal

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-17**

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **20 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,806 ft. ±** Easting: **640,062 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-17**

Permanent: **BIA-17**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**

☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **40.0 ft.**

Total Depth: **40.5 ft.**

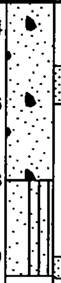
Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**



Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, 5 degrees
34 36 38		7		S2		SP	Poorly graded SAND with Gravel	30	65	5	0.25			Brown and gray, frozen, rounded gravel, fine to coarse sand, NP fines
40		8	Nbe	S2		SP-SM	Poorly graded SAND with Silt		94	6				Brown and gray, frozen, fine sand Bottom of Hole 40.5 ft. PID = (Cold/Hot) Photo Ionization Detector
42 44 46 48 50 52 54 56 58 60 62 64 66														

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-17**

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Project: **Coastal Storm Damage Reduction Barrow, Alaska**

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Date: **19 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,867 ft. ±** Easting: **643,126 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-18** Permanent: **BIA-18**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **38.5 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Light snow, 0 degrees
2						OL	Organic SILT							Dark brown, frozen, low plasticity fines
4 6 8		1	Ice		9 40 48	ICE	ICE with Sand/Fines Inclusions				0.5			90% ice by volume, few rounded gravel, NP fines
10 12		2	Vx & Vr	F4	3 22 45	ML	SILT							Brown, frozen, fine sand, NP fines, 40% ice by volume
14 16 18		3	Vx & Vr	F2	7 34 50/ 5in.	SM	Silty SAND				0.375			Brown, frozen, rounded gravel, fine sand, NP fines, ice 30% by volume
20 22		4	Vx & Vr	F3	14 58	SM	Silty SAND	8	76	16	0.25			Bown, frozen, rounded gravel, fine to coarse sand, NP fines, 20% ice by volume
24 26 28		5		F4	60/ 3in.	ML	Sandy SILT	9	37	54	0.5			Brown, frozen, rounded gravel, fine to coarse sand, NP fines
30 32		6	Nbn	S2	60/ 6in.	SP	Poorly graded SAND with Gravel	18	77	5	0.5			Brown, frozen, rounded gravel, fine to coarse sand

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-18**

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Project: **Coastal Storm Damage Reduction Barrow, Alaska**

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Date: **19 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,867 ft. ±** Easting: **643,126 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-18** Permanent: **BIA-18**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **38.5 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Light snow, 0 degrees**
34 36		7		F4		ML	Sandy SILT	5	40	55	0.5			Brown, frozen, rounded gravel, fine sand
38 40		8	Nbn	F2	GRAB	SP-SM	Poorly graded SAND with Silt and Gravel	38	52	10	0.5			Brown, frozen, rounded gravel, fine to coarse sand
42 44 46 48 50 52 54 56 58 60 62 64 66														Bottom of Hole 40.0 ft. PID = (Cold/Hot) Photo Ionization Detector

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-18**

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **18 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,916 ft. ±** Easting: **645,564 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-19**

Permanent: **BIA-19**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **30.0 ft.**

Total Depth: **30.8 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Clear, 0 degrees**
						OL	**Organic SILT**							**Brown, frozen, 50% ice by volume**
2														
4														
6		1	**Ice**	**F4**	**11** **29** **35**	**ICE + silt-OL**	**Ice with silt inclusions to Organic SILT**							**White ice with organics and nonplastic (NP) fines, 95% ice by volume**
8														
10		2	**Nbe & Vx**	**F4**	**22** **60**	**ML**	**Sandy SILT**							**Brown, frozen, fine sand, NP fines, 30% ice by volume**
12														
14														
16		3	**Vr & Vx**	**F4**	**15** **44**	**ML**	**Sandy SILT**							**Brown, frozen, rounded gravel, fine sand, NP fines, 40% ice by volume**
18														
20		4	**Vr & Vx**	**F3**	**29** **60**	**SM**	**Silty SAND**	**4**	**78**	**18**	**0.5**			**Brown, frozen, rounded gravel, fine sand, NP fines, 35% ice by volume**
22														
24														
26		5	**Vx & Vr**	**F4**	**21** **51**	**SM**	**Silty SAND**							**Brown, frozen, fine sand, NP fines, 25% ice by volume**
28														
30		6a	**Vr**	**NFS**	**27**	**SP**	**Poorly graded SAND**							**Gray, frozen, fine sand**
		6b	**Vr**	**F4**	**52/ 3in.**	**PT**	**PEAT**							**Dark brown peat, frozen**
32														**Bottom of Hole 30.8 ft.** **Groundwater Not Encountered** **PID = (Cold/Hot) Photo Ionization Detector**

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-19**

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **17 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,298,507 ft. ±** Easting: **645,593 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-20** Permanent: **BIA-20**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **30.0 ft.**

Total Depth: **30.8 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Clear, 5 degrees, windy**
2														
4														
6		1	Vx & Ice	F4	3 15 57	OL-ICE	**Organic SILT to ICE with Sand/Fines Inclusions**							**Dark brown, frozen, nonplastic (NP) fines, 90& ice by volume**
8														
10		2	Nbe	F4	20 55	ML	**SILT**							**Brown, frozen, NP to lowplasticity fines**
12														
14														
16		3	Nbe & Vx	F4	10 36 47	ML	**SILT**							**Brown, frozen, NP to low plasticity fines**
18														
20		4	Vr	F4	14 41 54	ML	**SILT**							**Brown, frozen, NP fines, 60% ice by volume**
22														
24														
26		5	Nbe	NFS	30 50/ 2in.	SP	**Poorly graded SAND**		97	3				**Brown, frozen, fine sand**
28														**10% gravel to 0.75 inch from 27.5 to 28.5 feet, no sample collected**
30		6	Nbe	NFS	37 50/ 3in.	SP	**Poorly graded SAND**							**Brown, frozen, fine sand**
32														**Bottom of Hole 30.8 ft.** **Groundwater Not Encountered** **PID = (Cold/Hot) Photo Ionization Detector**

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-20**

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Date: **20 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,266 ft. ±** Easting: **640,157 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-21** Permanent: **BIA-21**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **39.0 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Clear, -10 degrees
2						OL	Organic SILT							Dark brown, frozen
4 6 8		1	Ice	F4	8 30 27	ML	SILT							Brown, frozen, nonplastic (NP) fines, 75% ice by volume
10 12		2	Vx & Vr	F4	4 34 48	ML	Sandy SILT							Brown, frozen, NP fines, 50% ice by volume
14 16 18		3	Vx & Nbe	F4	24 50	SM	Silty SAND							Brown, frozen, NP fines
20		4	Nbe	F4	8 40 33	ML	SILT				0.5			Brown, frozen, NP fines
22				F2		SM	Silty SAND with Gravel				0.5			Brown, frozen, rounded gravel, fine to medium sand, NP fines
24 26		5	Nbn	F2	100	SP-SM	Poorly graded SAND with Silt and Gravel	39	50	11	0.75			Brown, frozen, rounded gravel, fine to coarse sand
28 30 32		6	Nbn	F1	Grab	GP-GM	Poorly graded GRAVEL with Silt and Sand	46	45	9	0.5			Dark brown, frozen, rounded gravel, fine to coarse sand, NP fines

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Hole Number: **BIA-21**

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Date: **20 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,266 ft. ±** Easting: **640,157 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-21** Permanent: **BIA-21**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **39.0 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Clear, -10 degrees**
34		7	Nbn	S1	Grab	GW	**Well-graded GRAVEL with Sand**	56	40	4	1			**Dark brown, frozen, rounded gravel, fine to coarse sand, NP fines**
36														
38														
40		8	Nbn	S2	Grab	SP	**Poorly graded SAND with Gravel**	47	49	4	1			**Dark brown, frozen, rounded gravel, fine to coarse sand, NP fines**
42														**Bottom of Hole 40.0 ft.** **PID = (Cold/Hot) Photo Ionization Detector**
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Hole Number: **BIA-21**

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Date: **24 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,300,612 ft. ±** Easting: **641,374 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-22**

Permanent: **BIA-22**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **29.0 ft.**

Total Depth: **30.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size			Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Clear, 5 degrees**
								%Gravel	%Sand	%Fines				
2						OL	Organic SILT							Dark brown, frozen
4 6 8		1	Vx & Vr	F4	9 33 53	ML	SILT							Brown, frozen, nonplastic (NP) fines, 60% ice by volume
10 12		2	Vx	F4	20 50/ 5in.	ML	Sandy SILT							Brown, frozen, fine sand, NP fines
14 16		3	Nbe	F2	10 50/ 4in.	SM	Silty SAND with Gravel				0.375			Brown, frozen, rounded gravel, fine sand, NP fines
18 20 22		4	Nf	F4	Grab	ML	SILT with Sand	6	42	52	0.5			Dark brown, frozen, rounded gravel, fine to coarse sand
24 26		5	Nf	NFS	Grab	GW	Well-graded GRAVEL with Sand	52	46	2	1			Brown, frozen, rounded gravel, fine to coarse sand
28 30		6	Nbe	F3	Grab	SM	Silty SAND	6	74	20	0.375			Brown, frozen, rounded gravel, fine to coarse sand
32														Bottom of Hole 30.0 ft. PID = (Cold/Hot) Photo Ionization Detector

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Date: **23 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,836 ft. ±** Easting: **641,594 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-23** Permanent: **BIA-23**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **39.0 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Partly cloudy, 5 degrees
2						OL	Organic SILT							Dark brown, frozen
4 6		1	Ice		9 34 30	ICE	ICE with Sand/Fines Inclusions							White ice with 5% silt
8 10 12		2	Nbe	F4	10 42 54	ML	Sandy SILT							Brown, frozen, fine sand, nonplastic (NP) fines
14 16		3	Nbe	F4	33 57	ML	Sandy SILT							Brown, frozen, fine sand, NP fines
18 20 22		4	Nf	F4	Grab	ML	Sandy SILT with Gravel	13	30	57	0.75			Brown, frozen, rounded gravel, medium to coarse sand, NP fines
24 26 28		5	Nf	F4	Grab	ML	Sandy SILT with Gravel	15	31	54	0.375			Dark brown, frozen, rounded gravel, fine to coarse sand, NP fines
30 32		6	Nf	S1	Grab	GP-GM	Poorly graded GRAVEL with Silt and Sand	55	39	6	0.75			Dark brown, frozen, rounded gravel, fine to coarse sand, NP fines

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Date: **23 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,836 ft. ±** Easting: **641,594 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-23** Permanent: **BIA-23**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **39.0 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size			Max Size (in.)	PID (ppm)	% Water	Description and Remarks Partly cloudy, 5 degrees
								%Gravel	%Sand	%Fines				
34		7	Nf	NFS	Grab	GP	Poorly graded GRAVEL with Sand	73	27		1			Dark brown, frozen, rounded gravel, fine to coarse sand, NP fines
36						SP	Poorly graded SAND							Fine frozen sand (by drill action)
38						GP	Poorly graded GRAVEL with Sand							By drill action
40		8	Nbe	F3	Grab	SM	Silty SAND with Gravel	21	65	14	0.25			Dark brown, frozen, rounded gravel, fine to coarse sand, NP fines
														Bottom of Hole 40.0 ft. PID = (Cold/Hot) Photo Ionization Detector
42														
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Hole Number: **BIA-23**

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Date: **23 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,403 ft. ±** Easting: **641,735 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-24**

Permanent: **BIA-24**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **39.0 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size			Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Cloudy, 5 degrees**
								%Gravel	%Sand	%Fines				
2						OL	**Organic SILT**							**Dark brown, frozen**
4 6 8		1	Ice		9 16 33	ICE	**ICE with Sand/Fines Inclusions**							**Clear-white ice**
10 12		2	Vx & Ice	F4	10 32 41	ML	**SILT**							**Brown, frozen, nonplastic (NP) fines, 75% ice by volume**
14						ICE	**ICE with Sand/Fines Inclusions**							**Ice**
16 18		3	Vx	F4	6 26 35	ML	**SILT**				0.5			**Brown, frozen, rounded gravel, fine sand, NP fines, 30% ice by volume**
20 22		4	Nf	F1	41 50/ 4in.	SP-SM	**Poorly graded SAND with Silt and Gravel**	32	61	7	0.5			**Brown, frozen, rounded gravel, fine and coarse sand, NP fines**
24 26		5	Nf	F2	Grab	SP-SM	**Poorly graded SAND with Silt and Gravel**	41	49	10	0.5			**Dark brown, frozen, rounded gravel, fine and coarse sand, NP fines, pieces of coal**
28 30		6	Nf	NFS	Grab	SW	**Well-graded SAND with Gravel**	35	62	3	0.5			**Dark brown, frozen, rounded gravel, fine to coarse sand, NP fines, pieces of coal**
32														

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Hole Number: **BIA-24**

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Date: **23 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,403 ft. ±** Easting: **641,735 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-24** Permanent: **BIA-24**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **39.0 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Cloudy, 5 degrees
34		7	Nbe	F3	Grab	SM	Silty SAND	3	78	19	0.5			Dark brown, frozen, rounded gravel, fine sand, NP fines
36														
38		8	Nbe	F2	Grab	SM	Silty SAND							Dark brown, frozen, fine sand, NP fines
40														Bottom of Hole 40.0 ft. PID = (Cold/Hot) Photo Ionization Detector
42														
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Hole Number: **BIA-24**

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Date: **21 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,316,285 ft. ±** Easting: **640,238 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-25** Permanent: **BIA-25**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, 0 degrees, 10 mph winds**
2														
4														
		1	Nbe	F3	46 50/ 3in.	SM	Silty SAND	4	49	47	0.375			Gray, frozen, subrounded to rounded gravel, fine sand, non plastic (NP) fines
6														
8														
10														
		2	Vr	F4	36 46 48	ML	Sandy SILT	3	30	67	0.25			Light brown, frozen, subrounded to rounded gravel, fine sand, NP fines, estimate 5% visible ice, randomly orientated veins of small white ice crystals
12														
14														
		3	Vr	F4	20 49 33	ML	SILT							Dark gray, frozen, very fine sand, NP fines, estimate 40% visible ice, small white ice crystals throughout
16														
18														
20														
		4	Vx	F4	28 40 52	ML	SILT				0.375			Dark gray, frozen, subrounded to rounded gravel, fine sand, NP fines, estimate 5% visible ice, small white crystals, on fresh surfaces
22														
24														
		5	Vx	F4	19 23 21	ML	SILT							Dark gray, frozen, very fine sand, NP fines, estimate 40% visible ice, small cloudy ice crystals on fresh surfaces
26														
28														
30														
		6	Vx	F4	14 16 18	ML	SILT							Dark gray, frozen, very fine sand, NP fines, estimate 40% visible ice, small cloudy ice crystals on fresh surfaces
32														Bottom of Hole 31.5 ft. PID = (Cold/Hot) Photo Ionization Detector

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Hole Number: **BIA-25**

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Date: **21 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,314,280 ft. ±** Easting: **640,304 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-26** Permanent: **BIA-26**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Cloudy, 0 degrees, 10 mph winds**
2														
4														
6		1	Vr	F4	36 50 50	ML	Sandy SILT	1	37	62	0.25			Light brown, frozen, subrounded to rounded gravel, fine sand, non plastic (NP) fines, small white ice crystals throughout on fresh surfaces, estimate 25% visible ice
8														
10		2	Nbe	F3	22 44 50/ 4in.	SM	Silty SAND		65	35				Light brown and gray, frozen, fine sand, NP fines
12														
14														
16		3	Vr	F4	18 32 40	ML	SILT							Dark gray, frozen, very fine sand, NP fines, estimate 45% visible ice, small cloudy white ice crystals throughout
18														
20		4	Nbe	F4	29 50 45	ML	Sandy SILT							Dark gray, frozen, fine sand, NP fines
22														
24														
26		5	Vr	F4	20 29 34	ML	SILT							Dark gray, frozen, NP fines, estimate 40% visible ice, small white ice crystals throughout
28														
30		6	Vr	F4	22 30 36	ML	Sandy SILT							Dark gray, frozen, subrounded to rounded gravel, fine sand, NP fines, estimate 15% visible ice, small white crystals throughout on fresh surfaces
32														Bottom of Hole 31.5 ft. ~~PID = (Cold/Hot) Photo Ionization Detector~~

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-26**

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Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

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Date: **22 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,314,590 ft. ±** Easting: **642,087 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-27** Permanent: **BIA-27**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Sunny, 5 degrees, 10 mph winds
2 4						ICE	ICE with Sand/Fines Inclusions							Ice and silt cuttings to 5 feet
6 8		1	Nbe	F3	25 50/ 3in.	SM	Silty SAND with Gravel				0.375			Light brown (2nd 5" of sample), frozen, subangular to subrounded gravel, fine to coarse sand, non plastic (NP) fines, first 4" of sample is ICE and Silt (this portion was not collected)
10 12		2	Vx	F4	50/ 5in.	ML	Sandy SILT with Gravel	6	42	52	0.5			Dark gray, frozen, subrounded to rounded gravel, fine to coarse sand, NP fines, estimate 30% visible ice, clear ice crystals with white interstitial ice inclusions <1" thick
14 16 18		3	Vx	F4	36 50/ 5in.	ML	Sandy SILT							Dark gray, frozen, fine sand, NP fines, estimated 10% visible ice, small clear and white flat ice crystals on fresh surface
20 22 24		4	Vx	F4	19 36 27	ML	Sandy SILT							Dark gray, frozen, fine sand, NP fines, estimate 10% visible ice, small clear and white flat ice crystals on fresh surface
26 28		5	Vr	F4	15 20 24	ML	SILT							Dark gray, frozen, very fine sand, NP fines, estimate 30% visible ice, small granular white ice crystals on fresh surfaces throughout
30		6	Vr	F4	11 14 19	ML	Sandy SILT							Dark gray, frozen, very fine sand, NP fines, estimate 30% visible ice, small granular white ice crystals on fresh surfaces throughout
32														Bottom of Hole 31.5 ft. PID = (Cold/Hot) Photo Ionization Detector

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-27**

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Date: **23 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,316,412 ft. ±**
Easting: **642,048 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-28**

Permanent: **BIA-28**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **30.0 ft.**

Total Depth: **30.9 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Cloudy, 10 degrees, 10 mph winds**
2 4														
6		1	Ice		13 24 50	ICE	**ICE with Sand/Fines Inclusions**							**Ice, large flat clear ice crystals with white interstitial ice and some trace of gray silt**
8 10		2	Vx	F3	36 46 50/ 5in.	SM	**Silty SAND with Gravel**	10	58	32	0.375			**Light brown, frozen, subrounded to rounded gravel, fine sand, non plastic (NP) fines, estimate 5% visible ice, small white ice crystals inclusions <.25" thick**
12 14 16		3	Vx	F3	41 39 48	SM	**Silty SAND with Gravel**	12	44	29	0.5			**Light brown, frozen, subangular to subrounded gravel, fine and coarse sand, NP fines, estimate 5% visible ice, small white ice crystals inclustions <0.25 in. thick**
18 20		4	Nbe	S2	80	SP	**Poorly graded SAND with Gravel**	46	49	5	1			**Brown, frozen, subangular to subrounded gravel, fine and coarse sand**
22 24 26		5	Nbe	F2	61	SM	**Silty SAND**							**Gray and brown, frozen, fine sand, NP fines**
28 30		6	Vx	F2	50 50/ 5in.	SM	**Silty SAND**							**Gray and brown, frozen, fine sand, NP fines, estimate 2% visible ice, clear ice crystals with white interstitial ice vien, < 0.25 in.**
32														**Bottom of Hole 30.9 ft.** **PID = (Cold/Hot) Photo Ionization Detector**

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

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Date: **24 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,315,455 ft. ±** Easting: **641,225 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-29** Permanent: **BIA-29**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size			Max Size (in.)	PID (ppm)	% Water	Description and Remarks Cloudy, 5 degrees, 10 mph winds
								%Gravel	%Sand	%Fines				
		1	Vx	F3	50/ 4in.	SM	Silty SAND with Gravel	37	45	18	0.5			Gray and brown, frozen, subangular to subrounded gravel, fine to coarse sand, non plastic (NP) fines, inclusions of small white ice crystals clusters less than .75 inches thick, estimated 10% visible ice, 50 blows for 4"
		2	Vr	F4	36 37 45	ML	SILT with Sand							Gray, frozen, fine sand, NP fines, estimated 20% visible ice, small white ice crystals throughout
		3	Vr	F4	26 32 30	ML	SILT with Sand							Gray, frozen, fine sand, NP fines, estimated 20% visible ice, small white ice crystals throughout
		4	Vr	F4	21 23 25	ML	SILT							Dark gray, frozen, very fine sand, NP fines, estimated 3% visible ice, small white ice crystals throughout on fresh surfaces, some muscle shell fragments are present in in sample
		5	Vr	F4	16 21 22	ML	SILT							Dark gray, frozen, NP fines, estimated 5% visible ice, small white ice crystals on fresh surfaces throughout
		6	Vr	F4	18 21 19	ML	Sandy SILT							Dark gray, frozen, very fine sand, NP fines, estimated 20% visible ice, small white ice crystals on fresh surfaces throughout
														Bottom of Hole 31.5 ft. PID = (Cold/Hot) Photo Ionization Detector

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Date: **25 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,300,540 ft. ±** Easting: **643,116 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-30** Permanent: **BIA-30**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **39.0 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D.: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Snow, 0 degrees**
2						OL	Organic SILT							Dark brown, frozen, nonplastic (NP) fines
4 6 8		1	Vx & Vr	F4	14 38	ML	SILT							Brown, frozen, NP fines, 50% ice by volume
10 12		2	Nbe	F4	15 52	ML	SILT with Sand				0.25			Brown, frozen, rounded gravel, fine sand, NP fines
14 16 18		3	Nbe	F4	16 51	ML	Sandy SILT				0.25			Brown, frozen, rounded gravel, fine sand, NP fines
20 22		4	Nf	F2	56	GM	Silty GRAVEL with Sand	43	41	16	0.5			Brown, frozen, rounded gravel, fine and coarse sand
24 26		5	Nf	F2	Grab	SM	Silty SAND with Gravel	37	50	13	0.75			Brown, frozen, rounded gravel, fine and coarse sand
28 30		6	Nf	F2	Grab	GP-GM	Poorly graded GRAVEL with Silt and Sand	47	41	12	1			Brown, frozen, rounded gravel, fine and coarse sand
						SM	Silty SAND							Fine sand, frozen, by drill action
32						GP	Poorly graded GRAVEL with Sand							By drill action

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Date: **25 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,300,540 ft. ±** Easting: **643,116 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-30** Permanent: **BIA-30**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **39.0 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size			Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Snow, 0 degrees**
								%Gravel	%Sand	%Fines				
34		7	**Nbe**	**F3**	**Grab**	**SM**	**Silty SAND with Gravel**	**6**	**78**	**16**				**Brown, frozen, fine sand**
36														
38		8	**Nbe**	**F2**	**Grab**	**SM**	**Silty SAND**							**Dark brown, frozen, fine sand, NP fines**
40														**Bottom of Hole 40.0 ft.** **Groundwater Not Encountered** **PID = (Cold/Hot) Photo Ionization Detector**
42														
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

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Project: **Coastal Storm Damage Reduction**
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Date: **26 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,225 ft. ±** Easting: **643,246 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-31**

Permanent: **BIA-31**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**

☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **39.0 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size			Max Size (in.)	PID (ppm)	% Water	Description and Remarks Windy, 5 degrees
								%Gravel	%Sand	%Fines				
2					Grab	OL	Organic SILT							Dark brown, frozen
4														
6		1	Vx & Vr	F4	12 34 40	ML	SILT							Brown, frozen, nonplastic (NP) fines, 60% ice by volume
8														
10		2	Nbe	F4	12 47	ML	SILT with Sand				0.5			Brown, frozen, rounded gravel, fine sand, NP fines
12														
14														
16		3	Nf	F3	19 50/ 3in.	SM	Silty SAND with Gravel	27	56	17	0.5			Brown, frozen, rounded gravel, fine to coarse sand, NP fines
18														
20		4	Nf	F3	Grab	SM	Silty SAND with Gravel	18	56	26	0.5			Brown, frozen, rounded gravel, fine and coarse sand, NP fines
22														
24		5	Nf	F3	Grab	SM	Silty SAND with Gravel	22	60	18	1			Brown, frozen, rounded gravel, fine to coarse sand, NP fines
26														
28														
30		6	Nf	F2	Grab	SP-SM	Poorly graded SAND with Silt and Gravel	35	54	11	1			Brown, frozen, rounded gravel, fine to coarse sand, NP fines
32														

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

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Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-31**

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Project: **Coastal Storm Damage Reduction**
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Date: **26 Apr 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,299,225 ft. ±**
Easting: **643,246 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-31**

Permanent: **BIA-31**

Operator: **Lyle Cain & Travis Coghill**

Inspector: **Gregory Carpenter**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NE**

Depth Drilled: **39.0 ft.**

Total Depth: **40.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D.: **3 in.**

Size and Type of Bit: **7 in. Hollow Stem Auger**

Type of Equipment: **CME-45**

Type of Samples: **Grab and Drive**

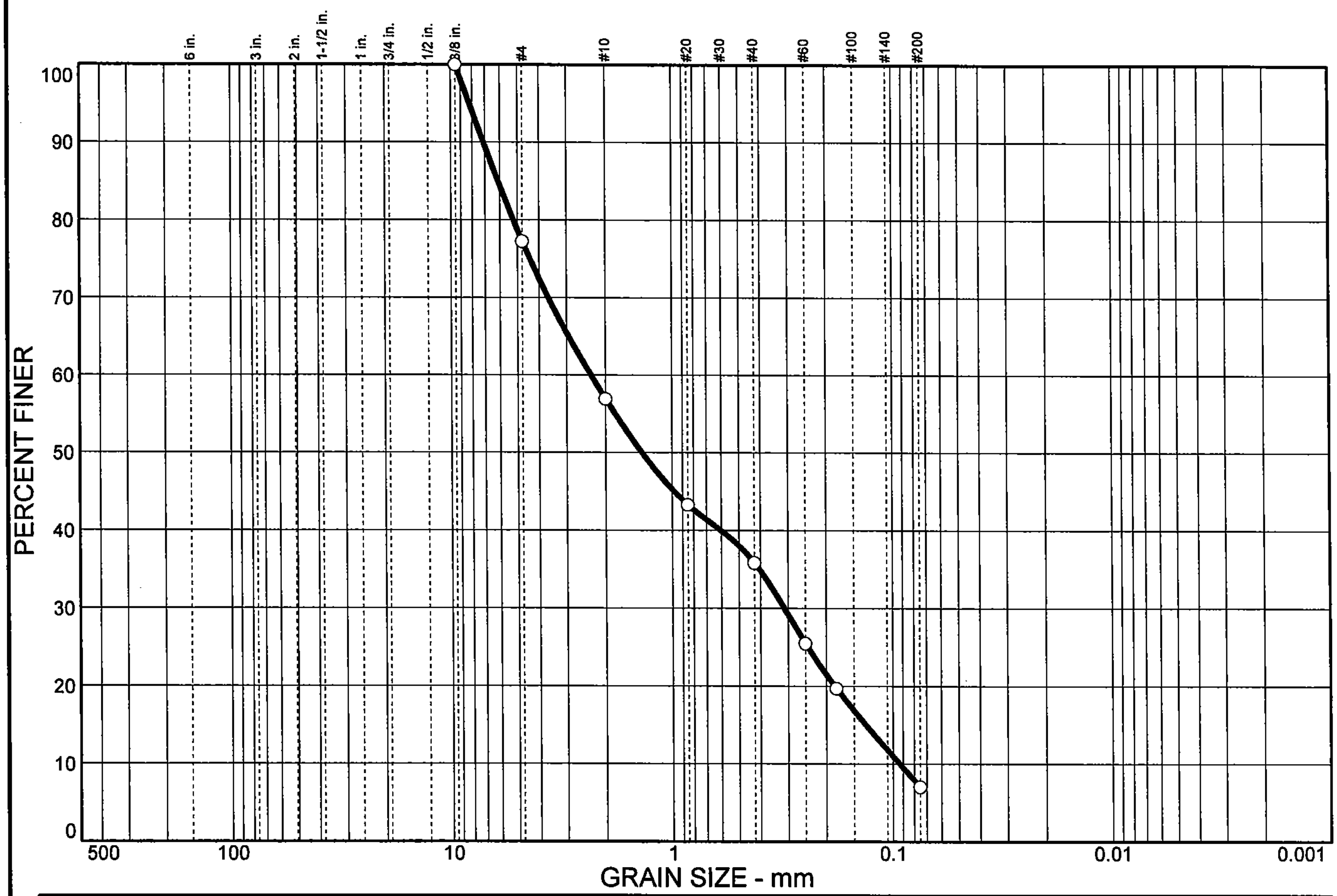
Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Windy, 5 degrees**
34		7	**Nf**	**S1**	**Grab**	**GP**	**Poorly graded GRAVEL with Sand**	**78**	**17**	**5**	**1.5**			**Brown, frozen, rounded gravel, fine sand, NP fines**
36														
38														
39		8	**Nbe**	**NFS**	**Grab**	**SP**	**Poorly graded SAND**							**Brown, frozen, fine sand**
40														**Bottom of Hole 40.0 ft.** **Groundwater Not Encountered** **PID = (Cold/Hot) Photo Ionization Detector**
42														
44														
46														
48														
50														
52														
54														
56														
58														
60														
62														
64														
66														

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **BIA-31**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	22.8	20.3	21.1	28.8	7.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	77.2		
# 10	56.9		
# 20	43.3		
# 40	35.8		
# 60	25.5		
# 80	19.7		
# 200	7.0		

* (no specification provided)

Soil Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 6.12 D_{60}= 2.34 D_{50}= 1.37
D_{30}= 0.312 D_{15}= 0.133 D_{10}= 0.0934
C_u= 25.01 C_c= 0.45

Classification

USCS= SP-SM AASHTO= A-1-b

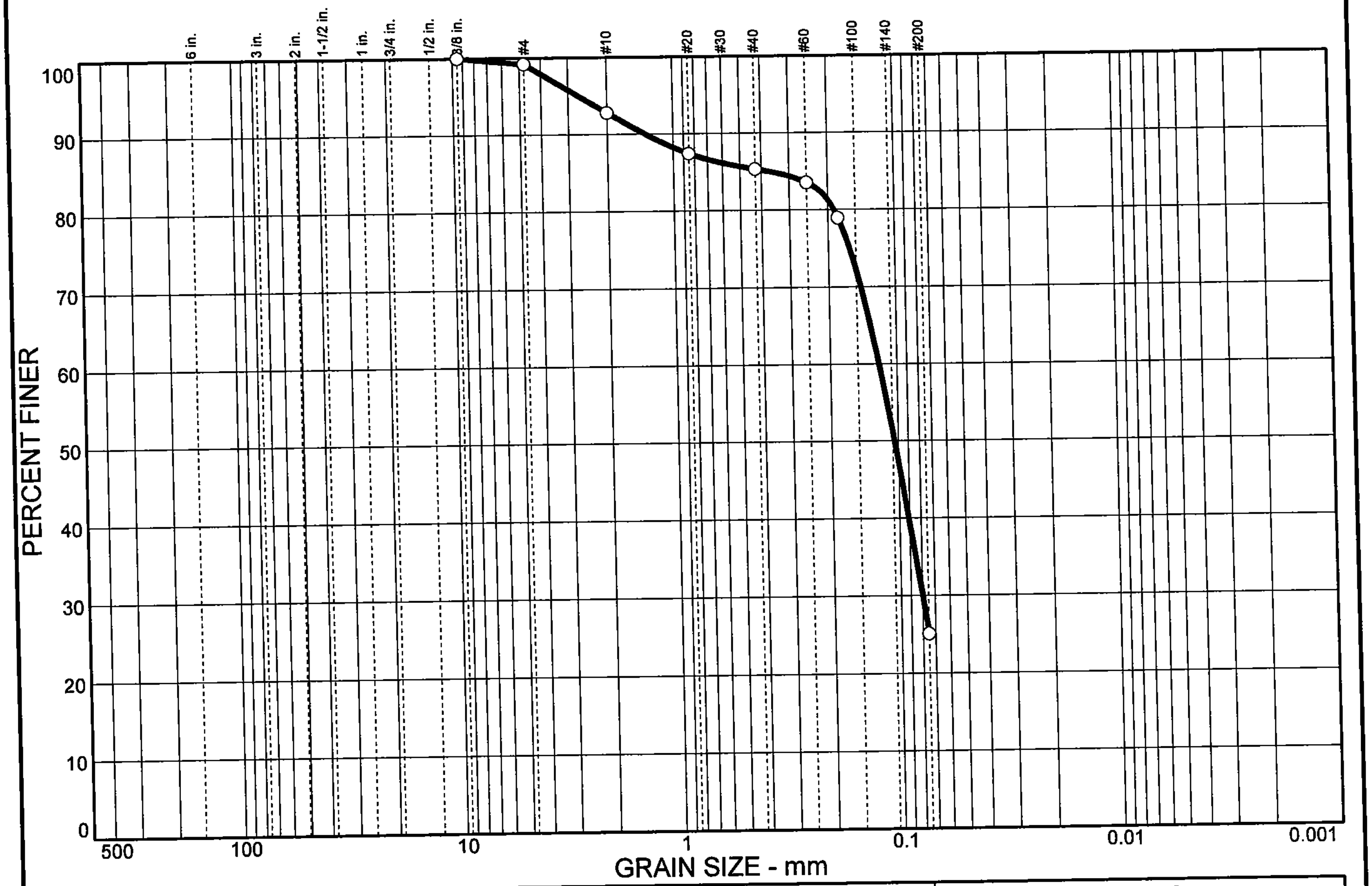
Remarks

Sample No.: 6043 **Source of Sample:** Client Samples **Date:**
Location: BIA-01 #3 **Elev./Depth:** 10 FT 3 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.8	6.4	7.5	60.2	25.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	99.2		
# 10	92.8		
# 20	87.4		
# 40	85.3		
# 60	83.5		
# 80	78.9		
# 200	25.1		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.371 D_{60}= 0.121 D_{50}= 0.104
D_{30}= 0.0798 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

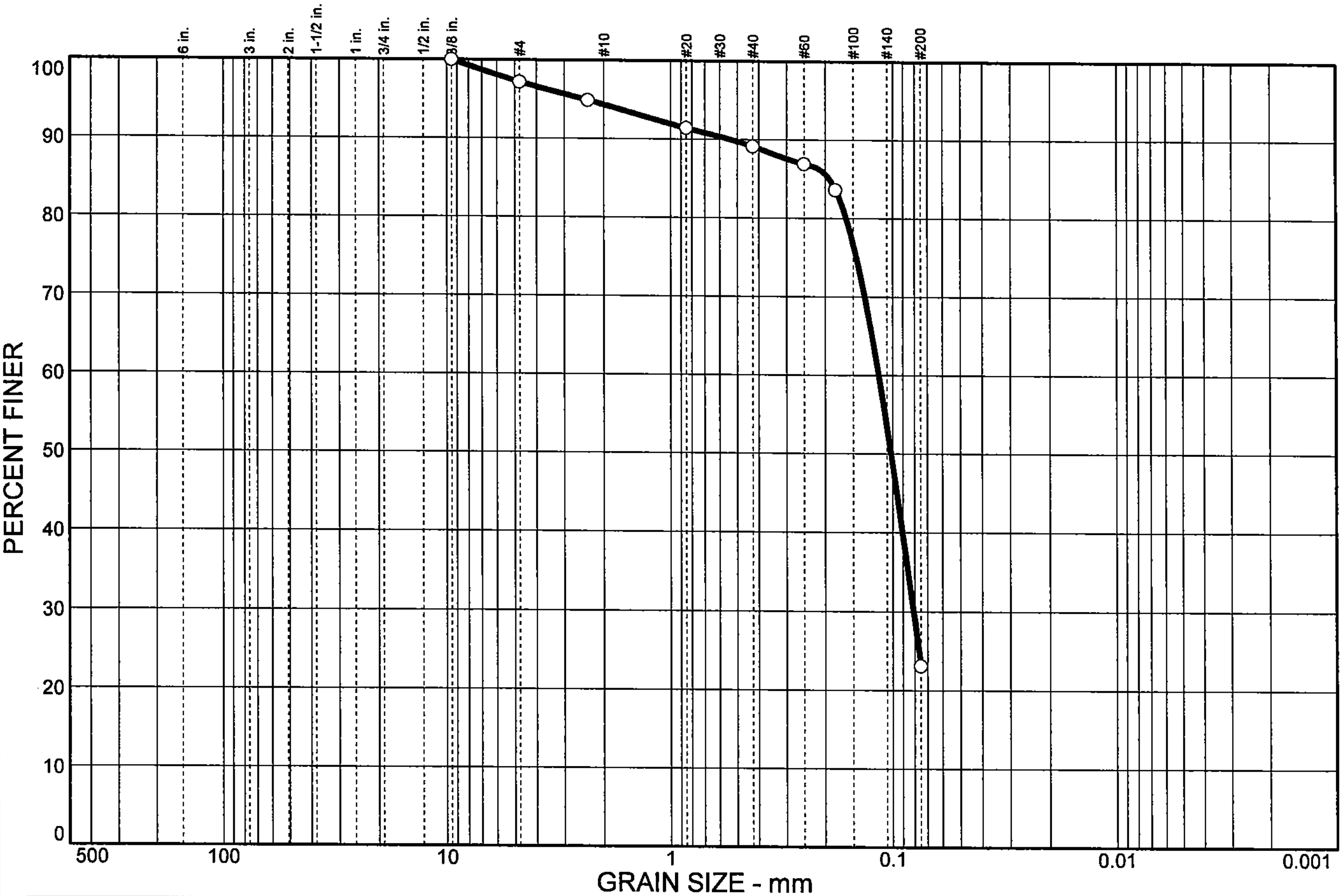
Remarks

Sample No.: 6045
Location: BIA-01 #5
Source of Sample: Client Samples
Date:
Elev./Depth: 20 FT 6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	2.8	2.9	5.2	66.0	23.1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	97.2		
# 8	94.9		
# 20	91.4		
# 40	89.1		
# 60	86.9		
# 80	83.6		
# 200	23.1		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.192 D_{60}= 0.115 D_{50}= 0.102
D_{30}= 0.0809 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

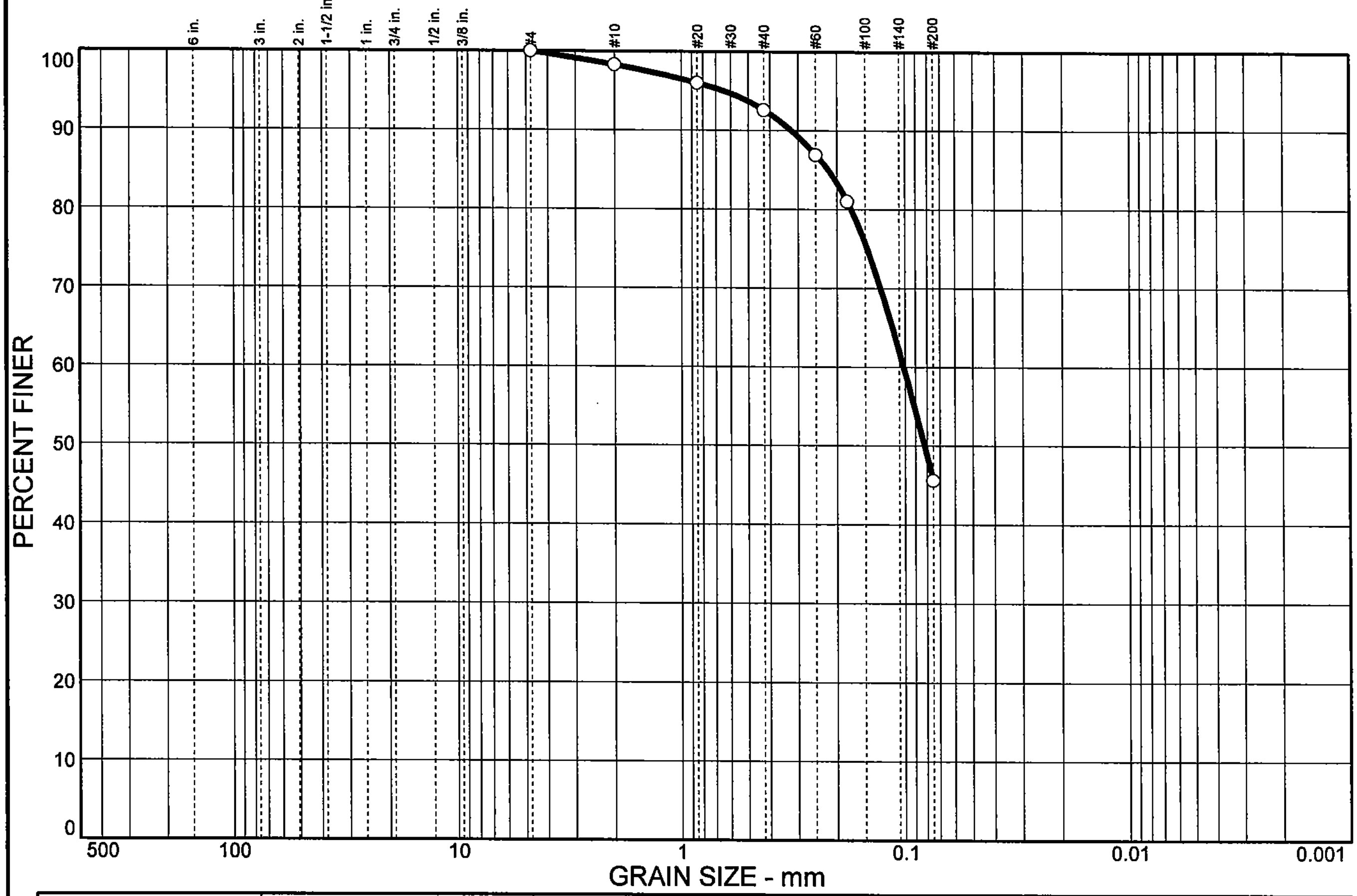
Remarks

Sample No.: 6046 **Source of Sample:** Client Samples **Date:**
Location: BIA-02 #4 **Elev./Depth:** 15 FT 4.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	1.7	5.7	47.0	45.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
# 4	100.0		
# 10	98.3		
# 20	96.0		
# 40	92.6		
# 60	86.9		
# 80	81.0		
# 200	45.6		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.220 D_{60}= 0.102 D_{50}= 0.0822
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-4(0)

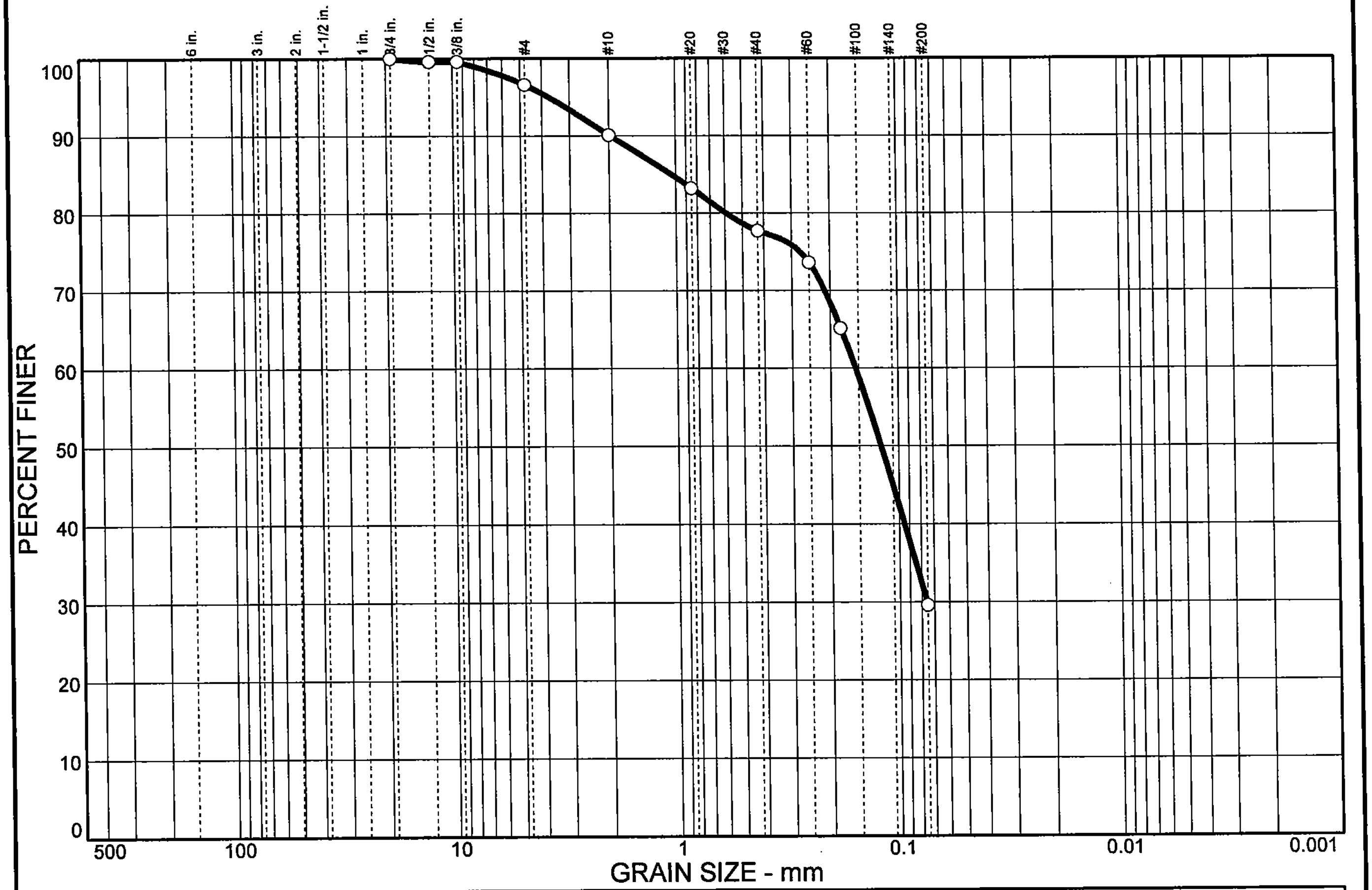
Remarks

Sample No.: 6047 **Source of Sample:** Client Samples **Date:**
Location: BIA-03 #1 **Elev./Depth:** 2.5 FT 0.75

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	3.4	6.5	12.4	48.1	29.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	99.6		
3/8 in.	99.6		
# 4	96.6		
# 10	90.1		
# 20	83.2		
# 40	77.7		
# 60	73.6		
# 80	65.1		
# 200	29.6		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 1.05 D_{60}= 0.155 D_{50}= 0.120
D_{30}= 0.0757 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6048
Location: BIA-03 #2

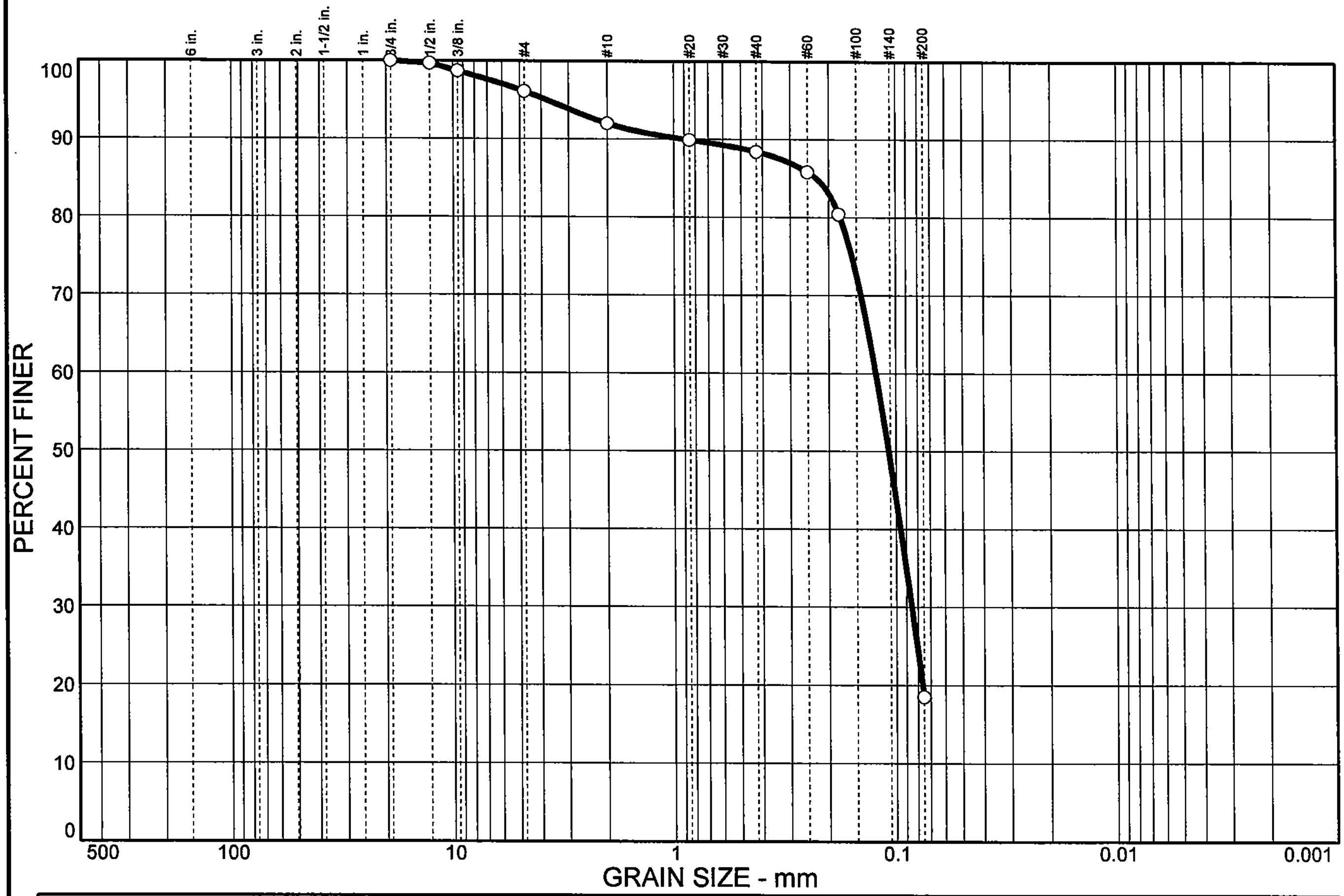
Source of Sample: Client Samples

Date:
Elev./Depth: 5 FT 1.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	3.9	4.1	3.6	69.9	18.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	99.7		
3/8 in.	98.7		
# 4	96.1		
# 10	92.0		
# 20	89.9		
# 40	88.4		
# 60	85.8		
# 80	80.4		
# 200	18.5		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.228 D_{60}= 0.123 D_{50}= 0.108
D_{30}= 0.0853 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

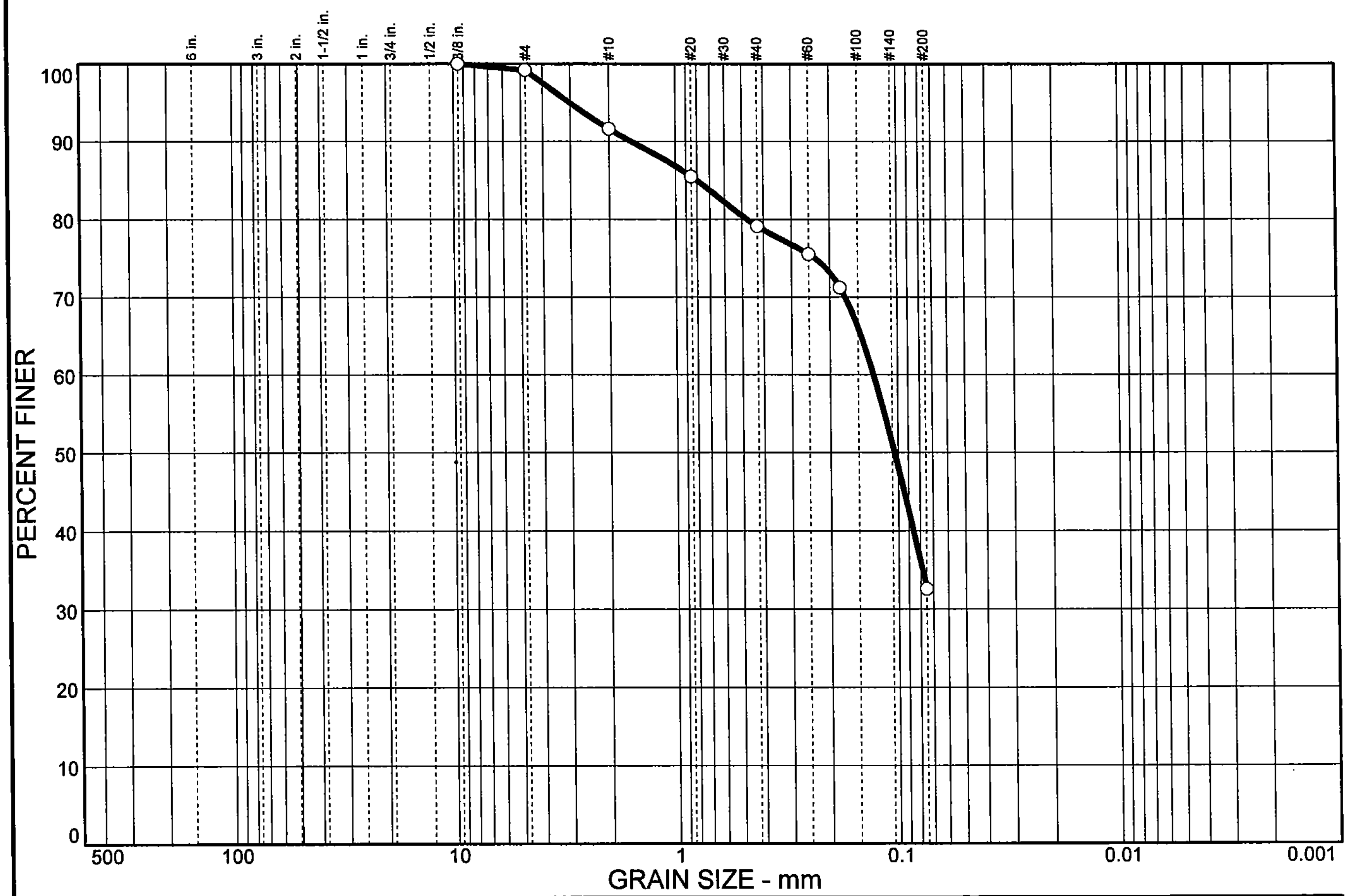
Remarks

Sample No.: 6049 **Source of Sample:** Client Samples **Date:**
Location: BIA-04 #3 **Elev./Depth:** 10 FT 3 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.8	7.6	12.5	46.5	32.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	99.2		
# 10	91.6		
# 20	85.5		
# 40	79.1		
# 60	75.5		
# 80	71.2		
# 200	32.6		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.803 D_{60}= 0.128 D_{50}= 0.104
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6050 **Source of Sample:** Client Samples **Date:**
Location: BIA-05 #1 **Elev./Depth:** 5 FT 1.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	1.3	0.8	2.7	51.0	44.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	98.7		
# 8	98.0		
# 20	97.0		
# 40	95.2		
# 60	92.4		
# 80	83.1		
# 200	44.2		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.190 D_{60}= 0.104 D_{50}= 0.0844

D_{30}= D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample No.: 6051 **Source of Sample:** Client Samples **Date:**

Location: BIA-05 #2 **Elev./Depth:** 10 FT 3 m

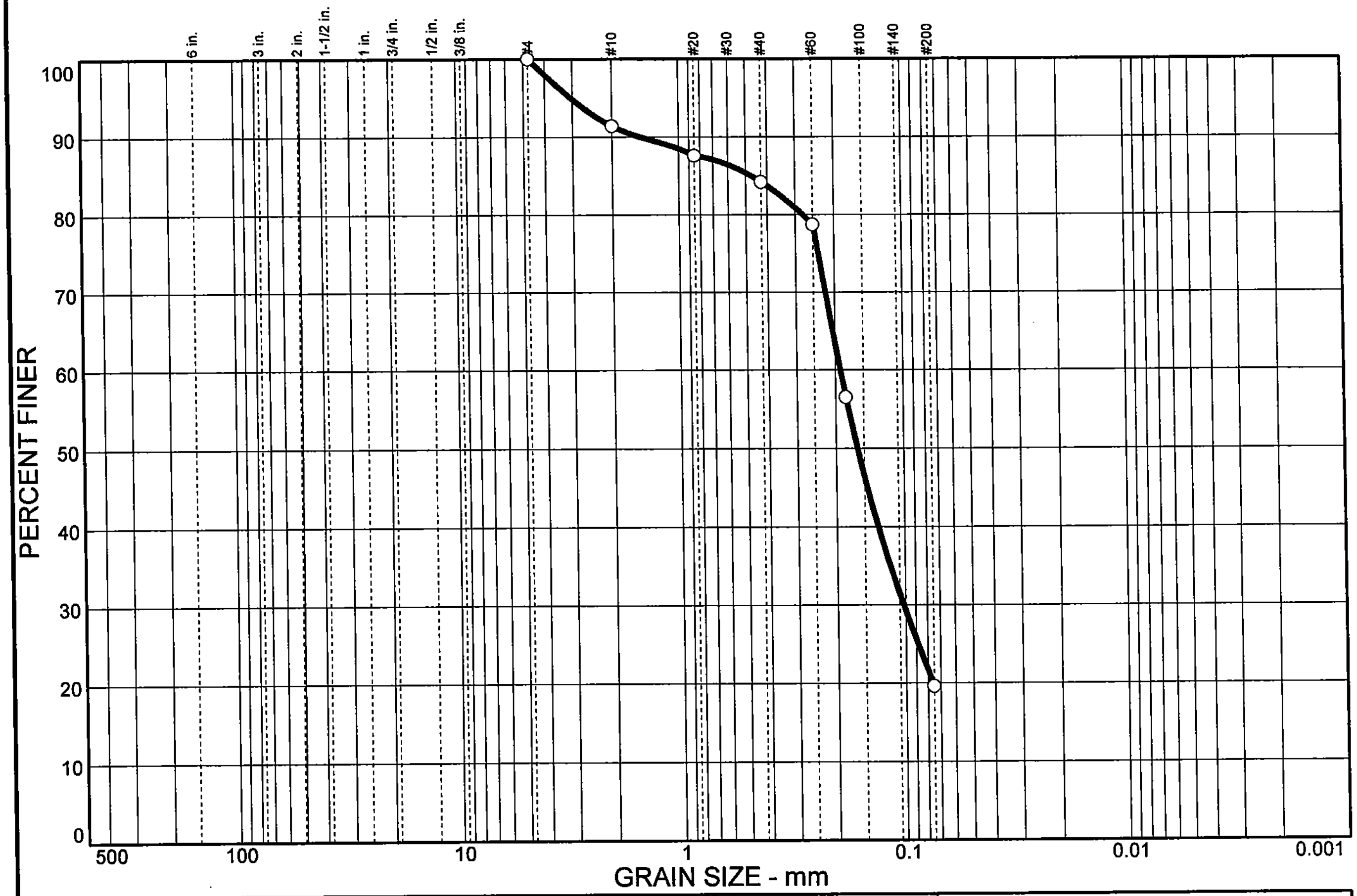
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	8.6	7.2	64.6	19.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
# 4	100.0		
# 10	91.4		
# 20	87.6		
# 40	84.2		
# 60	78.7		
# 80	56.5		
# 200	19.6		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.473 D_{60}= 0.190 D_{50}= 0.160
D_{30}= 0.102 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

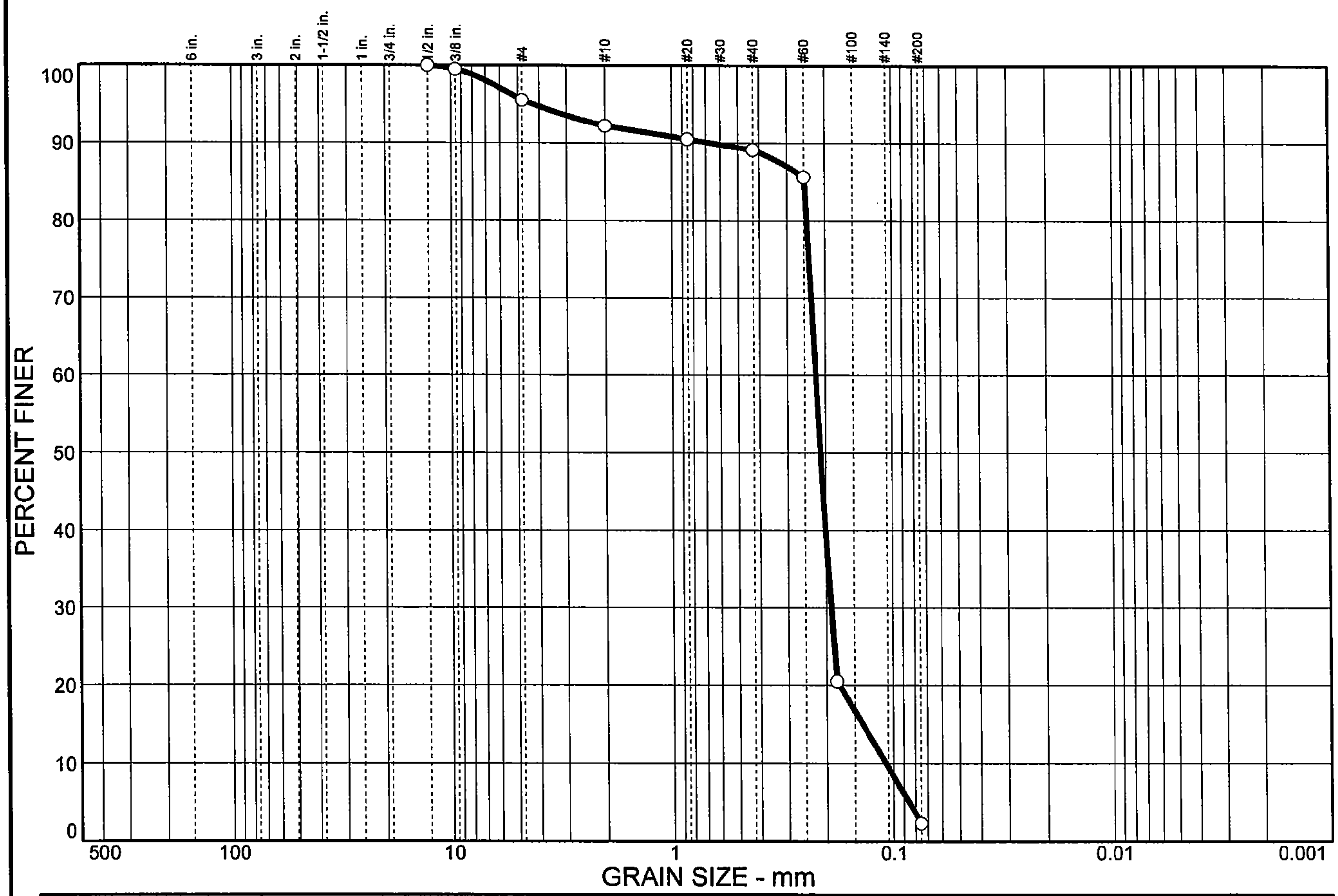
Remarks

Sample No.: 6052
Location: BIA-06 #2
Source of Sample: Client Samples
Date:
Elev./Depth: 10 FT 3 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	4.5	3.3	3.1	86.8	2.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	99.5		
# 4	95.5		
# 10	92.2		
# 20	90.5		
# 40	89.1		
# 60	85.6		
# 80	20.5		
# 200	2.3		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.249 D_{60}= 0.222 D_{50}= 0.212
D_{30}= 0.191 D_{15}= 0.138 D_{10}= 0.109
C_u= 2.05 C_c= 1.51

Classification

USCS= SP AASHTO= A-3

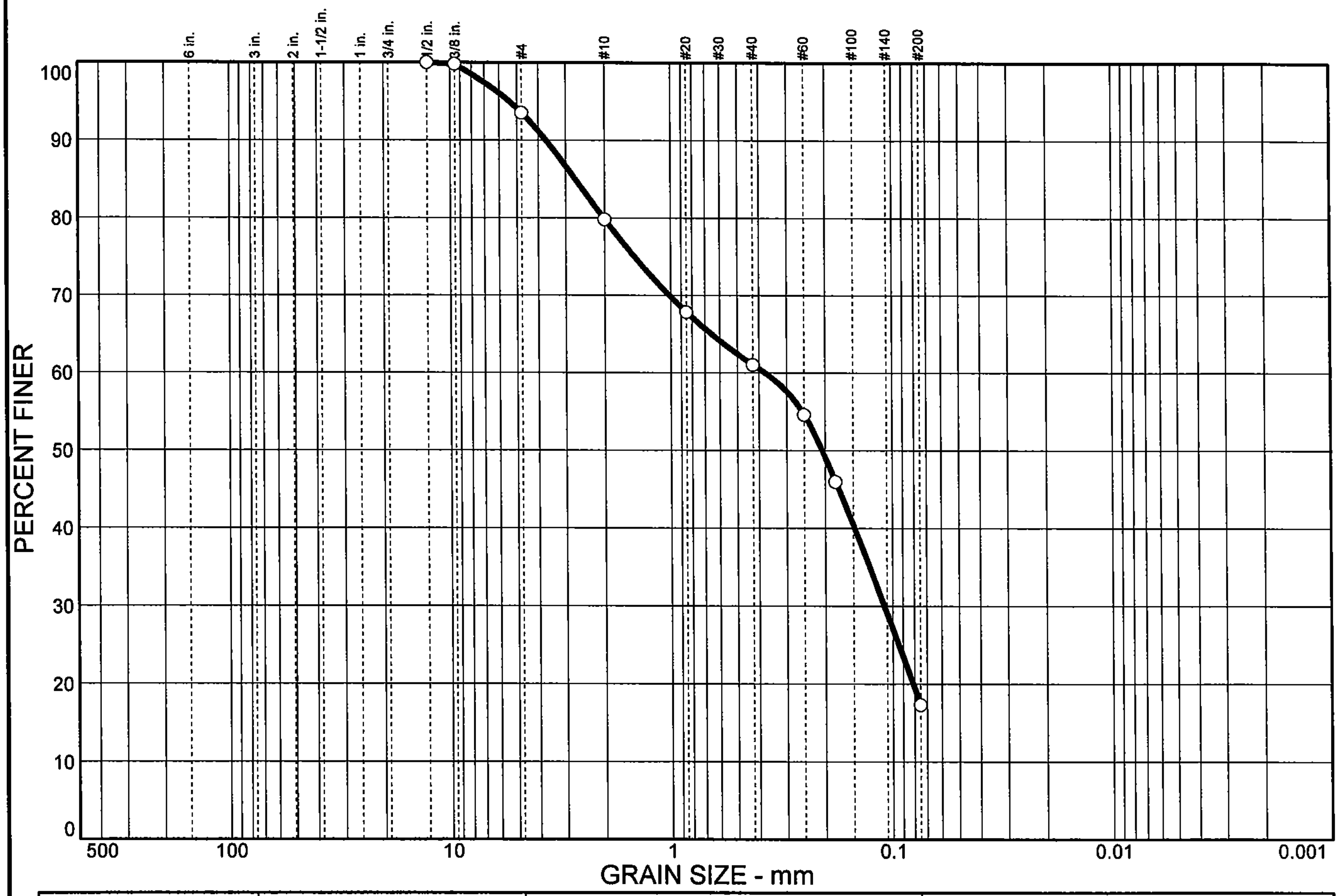
Remarks

Sample No.: 6053 **Source of Sample:** Client Samples **Date:**
Location: BIA-06 #3 **Elev./Depth:** 15 FT 4.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	6.5	13.7	18.8	43.7	17.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	99.8		
# 4	93.5		
# 10	79.8		
# 20	67.8		
# 40	61.0		
# 60	54.6		
# 80	46.0		
# 200	17.3		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 2.72
D_{60}= 0.377
D_{50}= 0.207
D_{30}= 0.109
D_{15}=
D_{10}=
C_u=
C_c=

Classification

USCS= SM
AASHTO= A-2-4(0)

Remarks

Sample No.: 6054
Location: BIA-06 #4
Source of Sample: Client Samples
Date:
Elev./Depth: 20 FT 6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	18.0	11.6	13.0	27.0	30.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	98.0		
# 4	81.9		
# 10	70.4		
# 20	61.3		
# 40	57.4		
# 60	53.8		
# 80	46.9		
# 200	30.4		

* (no specification provided)

Soil Description

Silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 5.38 D_{60}= 0.720 D_{50}= 0.206
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6055 **Source of Sample:** Client Samples **Date:**
Location: BIA-07 #2 **Elev./Depth:** 10 FT 3 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	30.1	3.7	1.9	62.4	1.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	92.1		
3/8 in.	85.3		
# 4	69.9		
# 8	66.4		
# 20	65.1		
# 40	64.3		
# 60	59.6		
# 80	9.4		
# 200	1.9		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 9.41
D_{60}= 0.258
D_{50}= 0.236
D_{30}= 0.209
D_{15}= 0.188
D_{10}= 0.181
C_u= 1.43
C_c= 0.94

Classification

USCS= SP
AASHTO= A-3

Remarks

Sample No.: 6056
Location: BIA-07 #4
Source of Sample: Client Samples
Date:
Elev./Depth: 17 FT 5.1 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	17.7	4.5	8.2	46.1	23.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	82.3		
# 10	77.8		
# 20	72.2		
# 40	69.6		
# 60	66.9		
# 80	58.0		
# 200	23.5		

* (no specification provided)

Soil Description

Silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 5.50 D_{60}= 0.193 D_{50}= 0.142
D_{30}= 0.0870 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

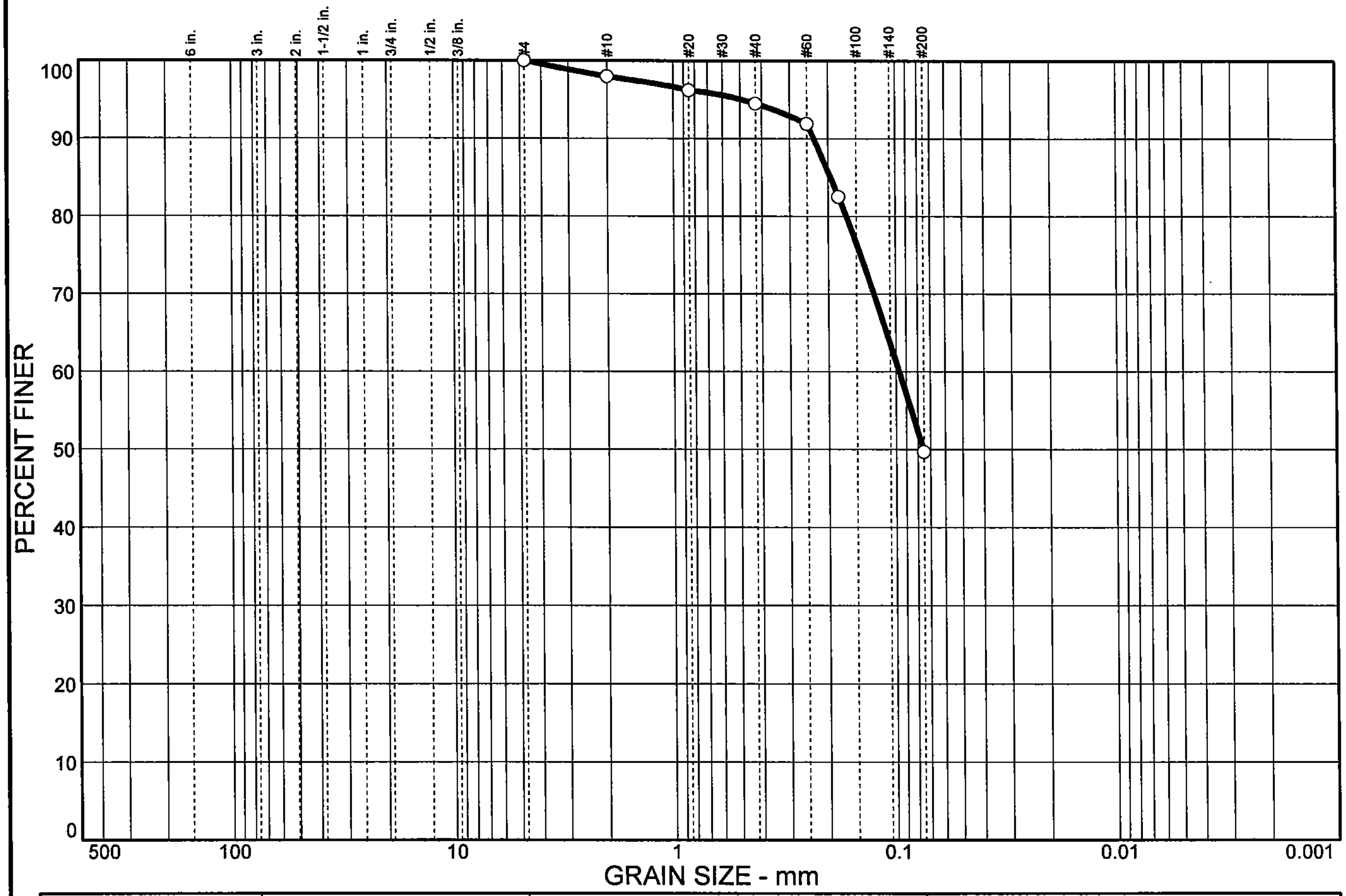
Remarks

Sample No.: 6057 **Source of Sample:** Client Samples **Date:**
Location: BIA-08 #2 **Elev./Depth:** 10 FT 3.0 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	2.0	3.5	44.8	49.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
# 4	100.0		
# 10	98.0		
# 20	96.2		
# 40	94.5		
# 60	91.9		
# 80	82.5		
# 200	49.7		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.195 D_{60}= 0.0968 D_{50}= 0.0756
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample No.: 6058 **Source of Sample:** Client Samples **Date:**
Location: BIA-08 #3 **Elev./Depth:** 15 FT 4.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
			1.3	3.5	49.6	43.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	99.8		
3/8 in.	99.5		
# 4	98.1		
# 10	96.8		
# 20	95.3		
# 40	93.3		
# 60	90.1		
# 80	78.9		
# 200	43.7		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.214 D_{60}= 0.111 D_{50}= 0.0871
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample No.: 6059 **Source of Sample:** Client Samples **Date:**
Location: BIA-08 # 4 **Elev./Depth:** 20 FT 6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	3.5	2.0	2.3	54.6	37.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	99.6		
# 4	96.5		
# 10	94.5		
# 20	93.5		
# 40	92.2		
# 60	90.3		
# 80	85.1		
# 200	37.6		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.179 D_{60}= 0.105 D_{50}= 0.0902

D_{30}= D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-4(0)

Remarks

Sample No.: 6060 **Source of Sample:** Client Samples **Date:**

Location: BIA-09 #3 **Elev./Depth:** 15 FT 4.5 m

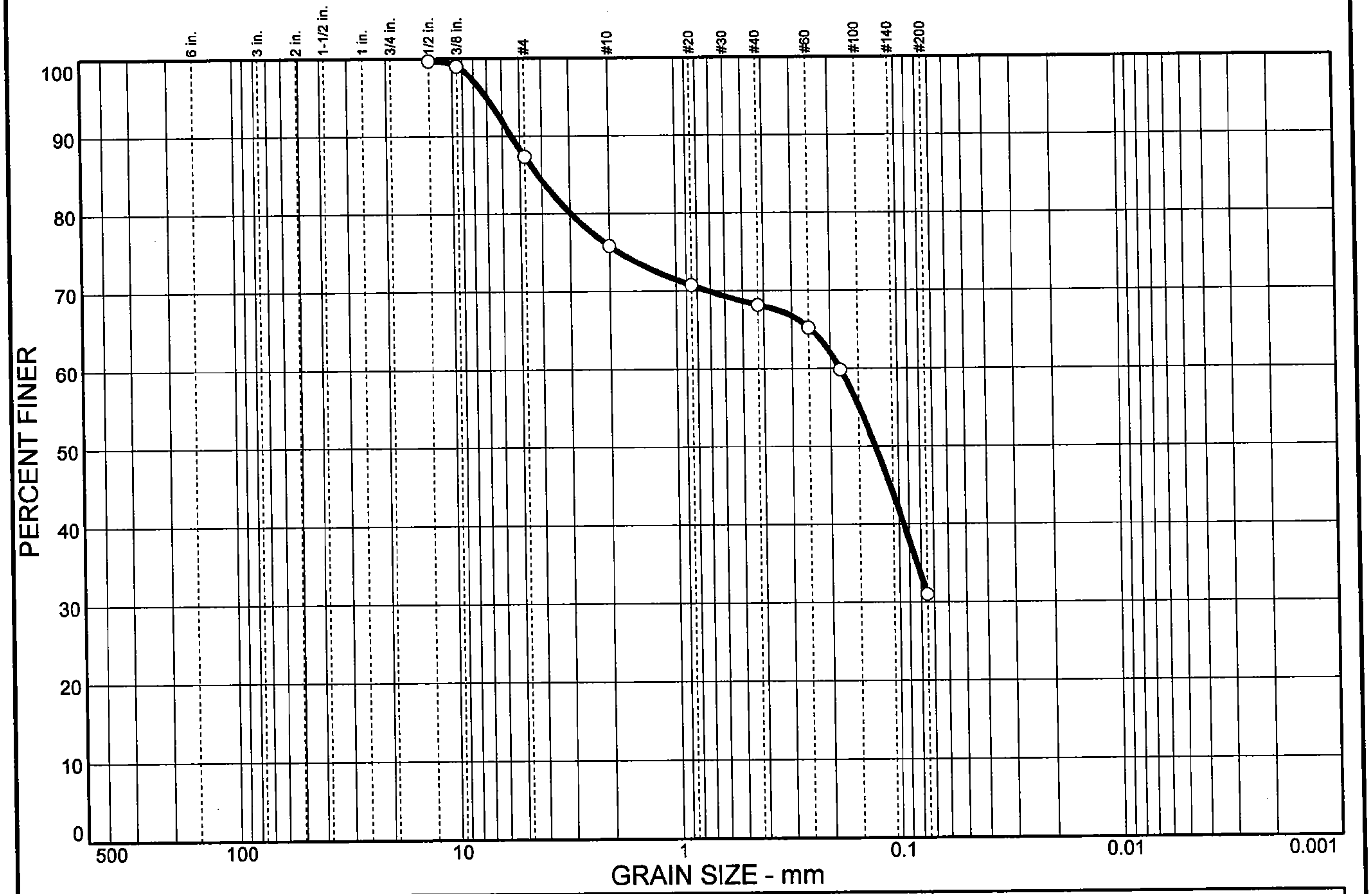
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
			11.5	7.7	37.1	31.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	99.7		
3/8 in.	99.0		
# 4	87.3		
# 10	75.8		
# 20	70.7		
# 40	68.1		
# 60	65.2		
# 80	59.8		
# 200	31.0		

* (no specification provided)

Soil Description

Silty sandSilty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 4.18 D_{60}= 0.182 D_{50}= 0.127

D_{30}= D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6061 **Source of Sample:** Client Samples **Date:**

Location: BIA-09 #4 **Elev./Depth:** 20 FT 6 m

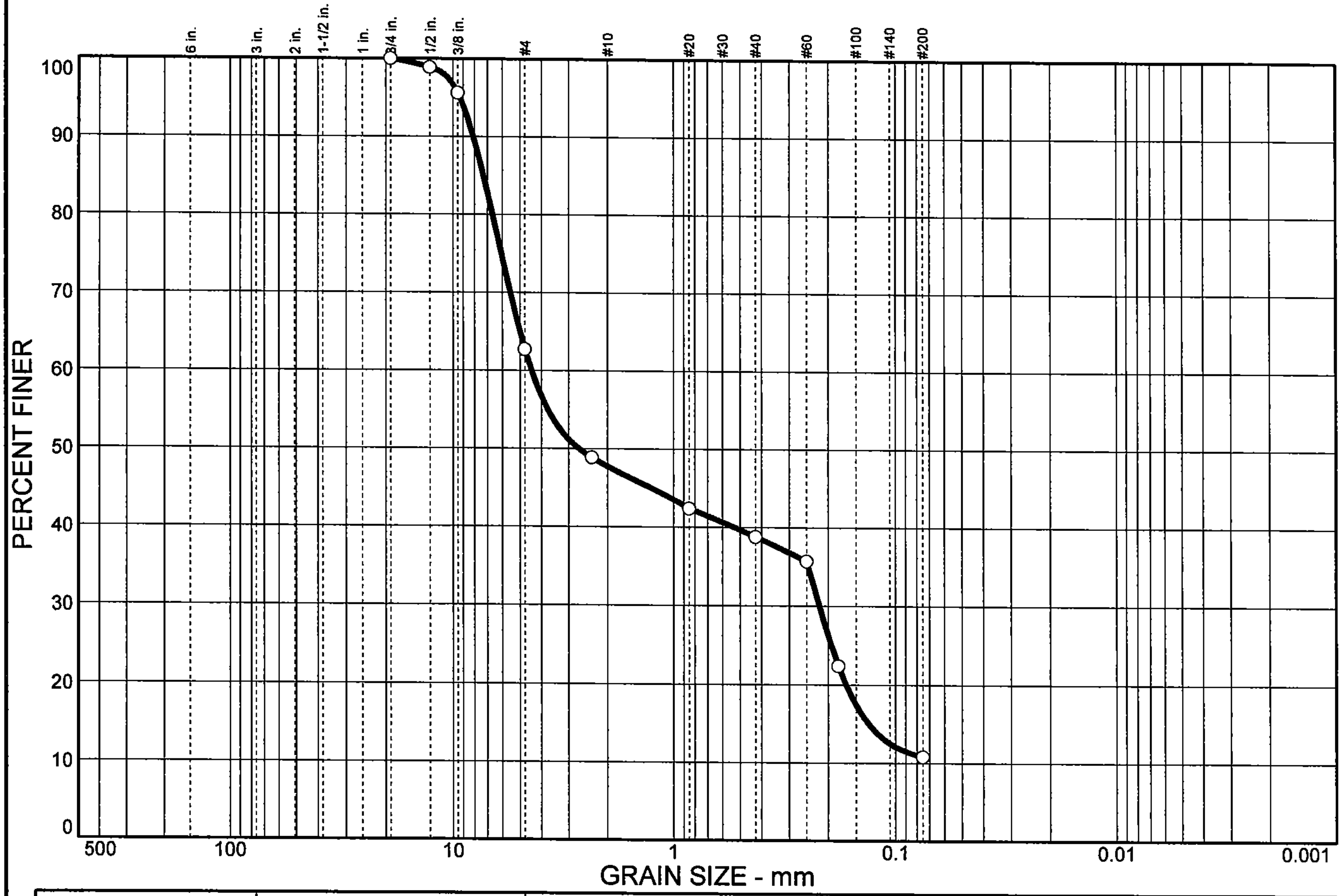
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	37.3	15.0	8.9	28.0	10.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	98.9		
3/8 in.	95.6		
# 4	62.7		
# 8	48.9		
# 20	42.4		
# 40	38.8		
# 60	35.7		
#80	22.4		
# 200	10.8		

* (no specification provided)

Soil Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 7.31 D_{60}= 4.43 D_{50}= 2.70
D_{30}= 0.219 D_{15}= 0.132 D_{10}=
C_u= C_c=

Classification

USCS= SP-SM AASHTO= A-1-b

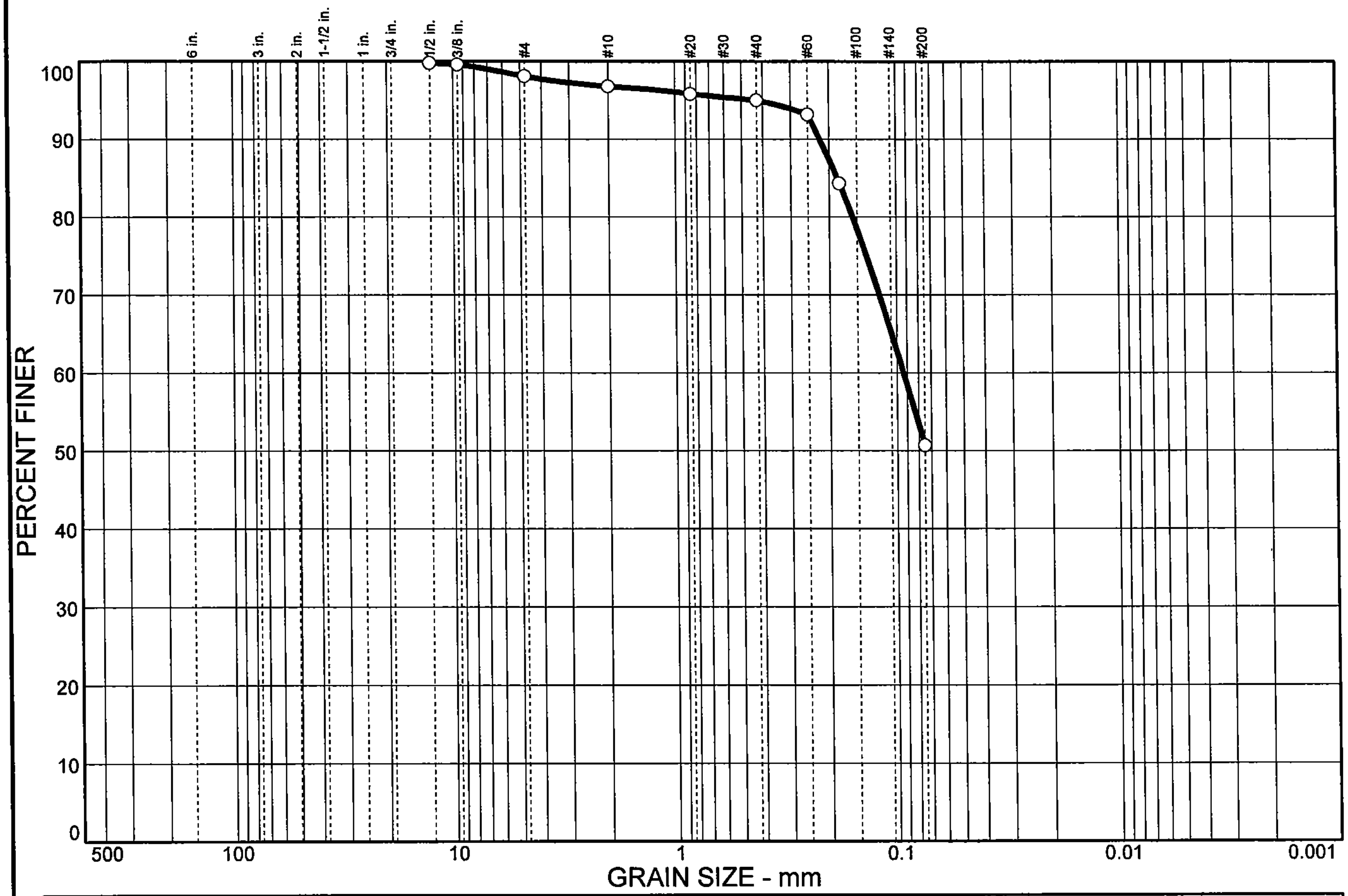
Remarks

Sample No.: 6062 **Source of Sample:** Client Samples **Date:**
Location: BIA-09 #6 **Elev./Depth:** 30 FT 9 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
			1.3	1.8	44.3	50.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	99.8		
3/8 in.	99.6		
# 4	98.1		
# 10	96.8		
# 20	95.8		
# 40	95.0		
# 60	93.2		
# 80	84.3		
# 200	50.7		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.184 D_{60}= 0.0935 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

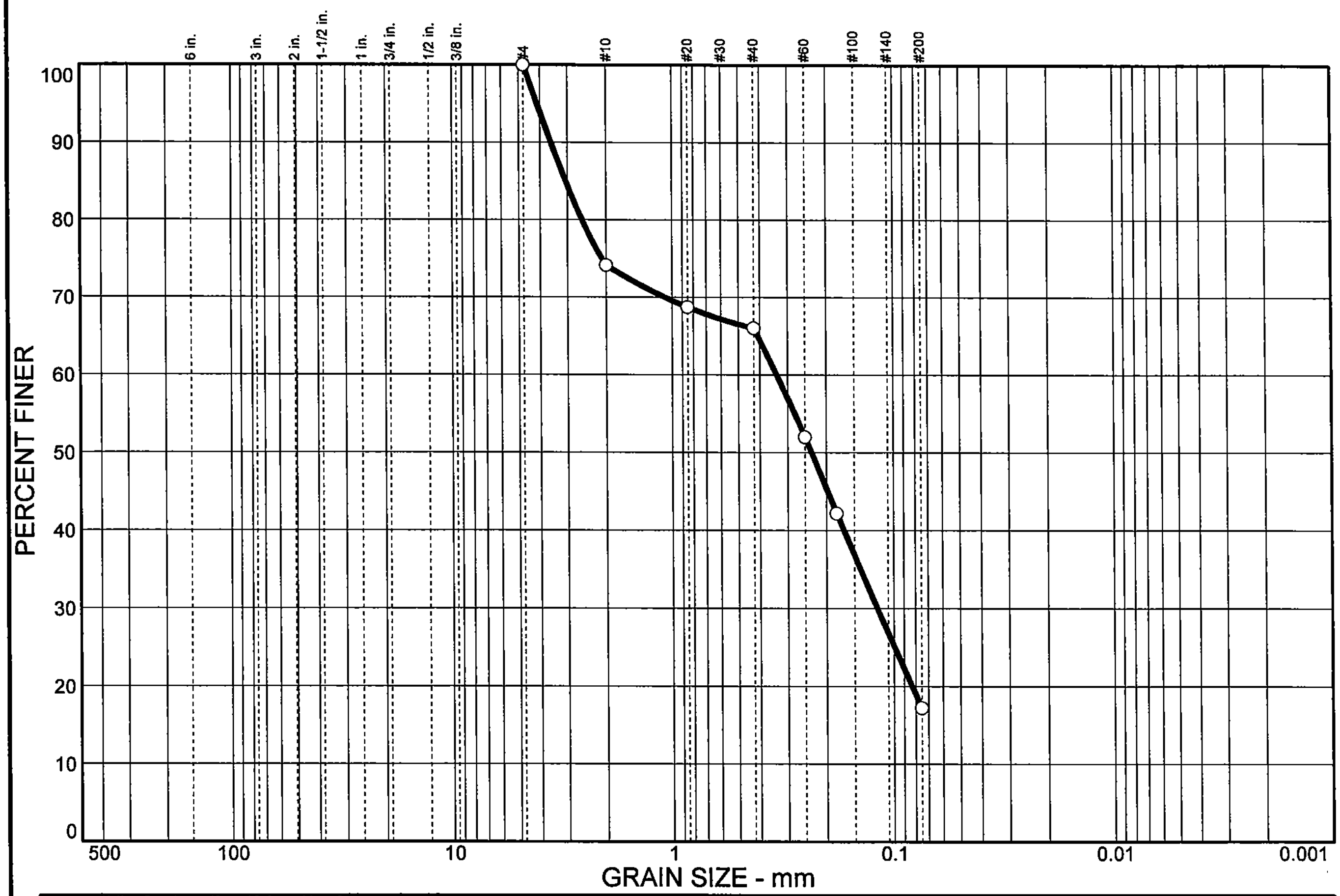
Remarks

Sample No.: 6063 **Source of Sample:** Client Samples **Date:**
Location: BIA-10 #3 **Elev./Depth:** 15 FT 4.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	25.9	8.1	48.8	17.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
# 4	100.0		
# 10	74.1		
# 20	68.7		
# 40	66.0		
# 60	52.0		
# 80	42.2		
# 200	17.2		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 3.06 D_{60}= 0.336 D_{50}= 0.233

D_{30}= 0.118 D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6064 **Source of Sample:** Client Samples **Date:**

Location: BIA-10 #5 **Elev./Depth:** 25 FT 7.5 m

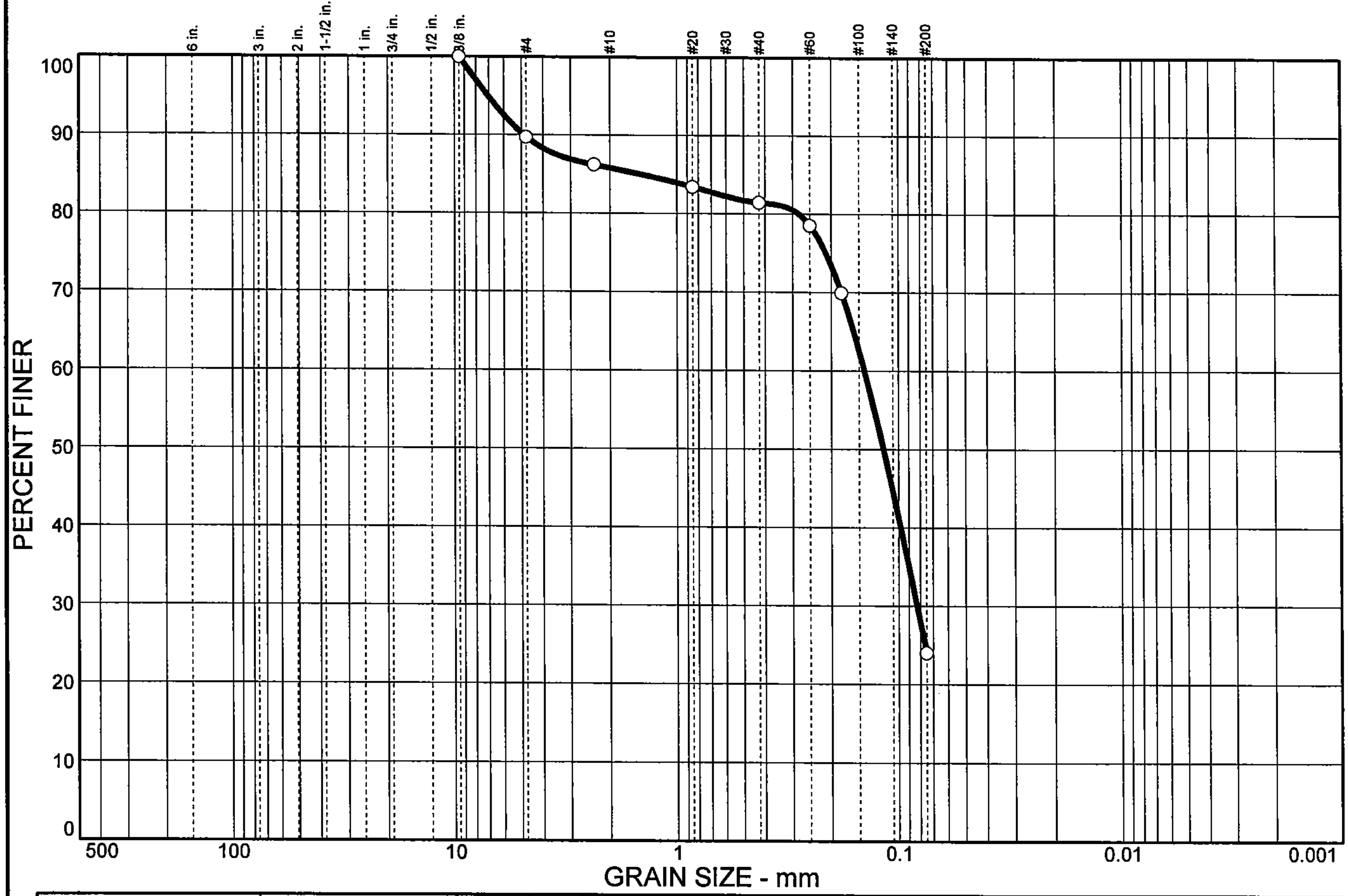
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	10.3	3.9	4.3	57.5	24.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	89.7		
# 8	86.2		
# 20	83.4		
# 40	81.4		
# 60	78.5		
# 80	69.9		
# 200	24.0		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 1.44 D_{60}= 0.142 D_{50}= 0.117

D_{30}= 0.0828 D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6065 **Source of Sample:** Client Samples **Date:**

Location: BIA-11 #2 **Elev./Depth:** 10 FT 3 m

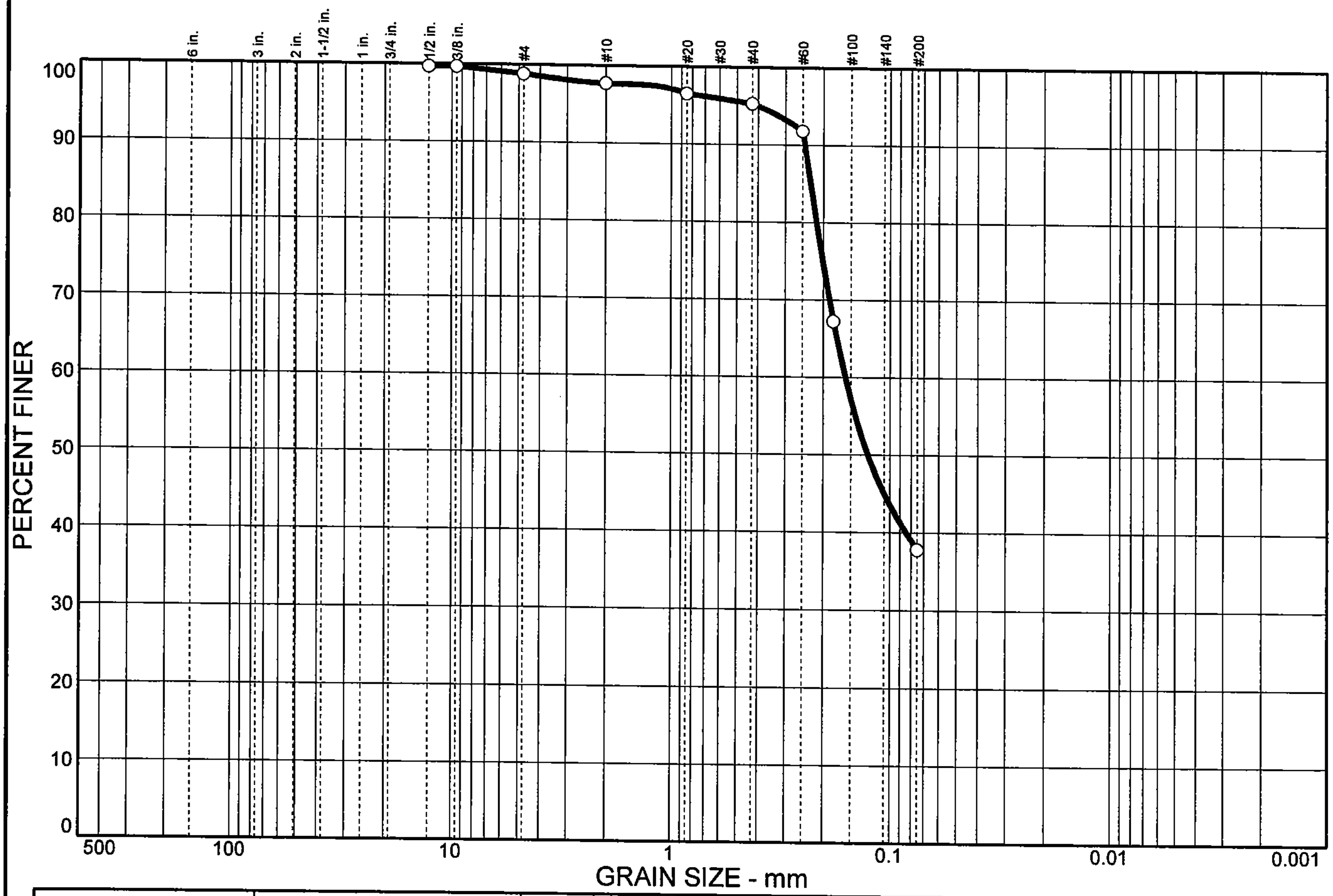
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
			1.1	2.4	57.5	37.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	99.7		
3/8 in.	99.7		
# 4	98.8		
# 10	97.7		
# 20	96.5		
# 40	95.3		
# 60	91.8		
# 80	67.2		
# 200	37.8		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 0.230
D_{60}= 0.159
D_{50}= 0.126
D_{30}=
D_{15}=
D_{10}=
C_u=
C_c=

Classification

USCS= SM
AASHTO= A-4(0)

Remarks

Sample No.: 6066
Location: BIA-13 #3
Source of Sample: Client Samples
Date:
Elev./Depth: 15 FT 4.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	3.8	2.4	1.8	88.6	3.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	96.2		
# 10	93.8		
# 20	92.9		
# 40	92.0		
# 60	86.8		
# 80	58.8		
# 200	3.4		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.245 D_{60}= 0.183 D_{50}= 0.160
D_{30}= 0.119 D_{15}= 0.0924 D_{10}= 0.0845
C_u= 2.16 C_c= 0.92

Classification

USCS= SP AASHTO= A-3

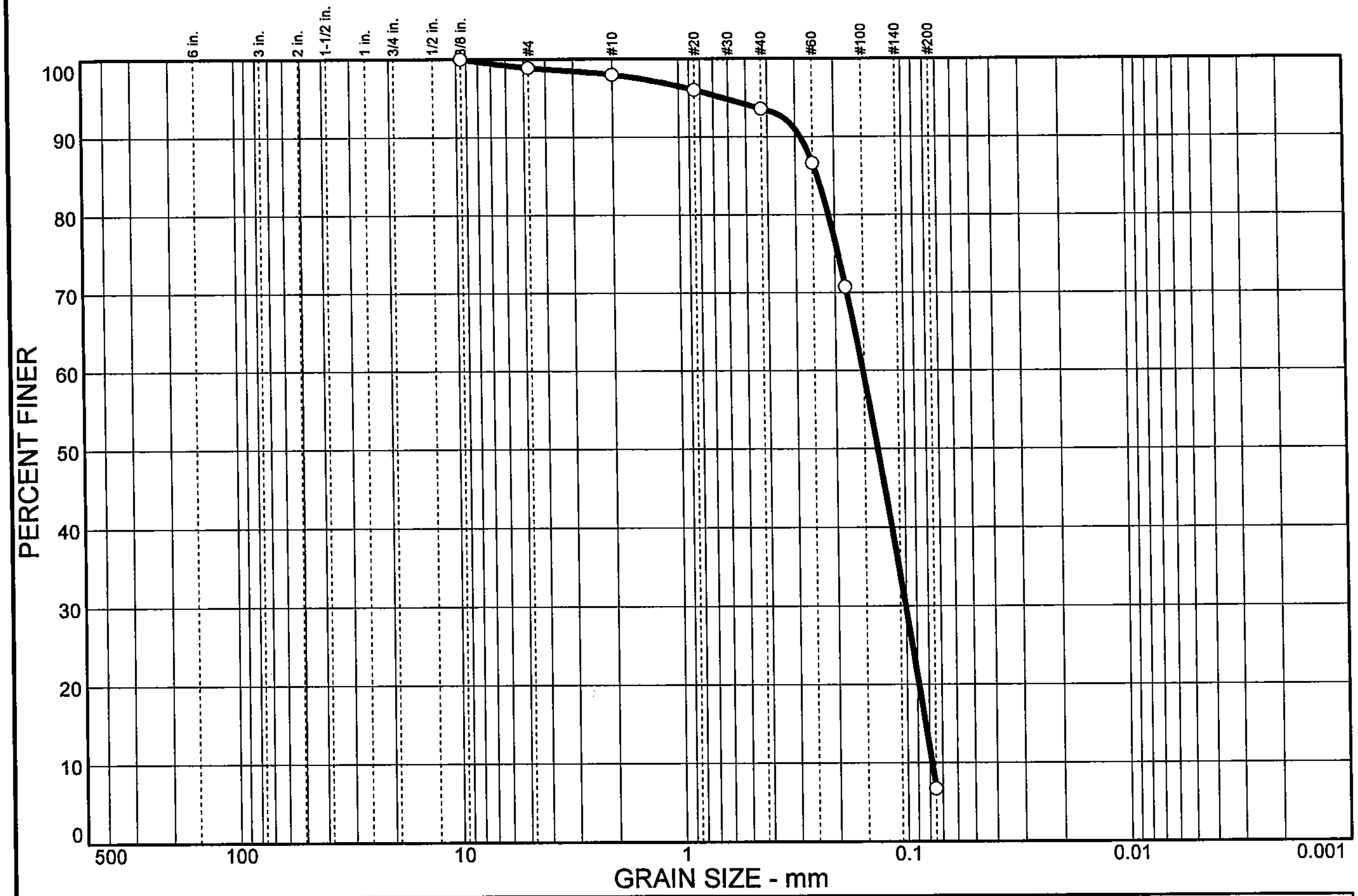
Remarks

Sample No.: 6067 **Source of Sample:** Client Samples **Date:**
Location: BIA-13 #4 **Elev./Depth:** 20 FT 6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	1.1	0.9	4.4	86.9	6.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	98.9		
# 10	98.0		
# 20	96.0		
# 40	93.6		
# 60	86.6		
# 80	70.7		
# 200	6.7		

* (no specification provided)

Soil Description

Poorly graded sand with silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.239 D_{60}= 0.152 D_{50}= 0.132
D_{30}= 0.101 D_{15}= 0.0832 D_{10}= 0.0782
C_u= 1.94 C_c= 0.85

Classification

USCS= SP-SM AASHTO= A-3

Remarks

Sample No.: 6068 **Source of Sample:** Client Samples **Date:**
Location: BIA-14 #4 **Elev./Depth:** 20 FT 6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	4.2	2.9	6.4	55.1	31.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	99.1		
# 4	95.8		
# 10	92.9		
# 20	89.3		
# 40	86.5		
# 60	80.5		
# 80	57.6		
# 200	31.4		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.361 D_{60}= 0.187 D_{50}= 0.156
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

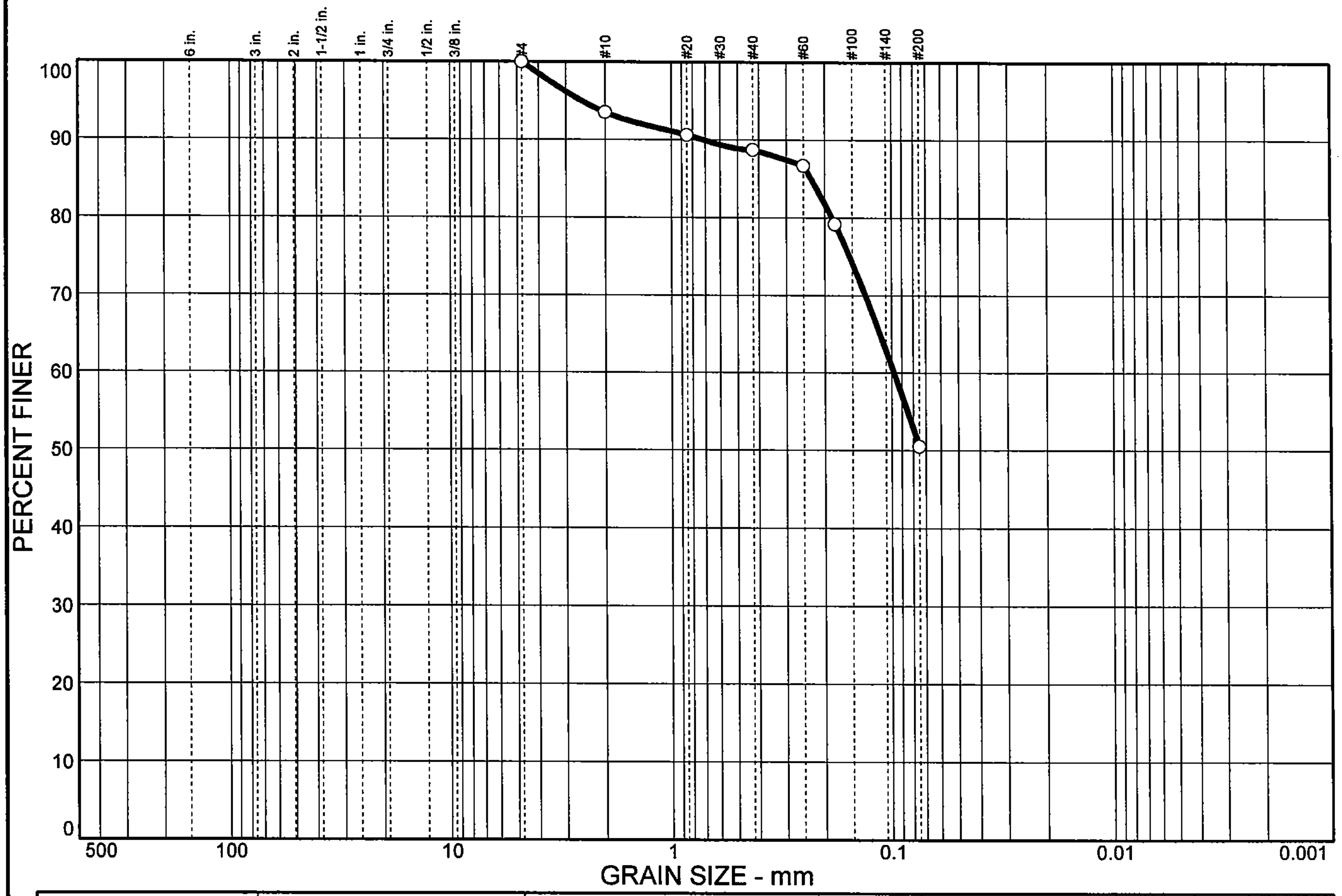
Remarks

Sample No.: 6069 **Source of Sample:** Client Samples **Date:**
Location: BIA-15 #2 **Elev./Depth:** 10 FT 3 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	6.5	4.8	38.2	50.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
# 4	100.0		
# 10	93.5		
# 20	90.6		
# 40	88.7		
# 60	86.7		
# 80	79.2		
# 200	50.5		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.231 D_{60}= 0.0976 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

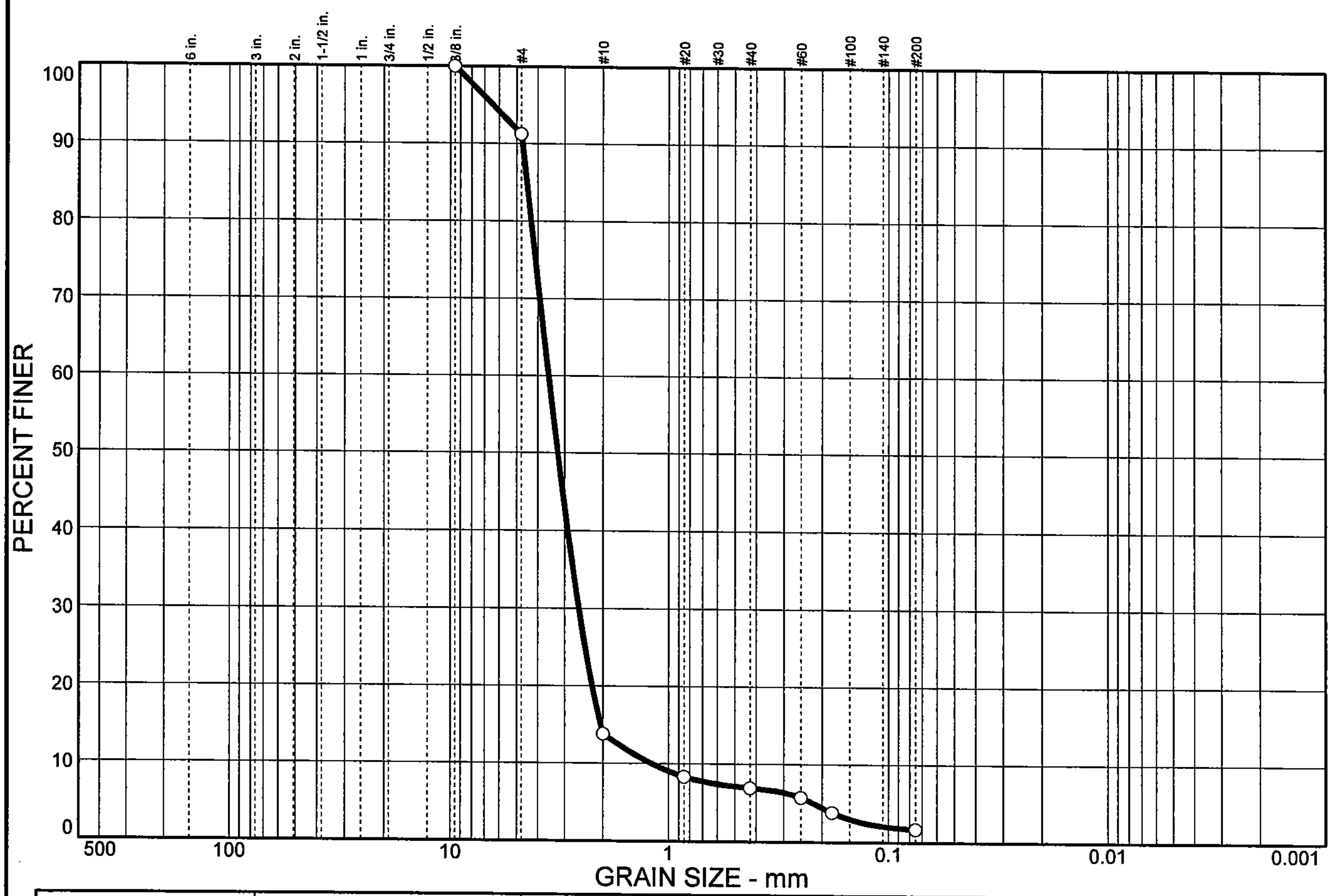
Remarks

Sample No.: 6070 **Source of Sample:** Client Samples **Date:**
Location: BIA-15 #4 **Elev./Depth:** 20 FT 6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	8.8	77.4	6.9	5.2	1.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	91.2		
# 10	13.8		
# 20	8.3		
# 40	6.9		
# 60	5.7		
# 80	3.8		
# 200	1.7		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 4.49 D_{60}= 3.57 D_{50}= 3.24
D_{30}= 2.59 D_{15}= 2.05 D_{10}= 1.20
C_u= 2.98 C_c= 1.57

Classification

USCS= SP AASHTO= A-1-a

Remarks

Sample No.: 6071 **Source of Sample:** Client Samples **Date:**
Location: BIA-16 #3 **Elev./Depth:** 15 FT 4.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	49.1	12.5	8.4	28.7	1.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	97.8		
3/8 in.	90.6		
# 4	50.9		
# 10	38.4		
# 20	32.7		
# 40	30.0		
# 60	25.4		
# 80	11.5		
# 200	1.3		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 8.46 D_{60}= 5.63 D_{50}= 4.65
D_{30}= 0.425 D_{15}= 0.198 D_{10}= 0.172
C_u= 32.76 C_c= 0.19

Classification

USCS= SP AASHTO= A-1-a

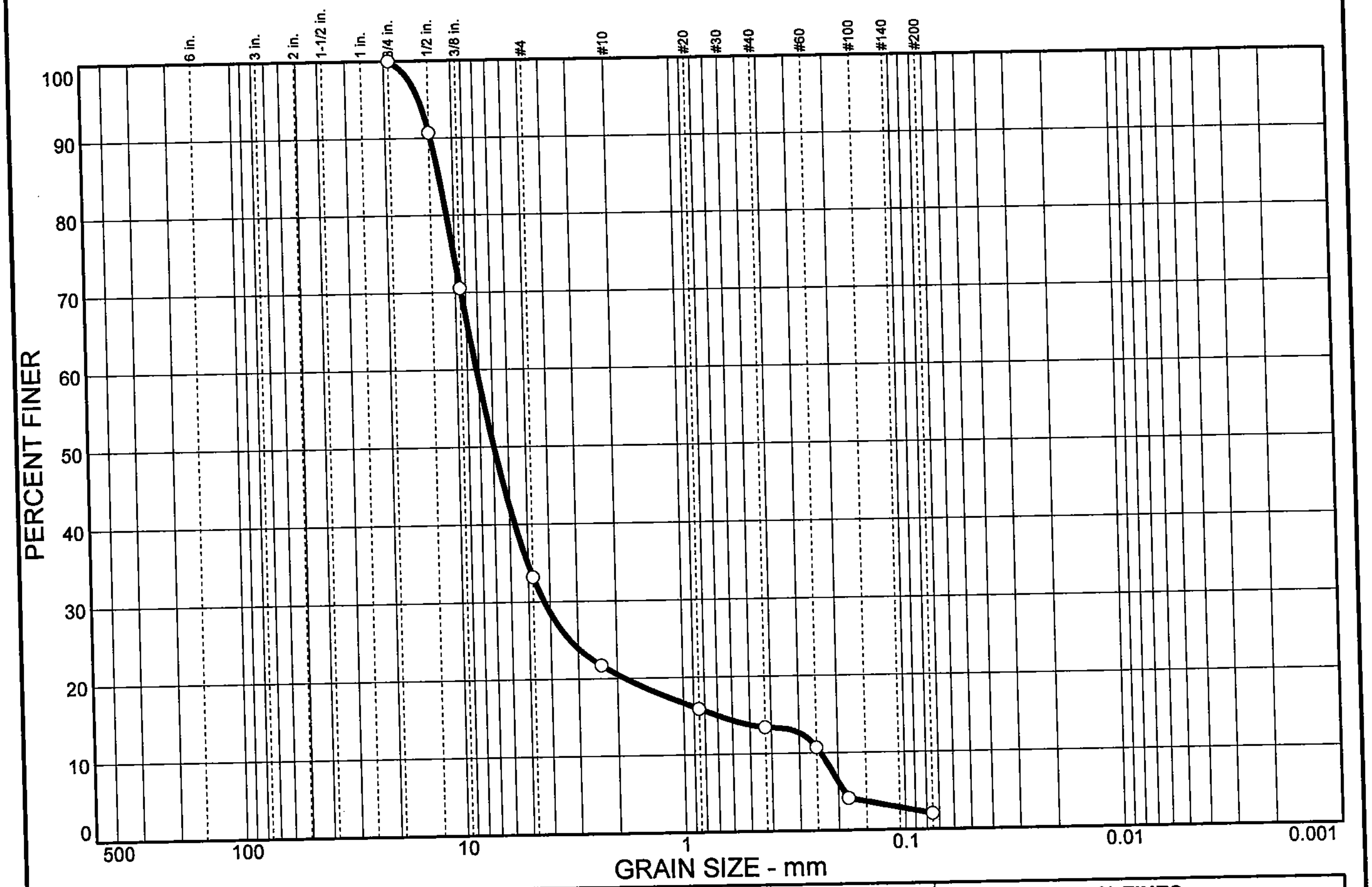
Remarks

Sample No.: 6072 **Source of Sample:** Client Samples **Date:**
Location: BIA-16 #4 **Elev./Depth:** 20 FT 6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	66.8	12.7	7.1	11.4	2.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	90.7		
3/8 in.	70.5		
# 4	33.2		
# 8	21.7		
# 20	15.9		
# 40	13.4		
# 60	10.7		
# 80	4.1		
# 200	2.0		

* (no specification provided)

Soil Description

Poorly graded gravel with sand

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 11.6
D_{60}= 8.20
D_{50}= 6.96
D_{30}= 4.25
D_{15}= 0.702
D_{10}= 0.240
C_u= 34.20
C_c= 9.16

Classification

USCS= GP
AASHTO= A-1-a

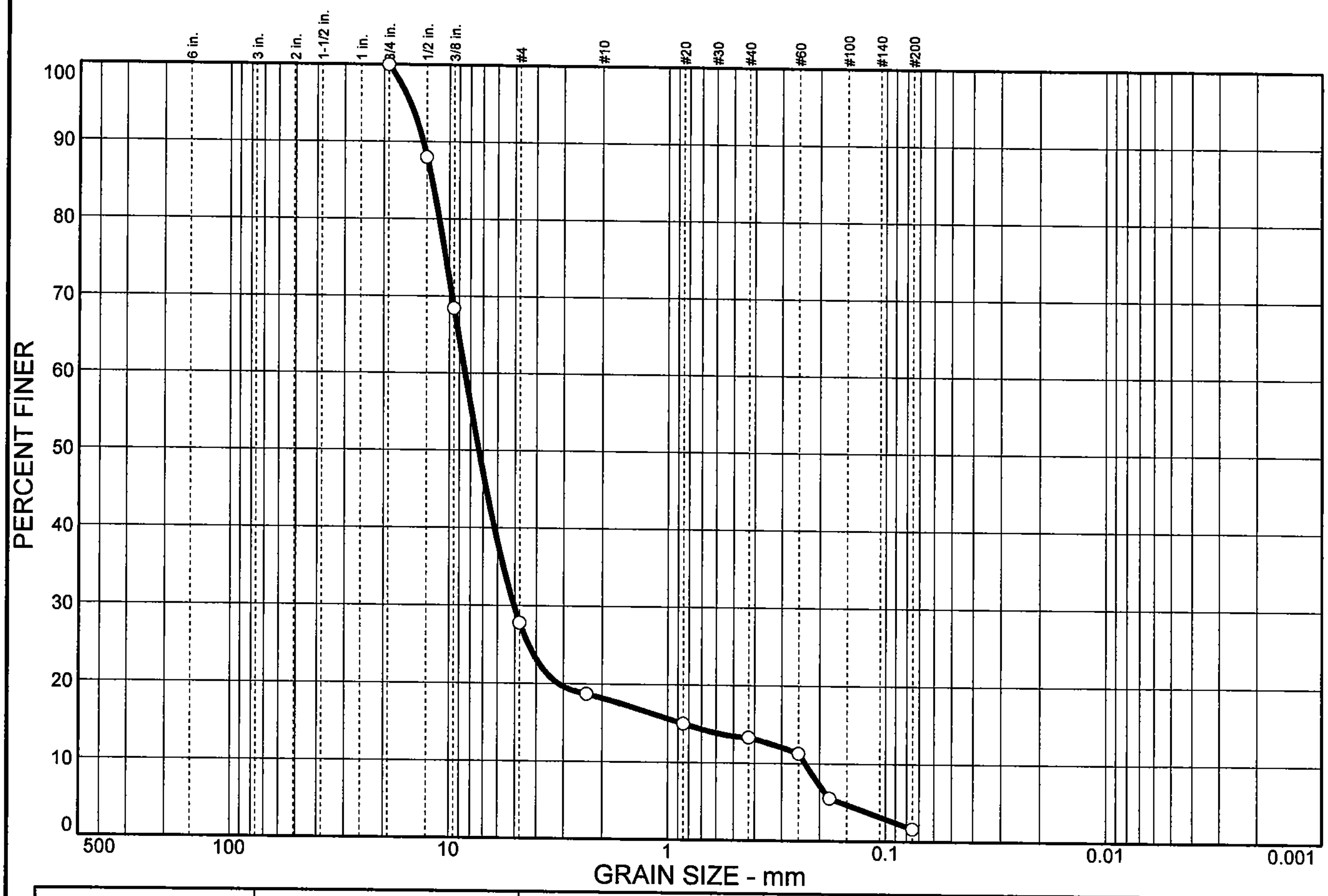
Remarks

Sample No.: 6073
Source of Sample: Client Samples
Date:
Location: BIA-16 #5
Elev./Depth: 25 FT 7.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	72.2	9.6	4.9	11.7	1.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	88.0		
3/8 in.	68.4		
# 4	27.8		
# 8	18.7		
# 20	15.0		
# 40	13.3		
# 60	11.3		
# 80	5.5		
# 200	1.6		

* (no specification provided)

Soil Description

Poorly graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 12.0 D_{60}= 8.49 D_{50}= 7.33
D_{30}= 5.04 D_{15}= 0.850 D_{10}= 0.234
C_u= 36.32 C_c= 12.82

Classification

USCS= GP AASHTO= A-1-a

Remarks

Sample No.: 6074
Location: BIA-16 #6

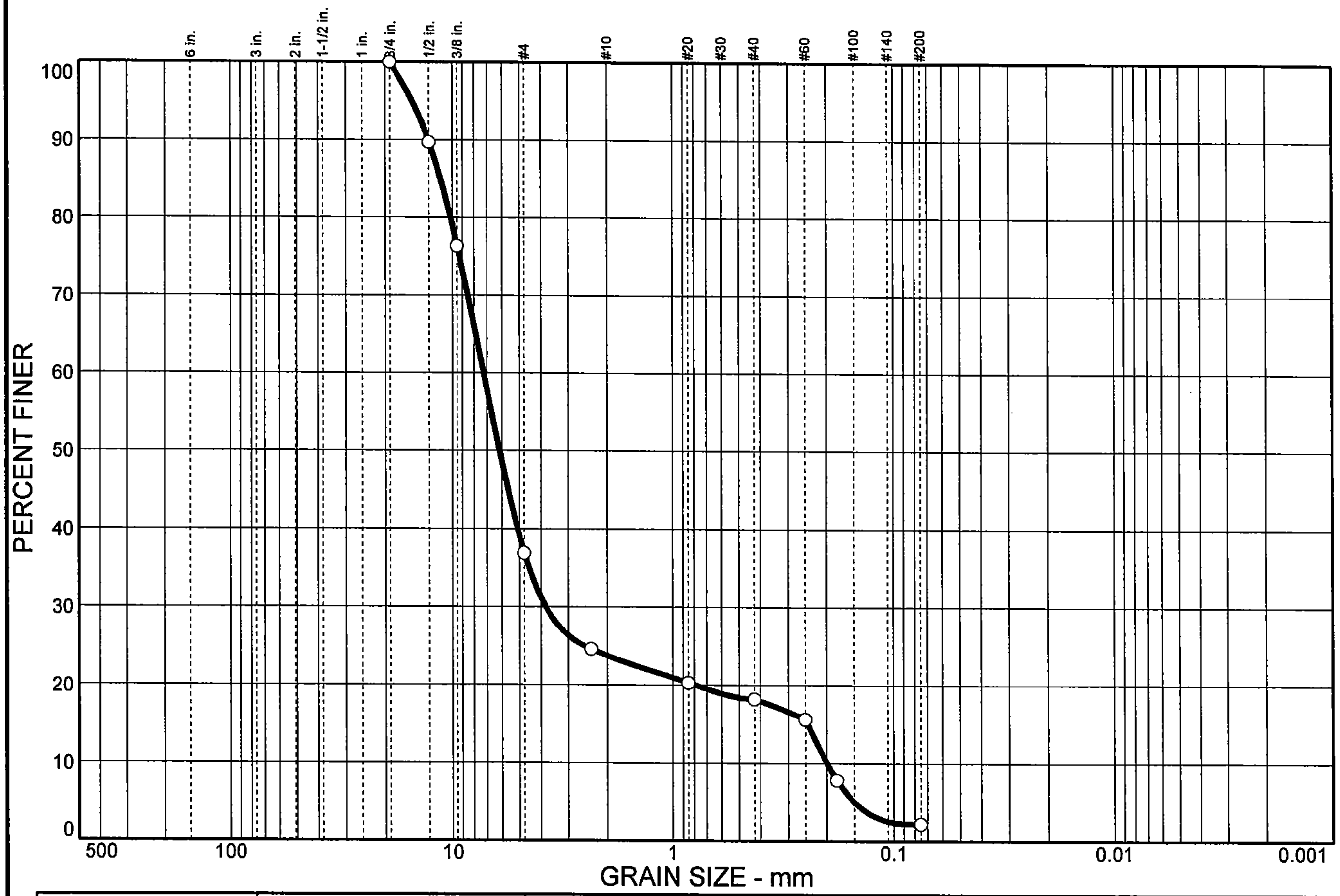
Source of Sample: Client Samples

Date:
Elev./Depth: 30 FT 9 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	63.1	13.1	5.6	16.0	2.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	89.7		
3/8 in.	76.3		
# 4	36.9		
# 8	24.6		
# 20	20.3		
# 40	18.2		
# 60	15.6		
# 80	7.8		
# 200	2.2		

* (no specification provided)

Soil Description

Poorly graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 11.3 D_{60}= 7.26 D_{50}= 6.16
D_{30}= 3.80 D_{15}= 0.244 D_{10}= 0.200
C_u= 36.35 C_c= 9.94

Classification

USCS= GP AASHTO= A-1-a

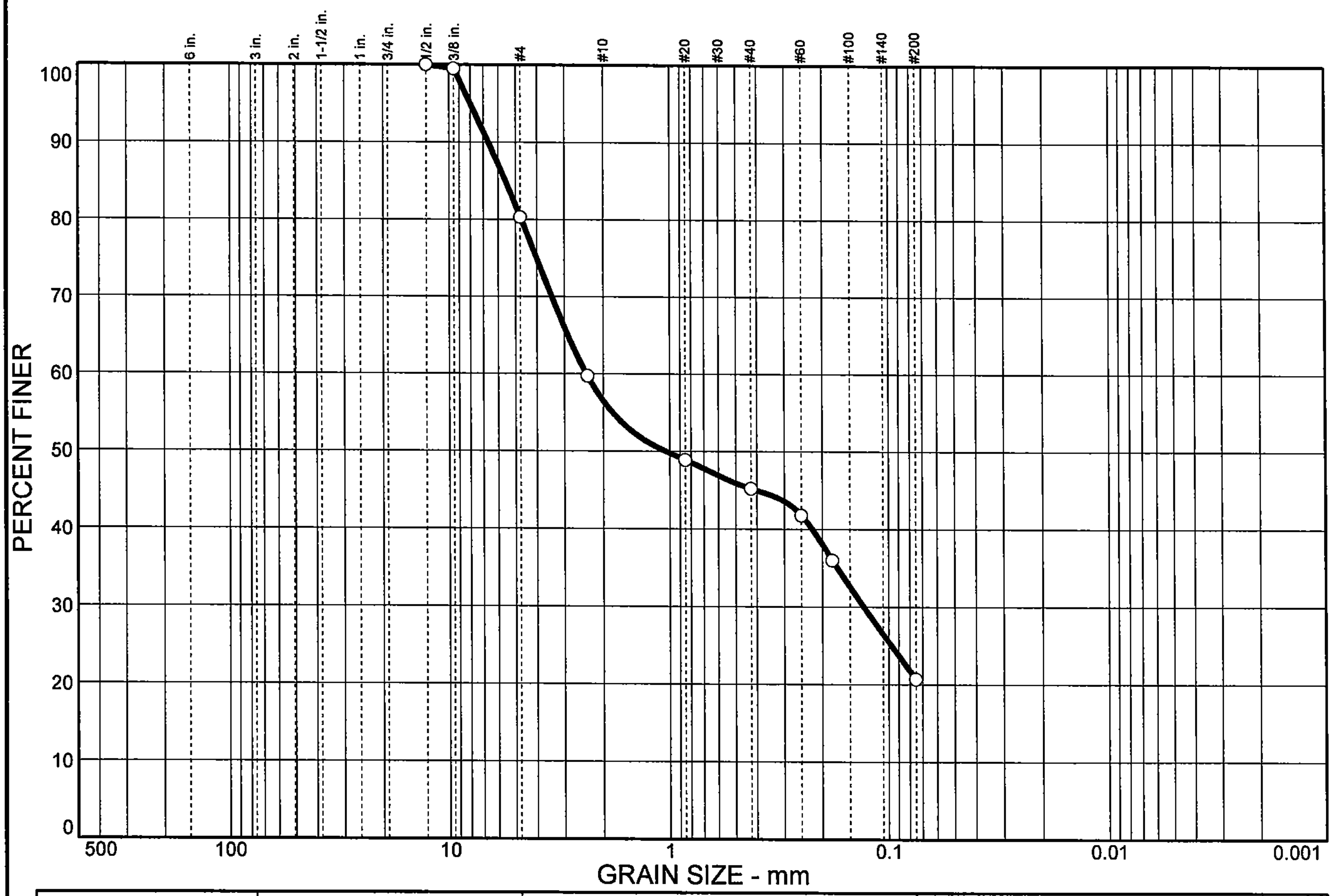
Remarks

Sample No.: 6075 **Source of Sample:** Client Samples **Date:**
Location: BIA-16 #7 **Elev./Depth:** 35 FT 10.5

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	19.7	23.8	11.3	24.5	20.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	99.5		
# 4	80.3		
# 8	59.7		
# 20	48.9		
# 40	45.2		
# 60	41.8		
# 80	36.0		
# 200	20.7		

* (no specification provided)

Soil Description

Silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 5.56 D_{60}= 2.39 D_{50}= 1.04

D_{30}= 0.130 D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-1-b

Remarks

Sample No.: 6076 **Source of Sample:** Client Samples **Date:**

Location: BIA-17 #3 **Elev./Depth:** 15 FT 4.5 m

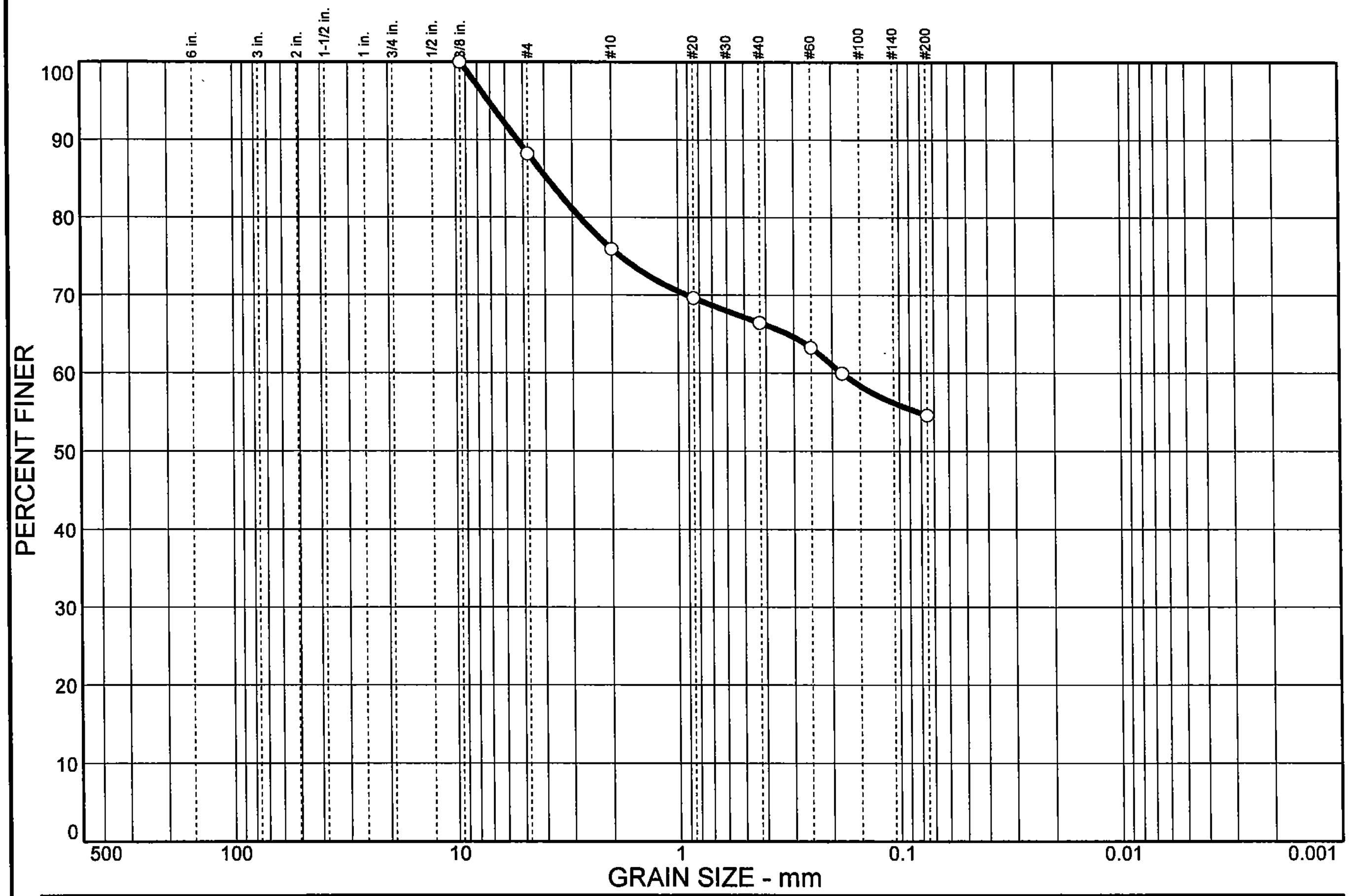
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	11.8	12.3	9.5	11.8	54.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	88.2		
# 10	75.9		
# 20	69.6		
# 40	66.4		
# 60	63.2		
# 80	59.9		
# 200	54.6		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 3.90 D_{60}= 0.182 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

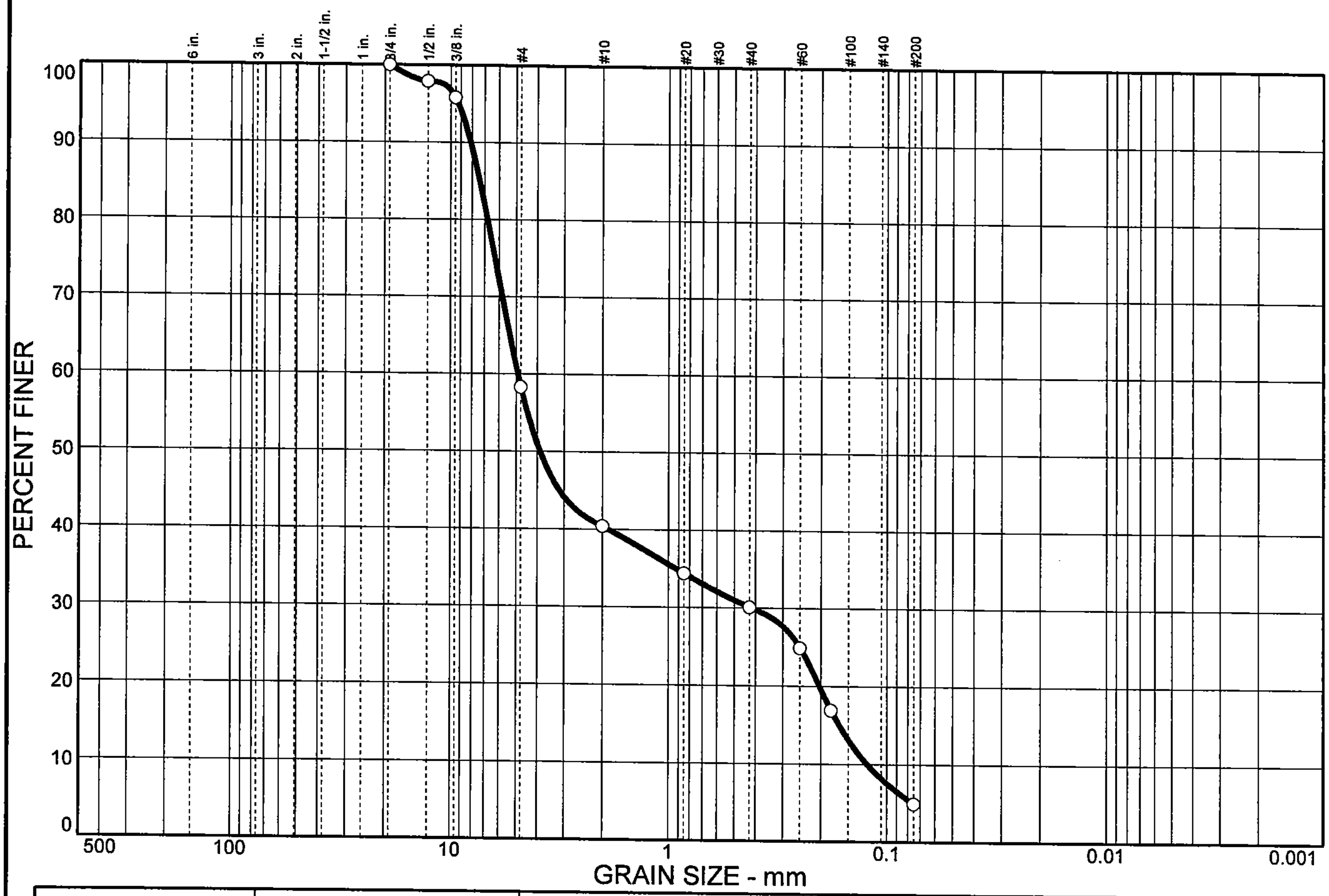
Remarks

Sample No.: 6077
Source of Sample: Client Samples
Date:
Location: BIA-17 #5
Elev./Depth: 25 FT 7.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	41.7	17.9	10.3	25.2	4.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	97.9		
3/8 in.	95.8		
# 4	58.3		
# 10	40.4		
# 20	34.4		
# 40	30.1		
# 60	24.9		
# 80	16.9		
# 200	4.9		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 7.38 D_{60}= 4.91 D_{50}= 3.88
D_{30}= 0.417 D_{15}= 0.165 D_{10}= 0.123
C_u= 39.85 C_c= 0.29

Classification

USCS= SP AASHTO= A-1-a

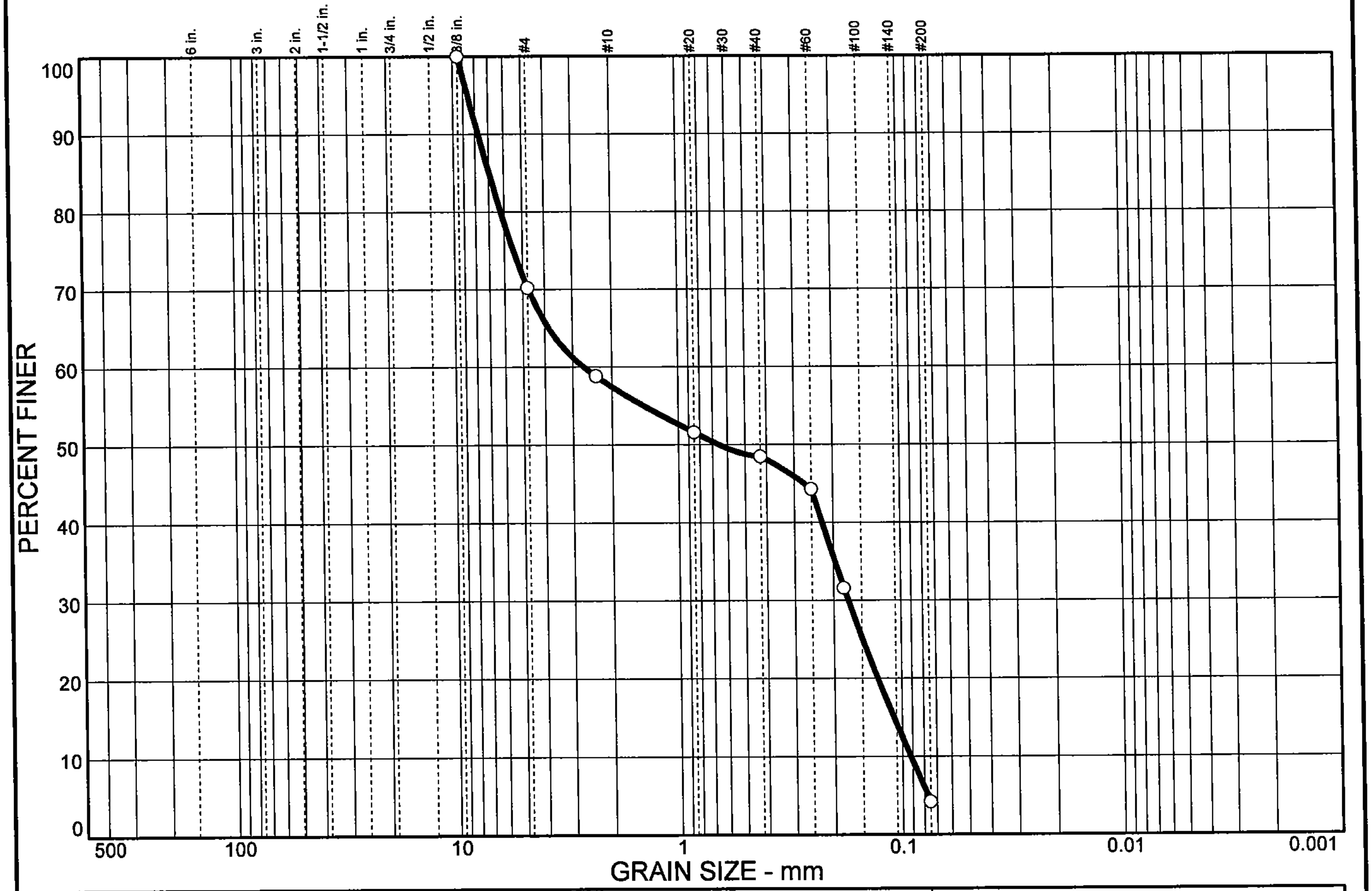
Remarks

Sample No.: 6078 **Source of Sample:** Client Samples **Date:**
Location: BIA-17 #6 **Elev./Depth:** 30 FT 9 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	29.8	12.8	8.9	44.3	4.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	70.2		
# 8	58.8		
# 20	51.6		
# 40	48.5		
# 60	44.3		
# 80	31.6		
# 200	4.2		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 6.97 D_{60}= 2.69 D_{50}= 0.656
D_{30}= 0.172 D_{15}= 0.109 D_{10}= 0.0918
C_u= 29.29 C_c= 0.12

Classification

USCS= SP AASHTO= A-1-b

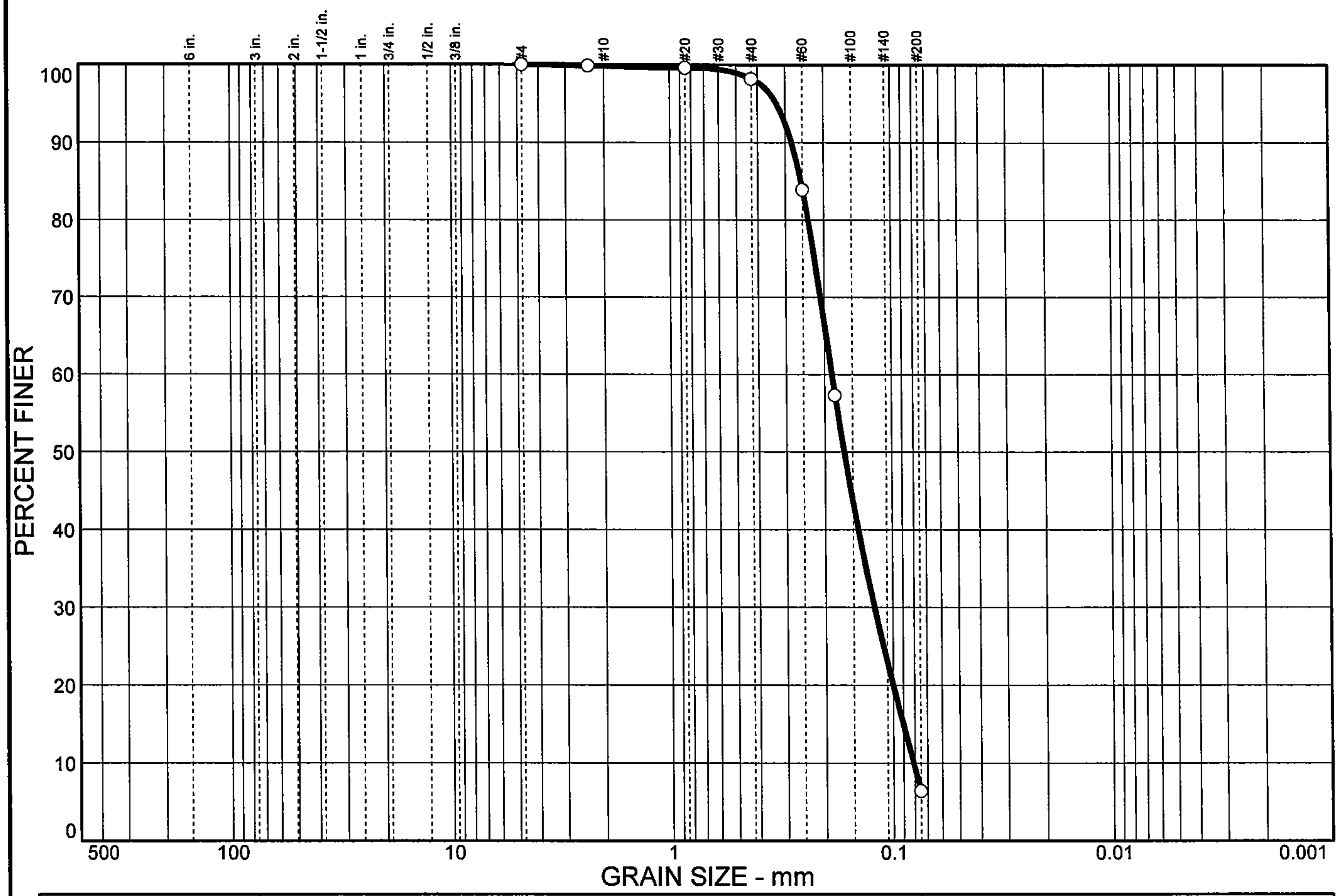
Remarks

Sample No.: 6079 **Source of Sample:** Client Samples **Date:**
Location: BIA-17 #7 **Elev./Depth:** 35 FT 10.5

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.0	0.1	1.7	91.8	6.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
# 4	100.0		
# 8	99.9		
# 20	99.6		
# 40	98.2		
# 60	83.9		
# 80	57.3		
# 200	6.4		

* (no specification provided)

Soil Description

Poorly graded sand with silt

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 0.254
D_{60}= 0.186
D_{50}= 0.164
D_{30}= 0.121
D_{15}= 0.0903
D_{10}= 0.0811
C_u= 2.29
C_c= 0.97

Classification

USCS= SP-SM
AASHTO= A-3

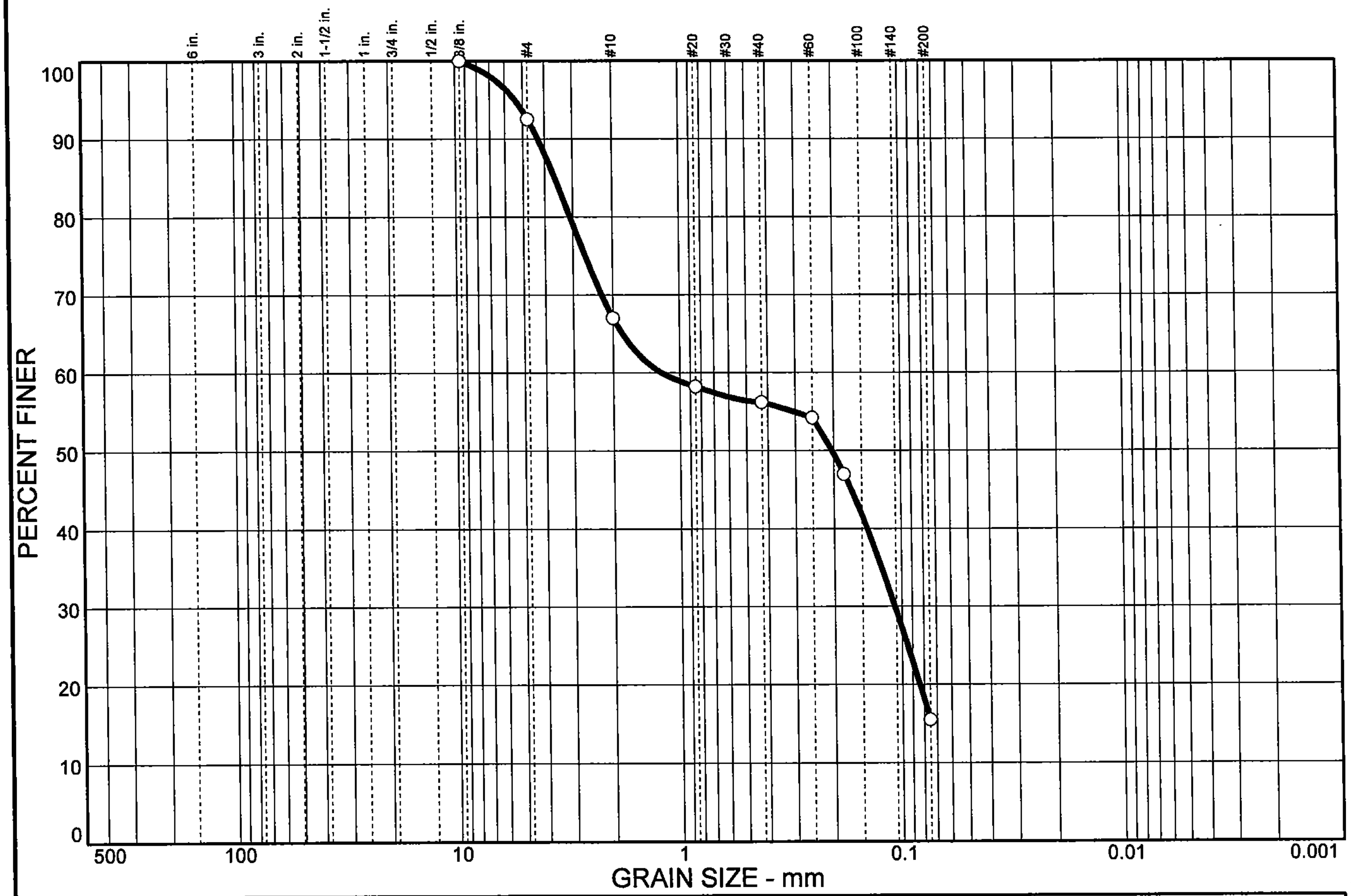
Remarks

Sample No.: 6080
Source of Sample: Client Samples
Date:
Location: BIA-17 #8
Elev./Depth: 40 FT 12 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	7.5	25.5	10.8	40.7	15.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	92.5		
# 10	67.0		
# 20	58.2		
# 40	56.2		
# 60	54.2		
# 80	47.0		
# 200	15.5		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 3.61 D_{60}= 1.22 D_{50}= 0.204

D_{30}= 0.108 D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6081
Location: BIA-18 #4

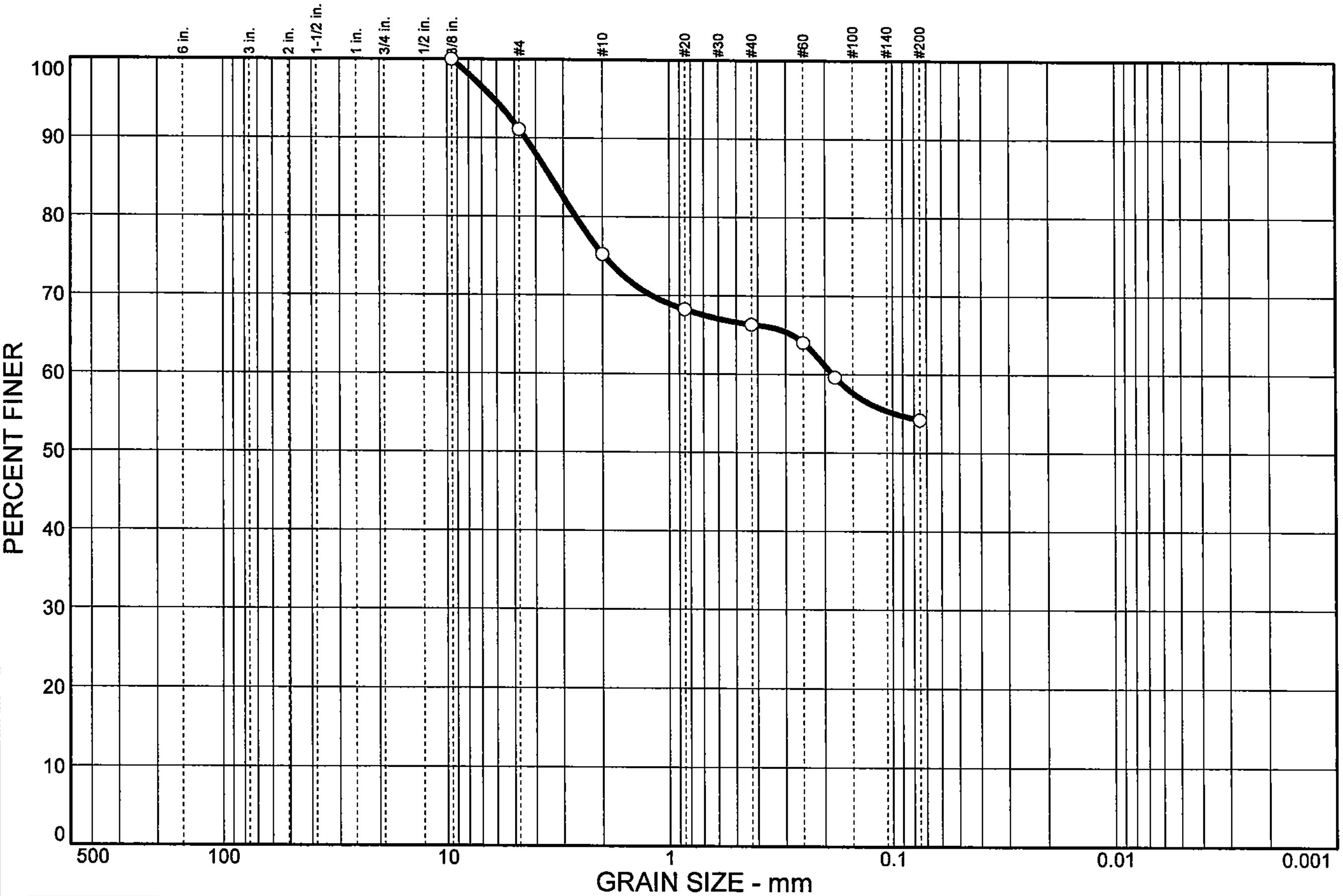
Source of Sample: Client Samples

Date:
Elev./Depth: 20 FT 6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	8.9	15.9	8.9	12.1	54.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	91.1		
# 10	75.2		
# 20	68.2		
# 40	66.3		
# 60	64.0		
# 80	59.6		
# 200	54.2		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 3.42 D_{60}= 0.186 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

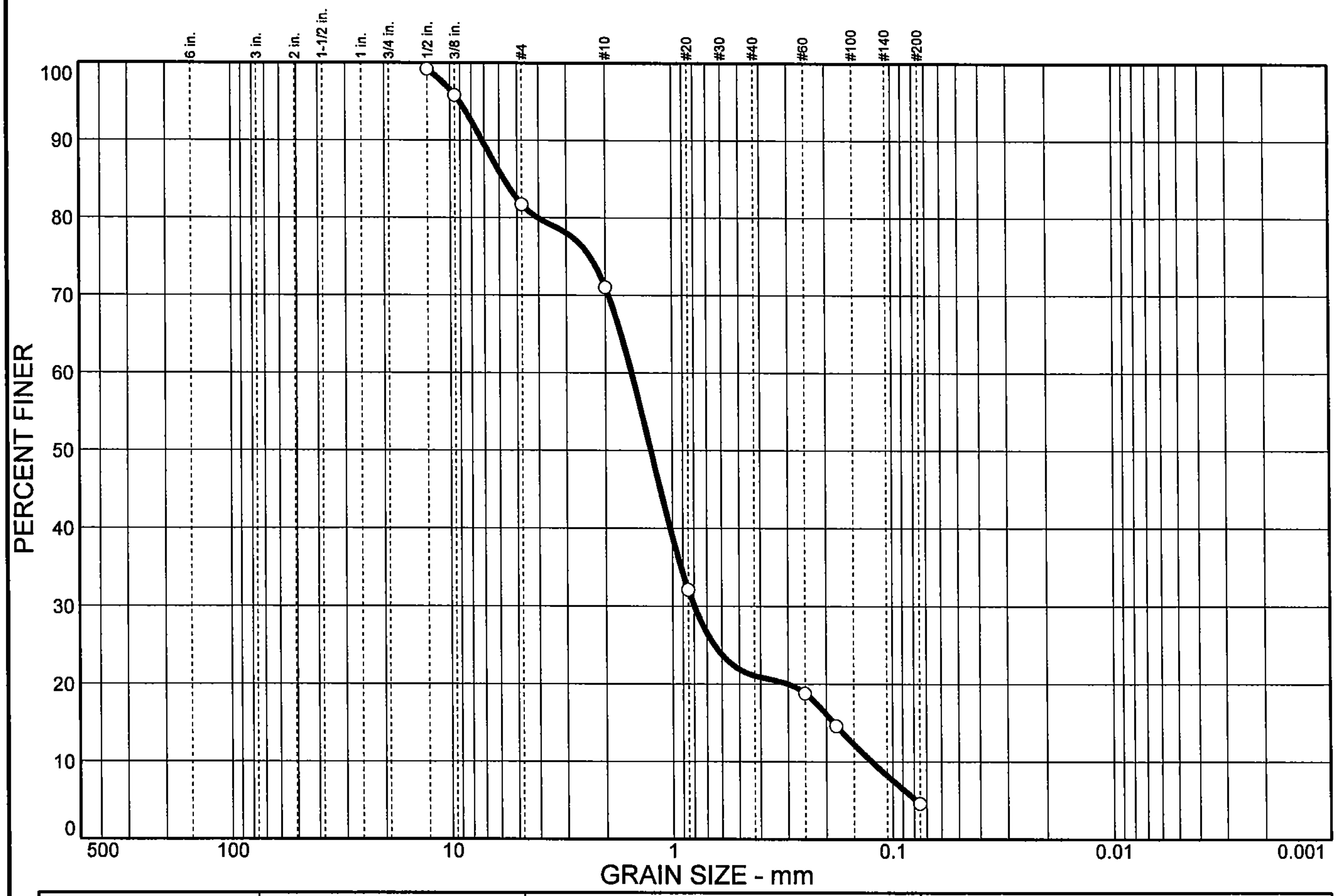
Remarks

Sample No.: 6082 **Source of Sample:** Client Samples **Date:**
Location: BIA-18 #5 **Elev./Depth:** 25 FT 7.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
			10.7	49.9	16.5	4.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	99.2		
3/8 in.	95.8		
# 4	81.7		
# 10	71.0		
# 20	32.1		
# 60	18.8		
# 80	14.6		
# 200	4.6		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 5.73 D_{60}= 1.53 D_{50}= 1.25

D_{30}= 0.798 D_{15}= 0.185 D_{10}= 0.125

C_u= 12.25 C_c= 3.34

Classification

USCS= SP AASHTO= A-1-b

Remarks

Sample No.: 6083 **Source of Sample:** Client Samples **Date:**

Location: BIA-18 #6 **Elev./Depth:** 30 FT 9 m

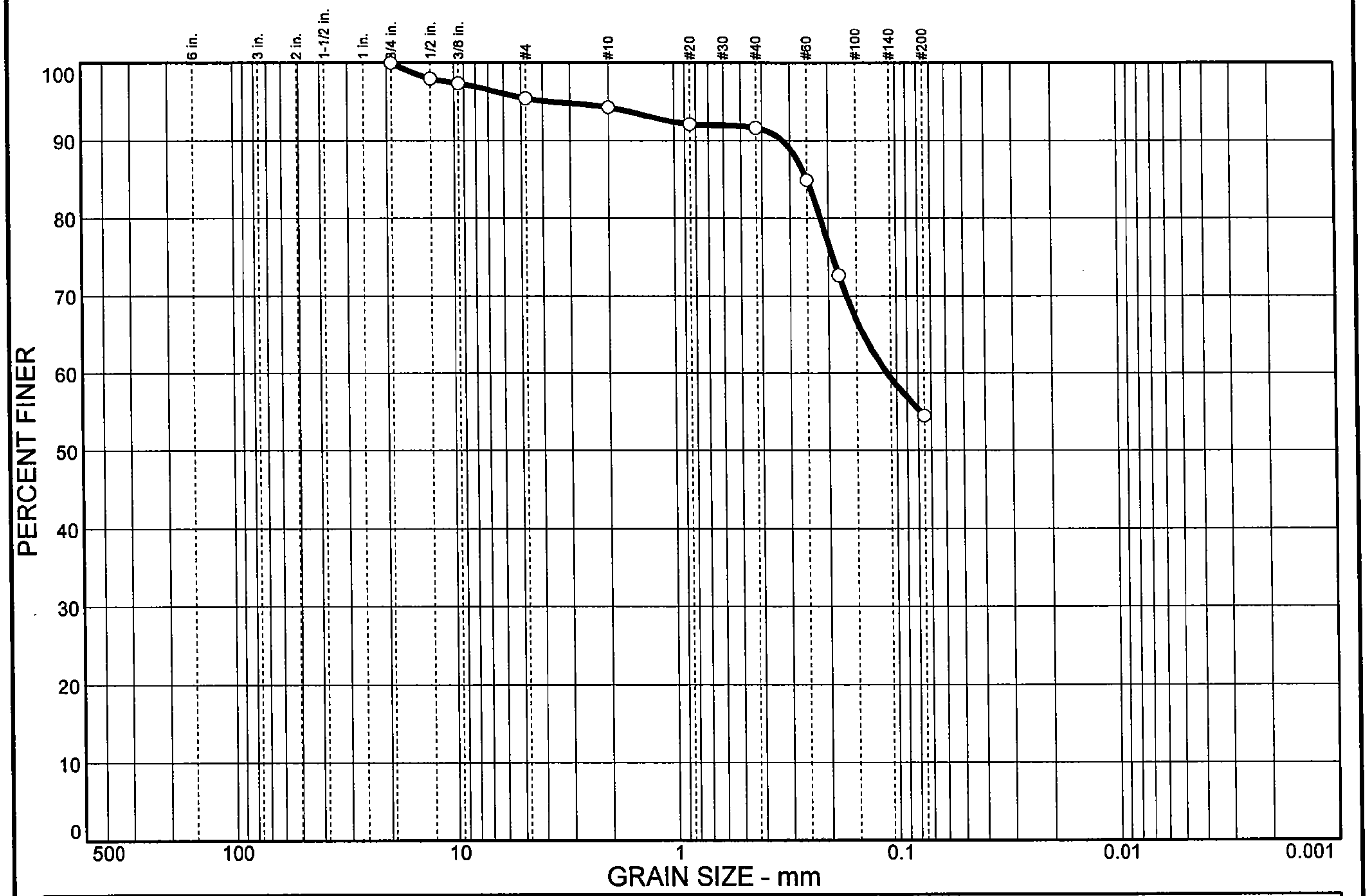
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	4.6	1.1	2.7	37.1	54.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	98.0		
3/8 in.	97.4		
# 4	95.4		
# 10	94.3		
# 20	92.1		
# 40	91.6		
# 60	84.9		
# 80	72.6		
# 200	54.5		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.251 D_{60}= 0.110 D_{50}=

D_{30}= D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

Remarks

Sample No.: 6084 **Source of Sample:** Client Samples **Date:**

Location: BIA-18 #7 **Elev./Depth:** 35 FT 10.5 m

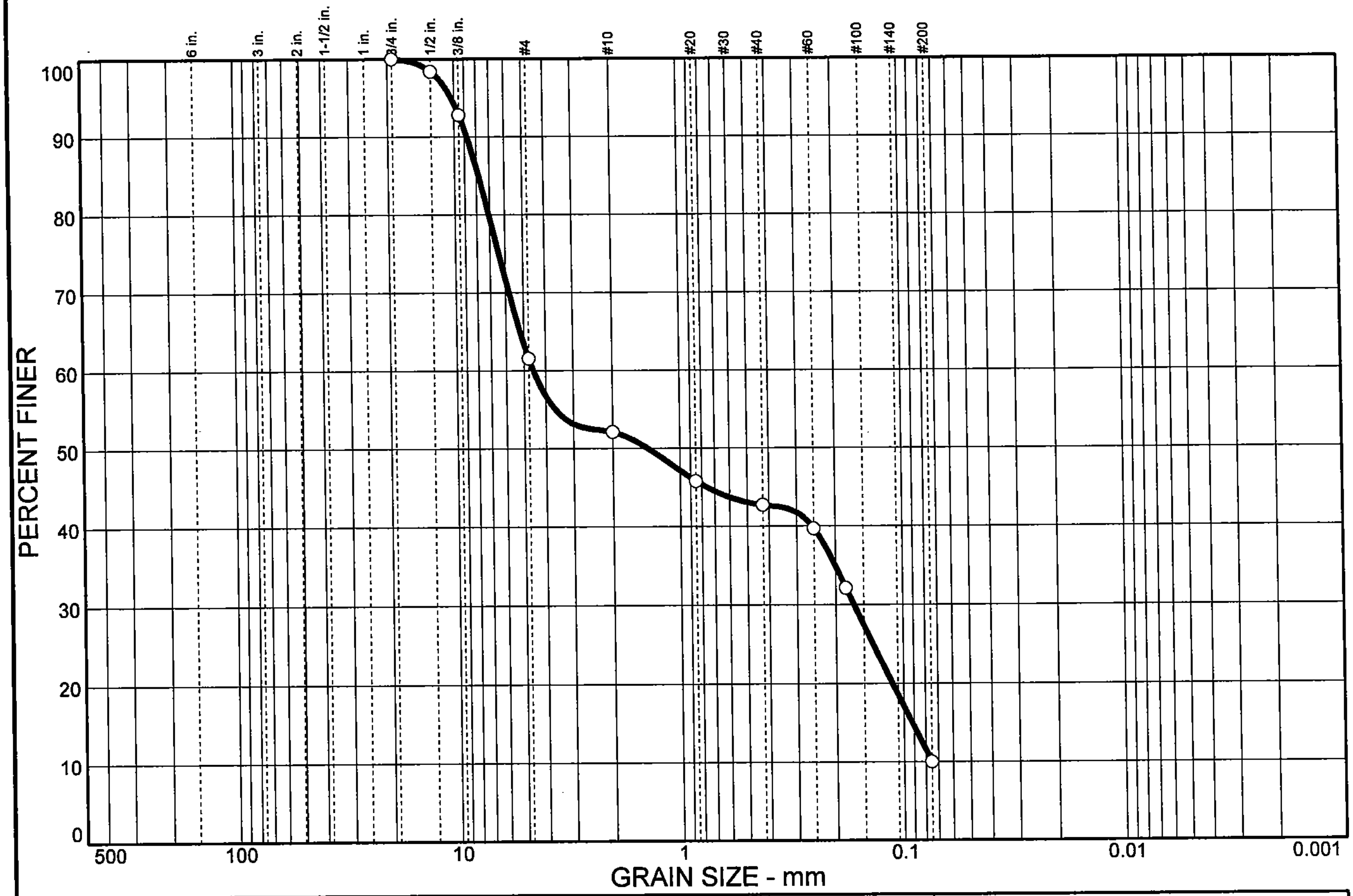
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	38.5	9.4	9.4	32.7	10.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	98.4		
3/8 in.	92.8		
# 4	61.5		
# 10	52.1		
# 20	45.8		
# 40	42.7		
# 60	39.7		
# 80	32.1		
# 200	10.0		

* (no specification provided)

Soil Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 7.84
D_{60}= 4.54
D_{50}= 1.40
D_{30}= 0.166
D_{15}= 0.0918
D_{10}= 0.0750
C_u= 60.53
C_c= 0.08

Classification

USCS= SP-SM
AASHTO= A-1-b

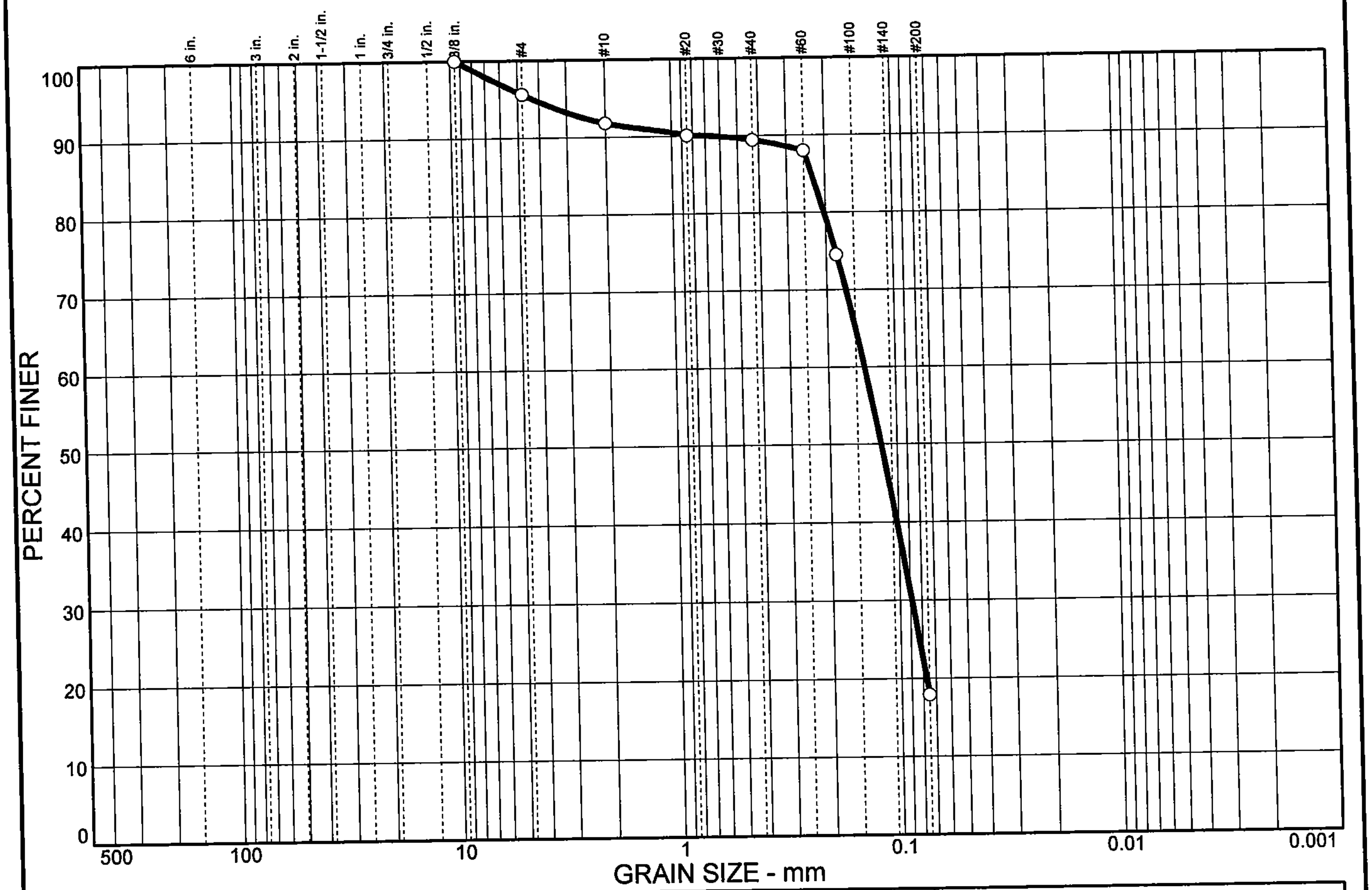
Remarks

Sample No.: 6085
Location: BIA-18 #8
Source of Sample: Client Samples
Date:
Elev./Depth: 37 FT 11.1

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	4.4	3.8	2.4	71.5	17.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	95.6		
# 10	91.8		
# 20	90.1		
# 40	89.4		
# 60	88.0		
# 80	74.5		
# 200	17.9		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.231 D_{60}= 0.138 D_{50}= 0.118
D_{30}= 0.0886 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6086
Location: BIA-19 #4

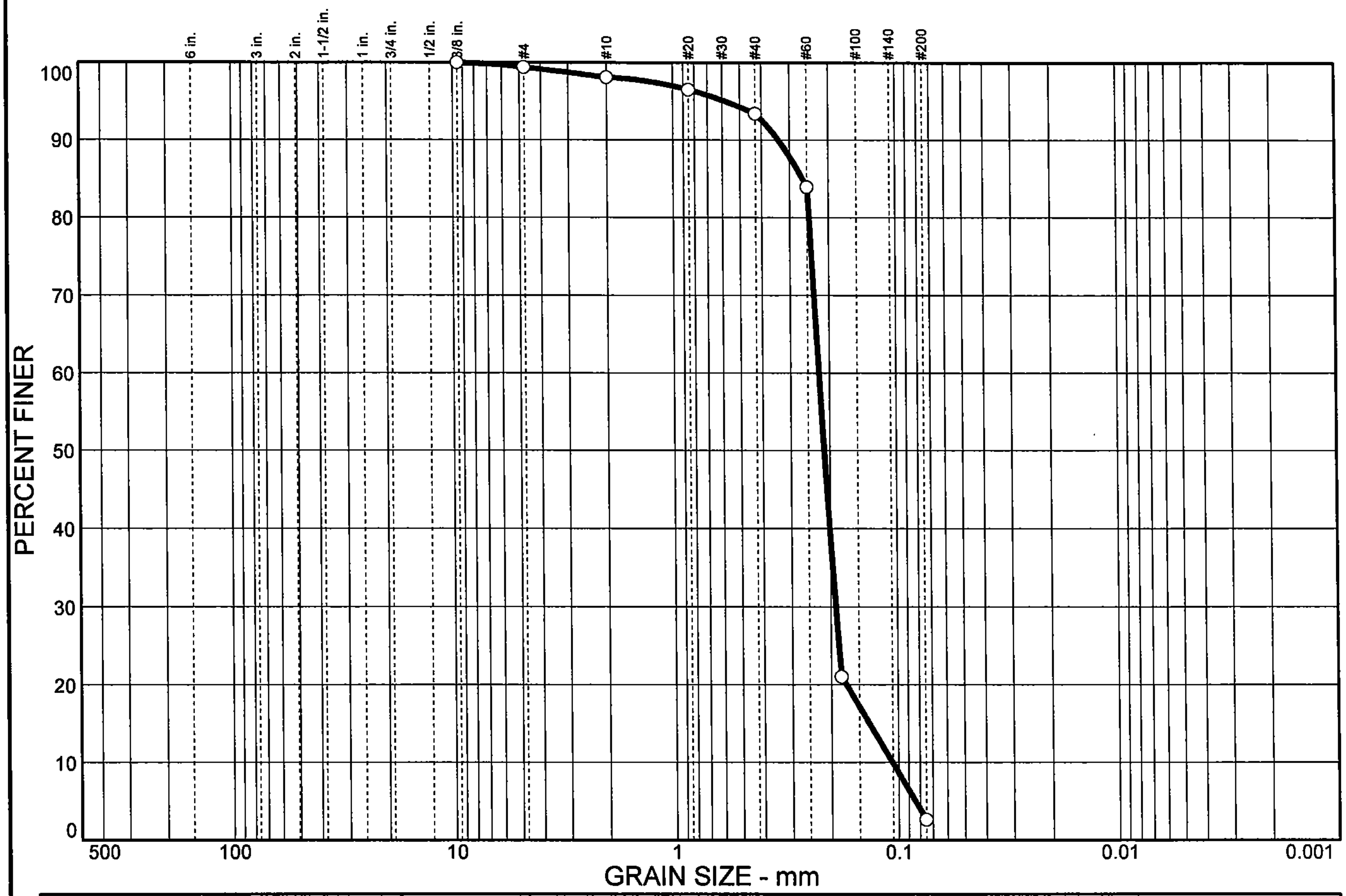
Source of Sample: Client Samples

Date:
Elev./Depth: 20 FT 6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.6	1.3	4.7	90.8	2.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	99.4		
# 10	98.1		
# 20	96.5		
# 40	93.4		
# 60	83.9		
# 80	21.0		
# 200	2.6		

* (no specification provided)

Soil Description

Poorly graded sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.262 D_{60}= 0.223 D_{50}= 0.212
D_{30}= 0.191 D_{15}= 0.135 D_{10}= 0.107
C_u= 2.09 C_c= 1.53

Classification

USCS= SP AASHTO= A-3

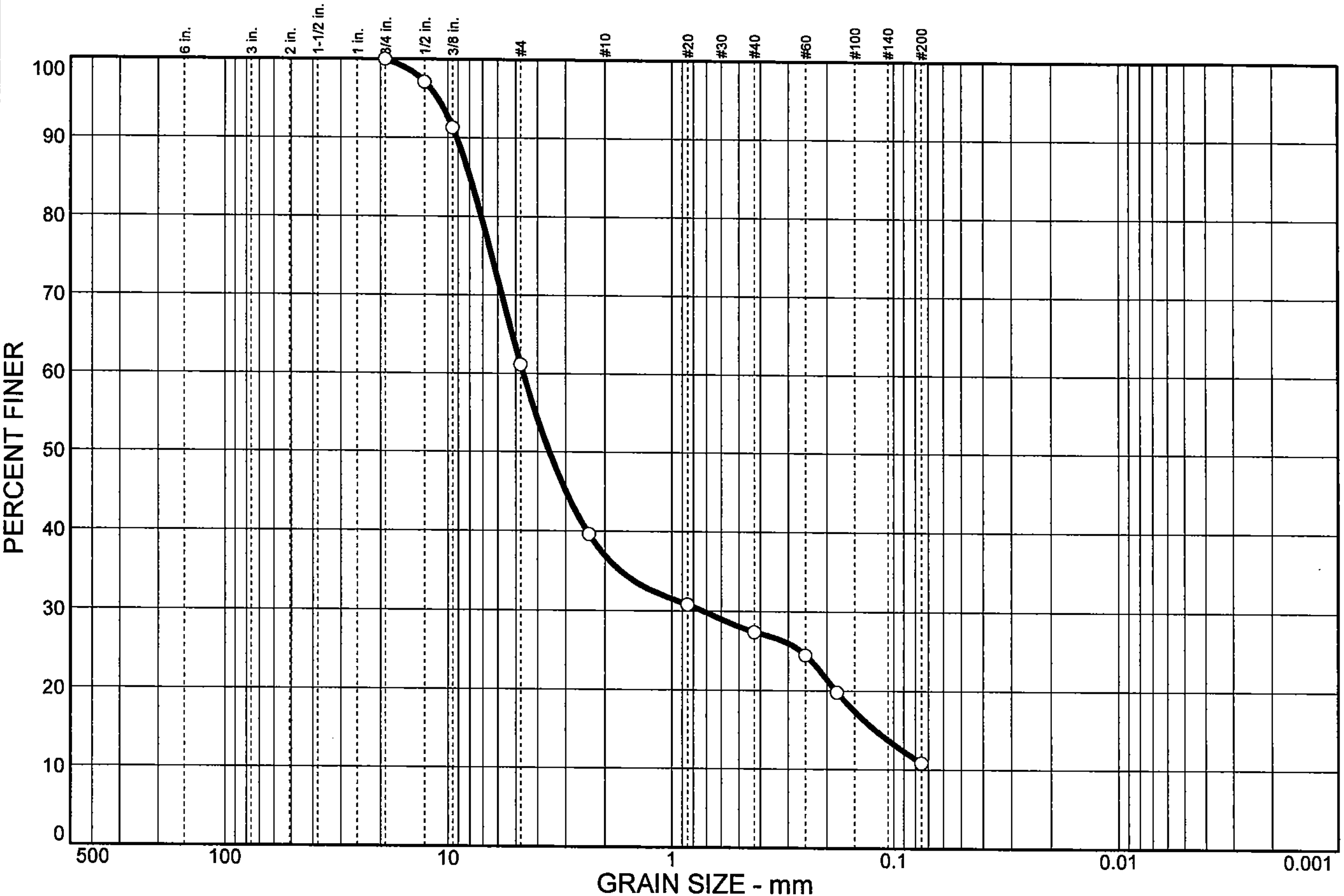
Remarks

Sample No.: 6087 **Source of Sample:** Client Samples **Date:**
Location: BIA-20 #5 **Elev./Depth:** 25 FT 7.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	38.9	24.2	9.5	16.6	10.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	97.1		
3/8 in.	91.3		
# 4	61.1		
# 8	39.6		
# 20	30.8		
# 40	27.4		
# 60	24.5		
# 80	19.8		
# 200	10.8		

* (no specification provided)

Soil Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 7.98 D_{60}= 4.63 D_{50}= 3.55

D_{30}= 0.725 D_{15}= 0.121 D_{10}=

C_u= C_c=

Classification

USCS= SP-SM AASHTO= A-1-a

Remarks

Sample No.: 6088 **Source of Sample:** Client Samples **Date:**

Location: BIA-21 #5 **Elev./Depth:** 25 FT 7.5

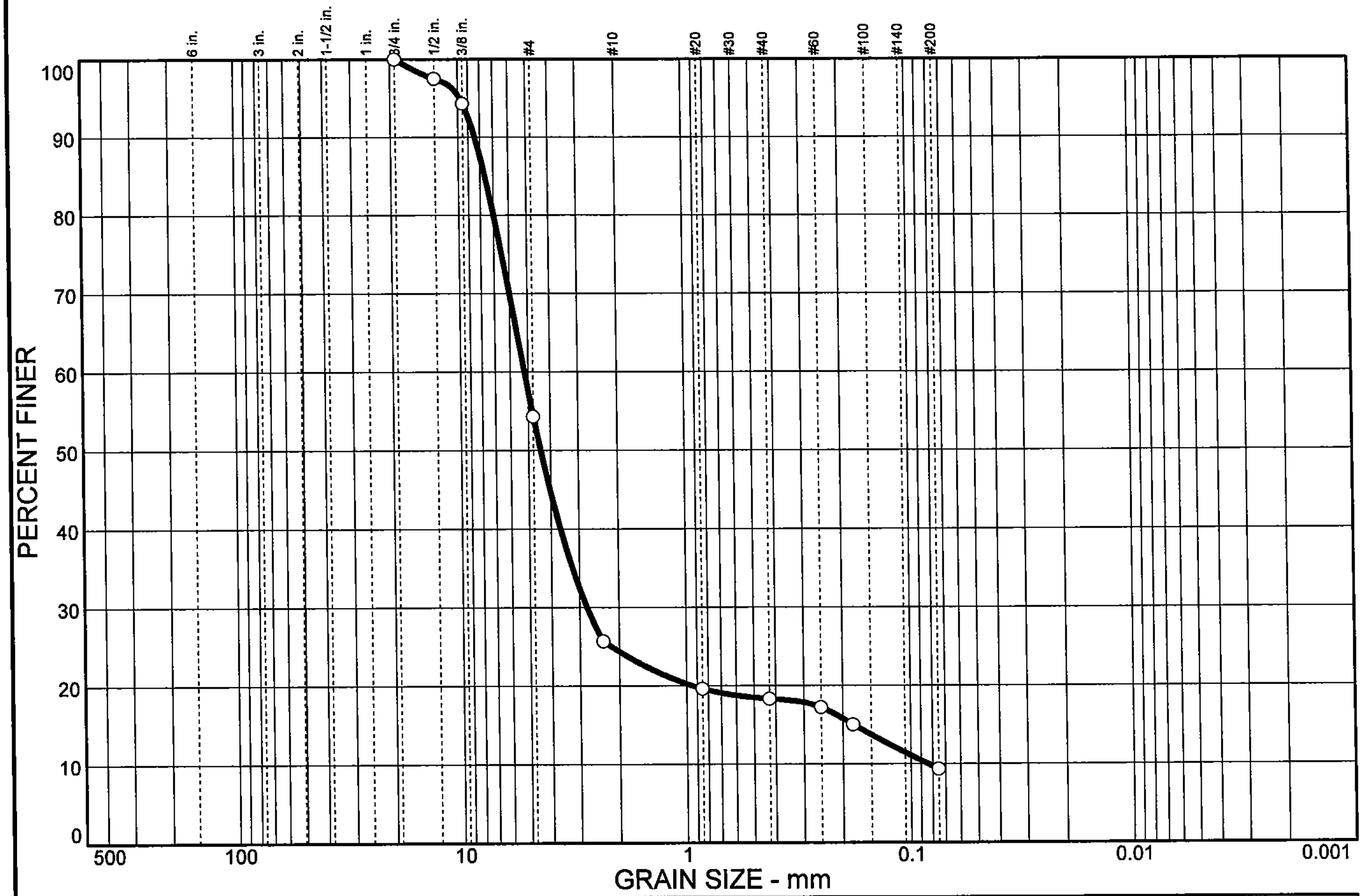
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	45.7	29.9	6.1	9.0	9.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	97.5		
3/8 in.	94.3		
# 4	54.3		
# 8	25.7		
# 20	19.6		
# 40	18.3		
# 60	17.2		
# 80	15.0		
# 200	9.3		

* (no specification provided)

Soil Description

Poorly graded gravel with silt and sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 7.64 D_{60}= 5.19 D_{50}= 4.42
D_{30}= 2.79 D_{15}= 0.180 D_{10}= 0.0841
C_u= 61.71 C_c= 17.78

Classification

USCS= GP-GM AASHTO= A-1-a

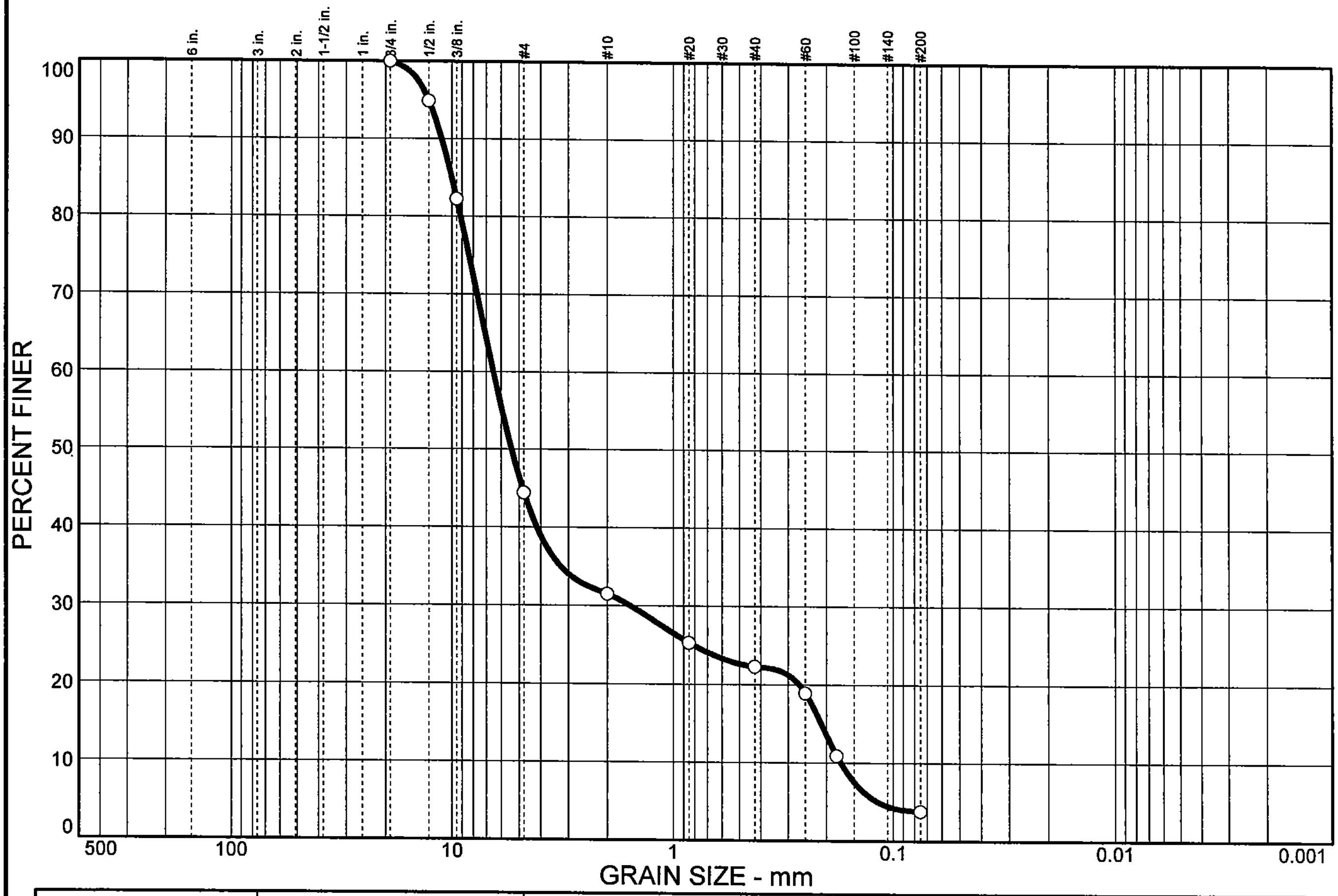
Remarks

Sample No.: 6089 **Source of Sample:** Client Samples **Date:**
Location: BIA-21 #6 **Elev./Depth:** 29 FT 8.7 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	55.6	12.9	9.2	18.5	3.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	94.9		
3/8 in.	82.2		
# 4	44.4		
# 10	31.5		
# 20	25.3		
# 40	22.3		
# 60	18.9		
# 80	10.9		
# 200	3.8		

* (no specification provided)

Soil Description

Well-graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 10.0 D_{60}= 6.50 D_{50}= 5.39
D_{30}= 1.57 D_{15}= 0.212 D_{10}= 0.173
C_u= 37.65 C_c= 2.20

Classification

USCS= GW AASHTO= A-1-a

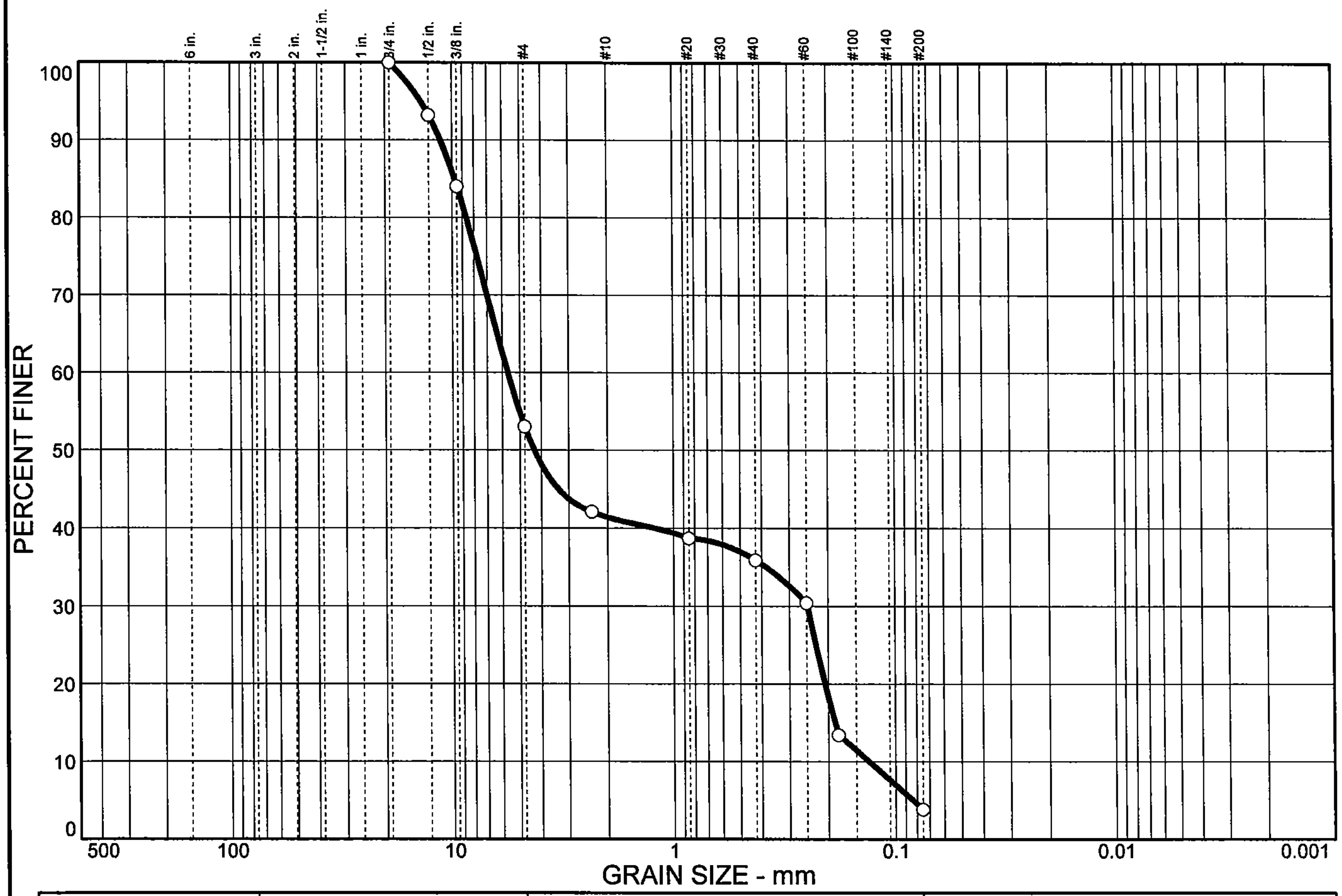
Remarks

Sample No.: 6090
Location: BIA-21 #7
Source of Sample: Client Samples
Date:
Elev./Depth: 34 FT 10.2

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	47.0	11.6	5.5	32.1	3.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	93.2		
3/8 in.	84.0		
# 4	53.0		
# 8	42.1		
# 20	38.7		
# 40	35.9		
# 60	30.4		
# 80	13.4		
# 200	3.8		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 9.77 D_{60}= 5.67 D_{50}= 4.30

D_{30}= 0.248 D_{15}= 0.187 D_{10}= 0.132

C_u= 42.96 C_c= 0.08

Classification

USCS= SP AASHTO= A-1-b

Remarks

Sample No.: 6091 **Source of Sample:** Client Samples **Date:**

Location: BIA-21 #8 **Elev./Depth:** 39 FT 11.7

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report

% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	5.8	27.6	7.0	7.2	52.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	94.2		
# 10	66.6		
# 20	60.9		
# 40	59.6		
# 60	58.6		
# 80	56.9		
# 200	52.4		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 3.50 D_{60}= 0.587 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

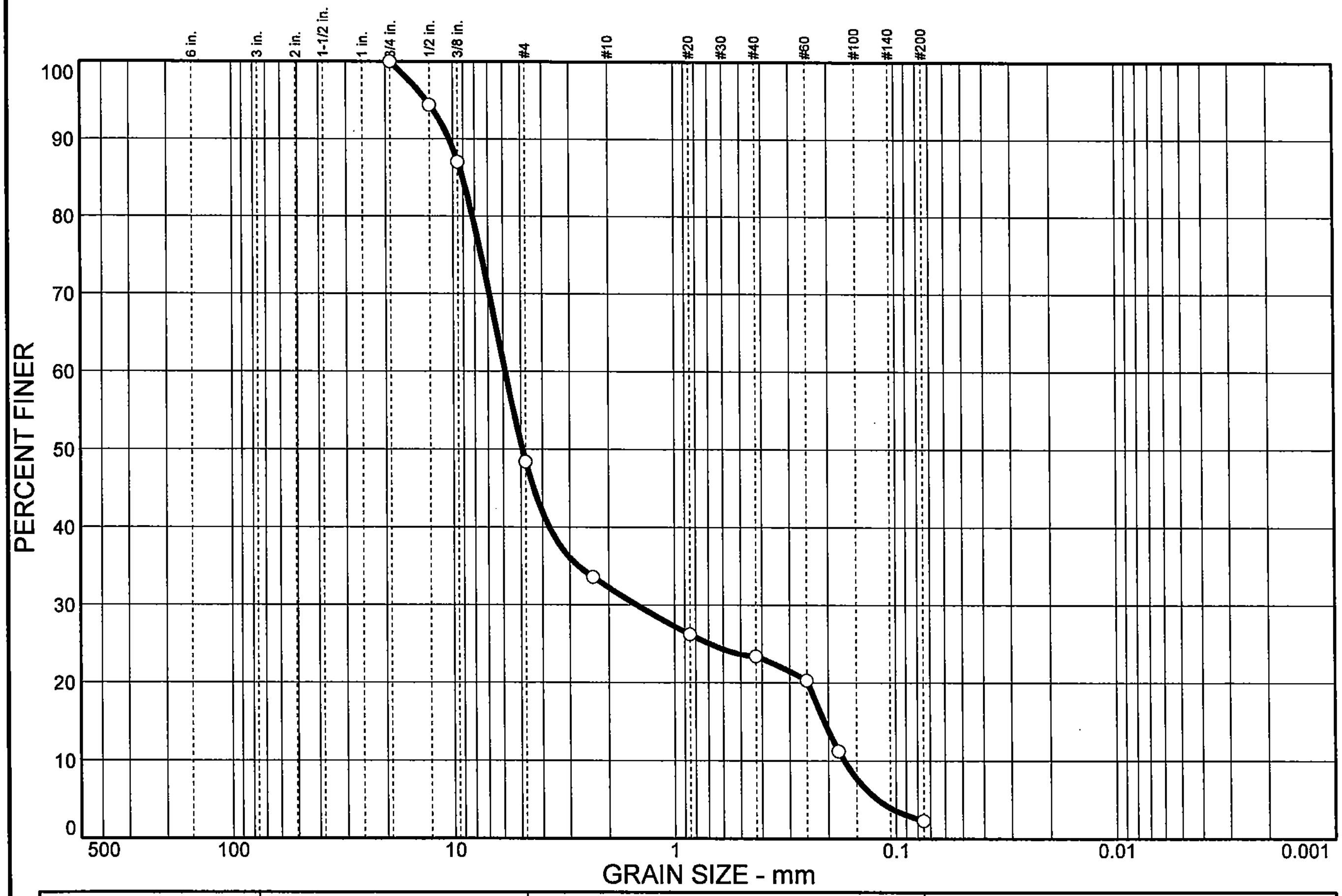
Remarks

Sample No.: 6092 **Source of Sample:** Client Samples **Date:**
Location: BIA-22 #4 **Elev./Depth:** 19 FT 5.7 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	51.6	16.2	8.8	21.1	2.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	94.4		
3/8 in.	87.0		
# 4	48.4		
# 8	33.6		
# 20	26.2		
# 40	23.4		
# 60	20.3		
# 80	11.2		
# 200	2.3		

* (no specification provided)

Soil Description

Well-graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 9.08 D_{60}= 5.88 D_{50}= 4.91
D_{30}= 1.49 D_{15}= 0.209 D_{10}= 0.170
C_u= 34.52 C_c= 2.23

Classification

USCS= GW AASHTO= A-1-a

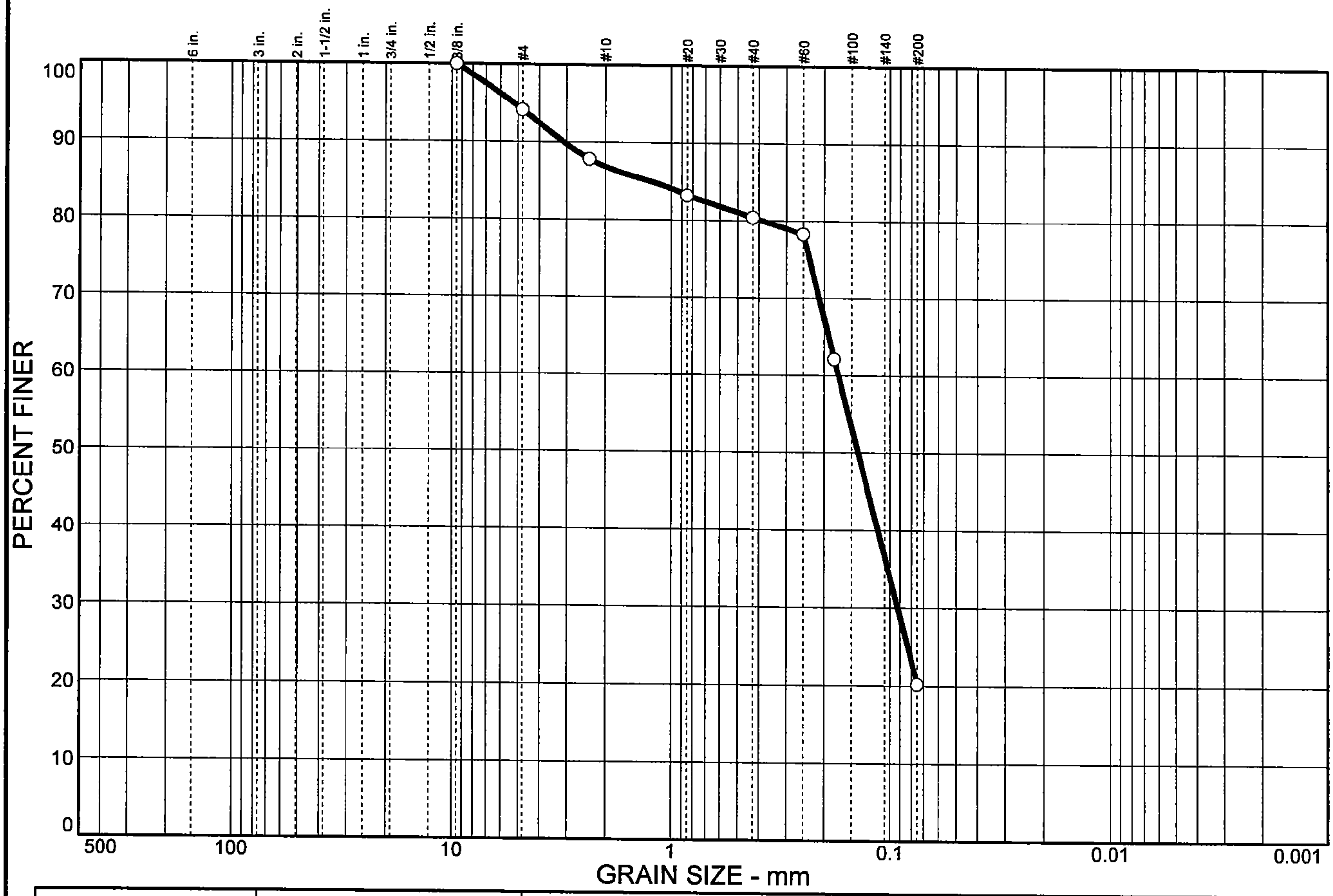
Remarks

Sample No.: 6093 **Source of Sample:** Client Samples **Date:**
Location: BIA-22 #5 **Elev./Depth:** 24 FT 7.2 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	5.9	7.3	6.4	60.2	20.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	94.1		
# 8	87.8		
# 20	83.2		
# 40	80.4		
# 60	78.3		
# 80	62.1		
# 200	20.2		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 1.25 D_{60}= 0.172 D_{50}= 0.140

D_{30}= 0.0922 D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6094 **Source of Sample:** Client Samples **Date:**

Location: BIA-22 #6 **Elev./Depth:** 29 FT 8.7 m

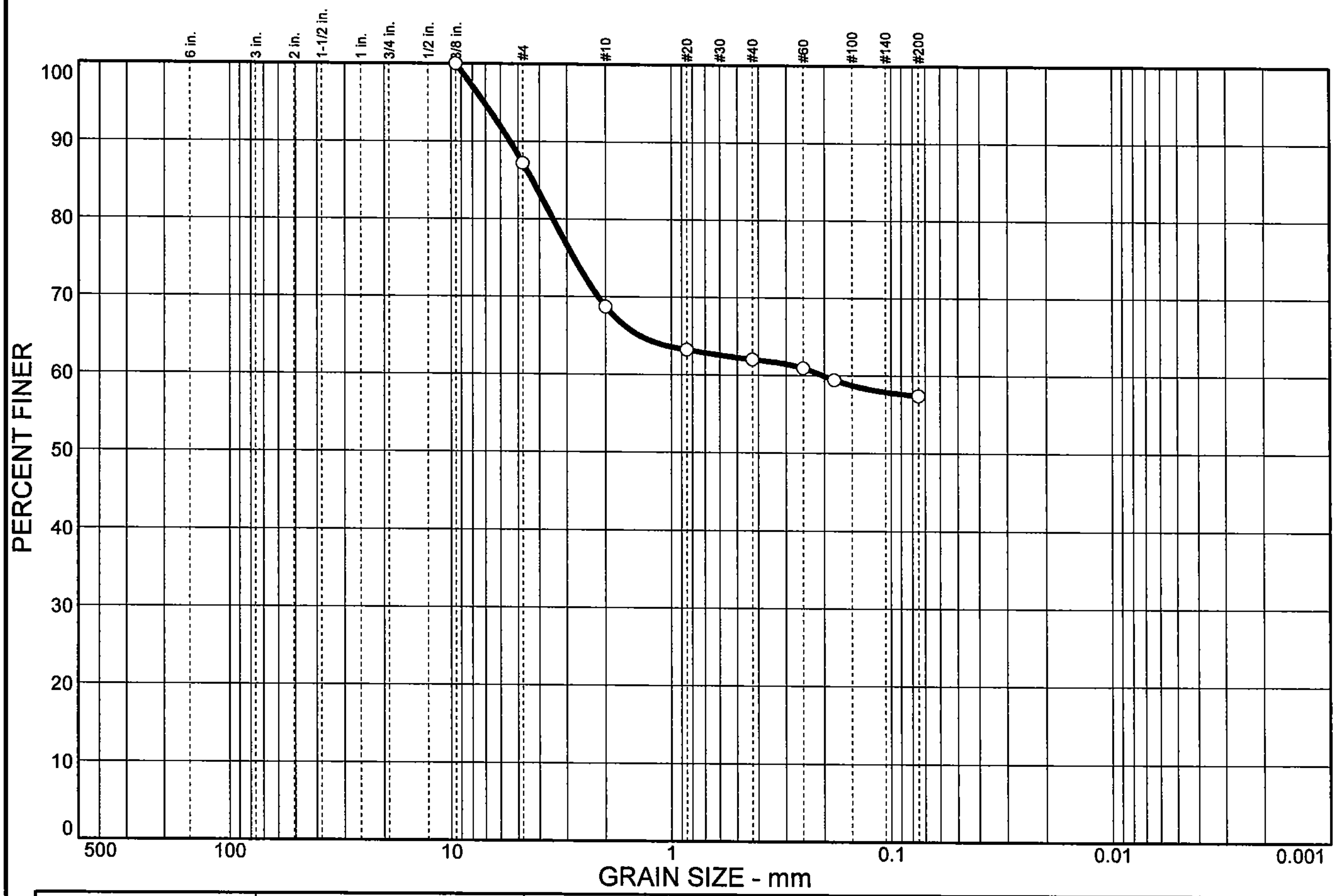
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	12.8	18.5	6.7	4.6	57.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	87.2		
# 10	68.7		
# 20	63.2		
# 40	62.0		
# 60	60.9		
# 80	59.4		
# 200	57.4		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 4.30 D_{60}= 0.205 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

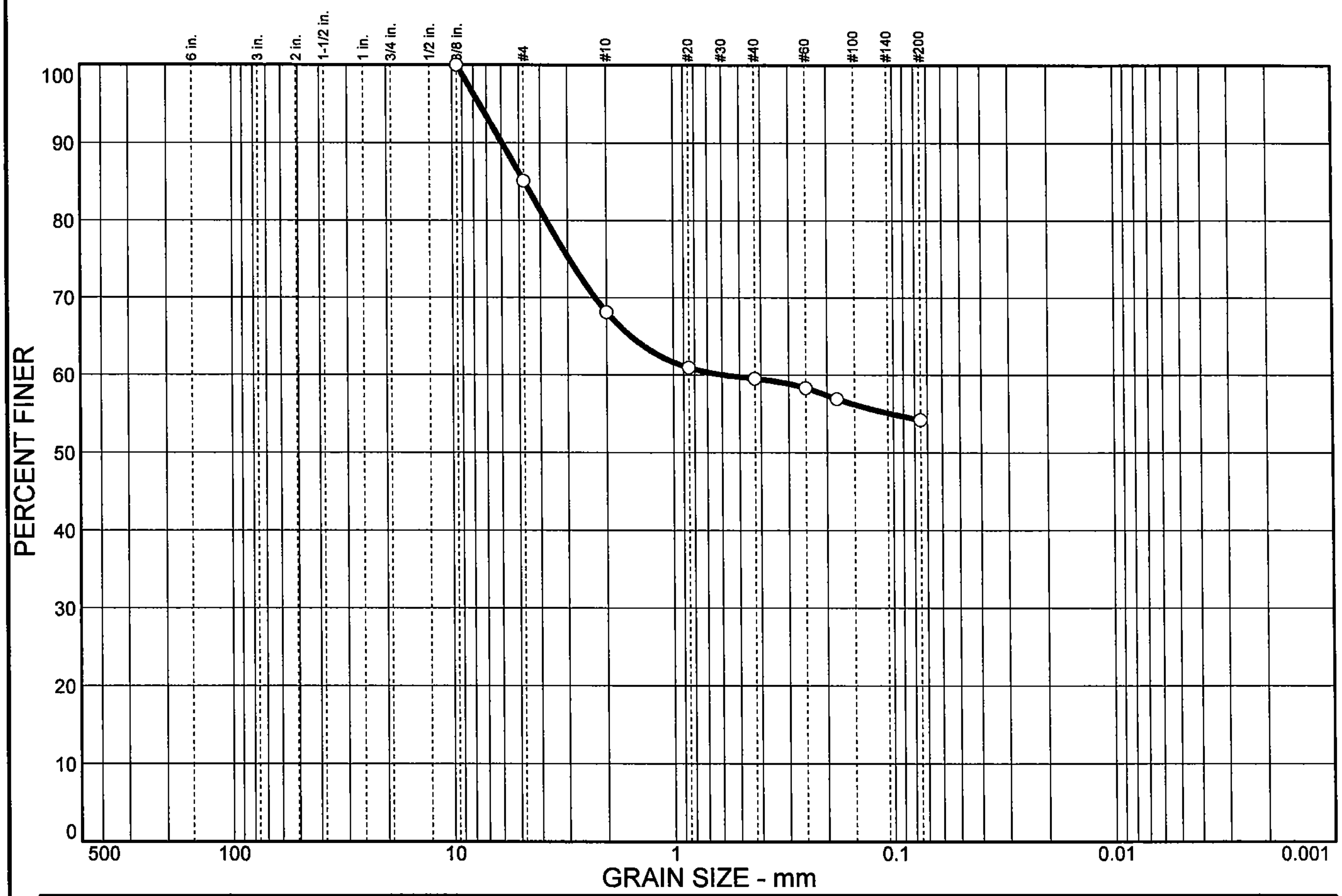
Remarks

Sample No.: 6095 **Source of Sample:** Client Samples **Date:**
Location: BIA-23 #4 **Elev./Depth:** 19 FT 5.7 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	14.9	17.0	8.6	5.3	54.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	85.1		
# 10	68.1		
# 20	60.9		
# 40	59.5		
# 60	58.3		
# 80	56.9		
# 200	54.2		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 4.73 D_{60}= 0.599 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

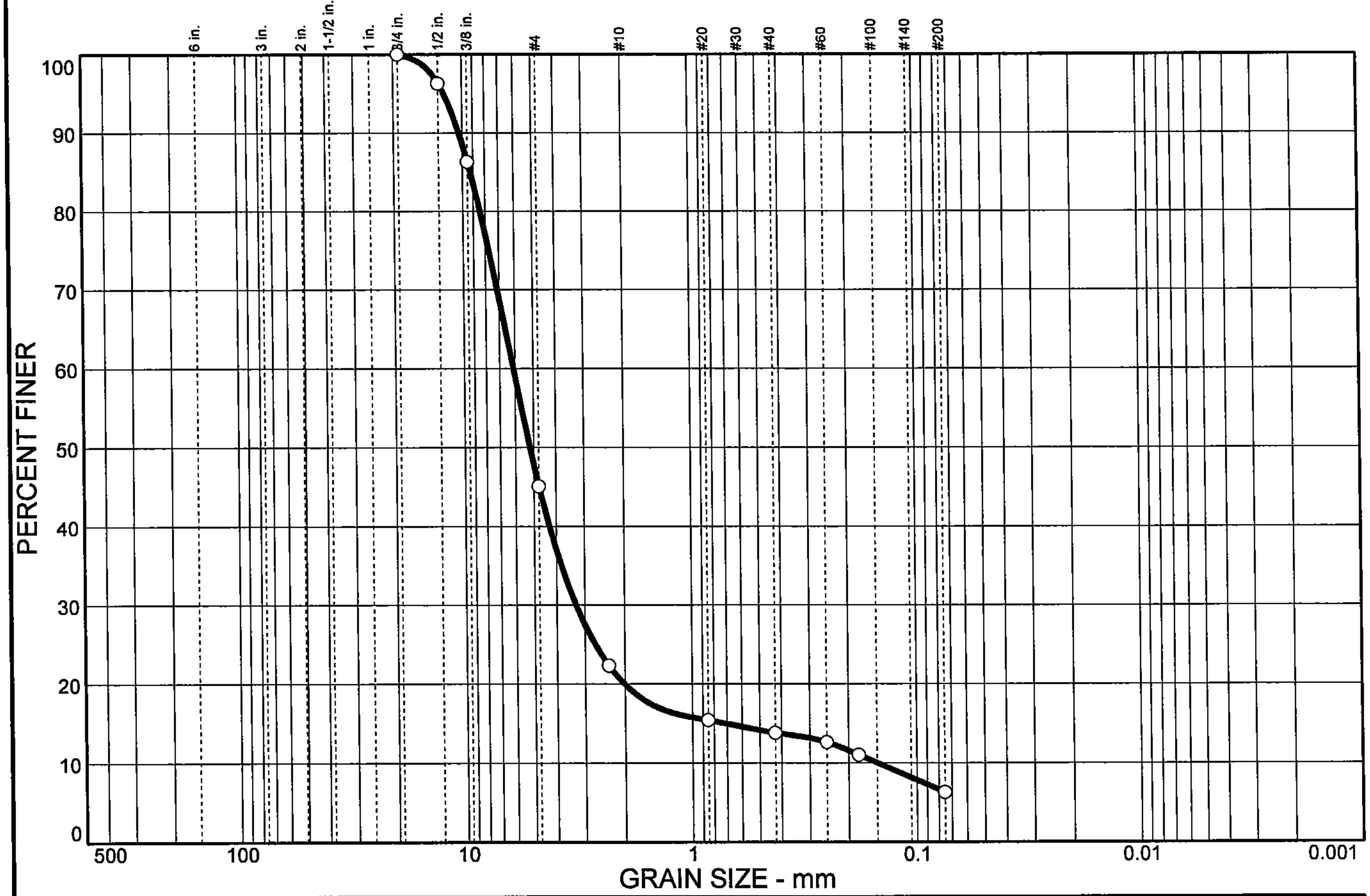
Remarks

Sample No.: 6096 **Source of Sample:** Client Samples **Date:**
Location: BIA-23 #5 **Elev./Depth:** 24 FT 7.2 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	54.9	25.2	6.1	7.5	6.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	96.3		
3/8 in.	86.3		
# 4	45.1		
# 8	22.3		
# 20	15.4		
# 40	13.8		
# 60	12.6		
# 80	11.0		
# 200	6.3		

* (no specification provided)

Soil Description

Poorly graded gravel with silt and sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 9.27 D_{60}= 6.11 D_{50}= 5.19
D_{30}= 3.29 D_{15}= 0.714 D_{10}= 0.150
C_u= 40.84 C_c= 11.83

Classification

USCS= GP-GM AASHTO= A-1-a

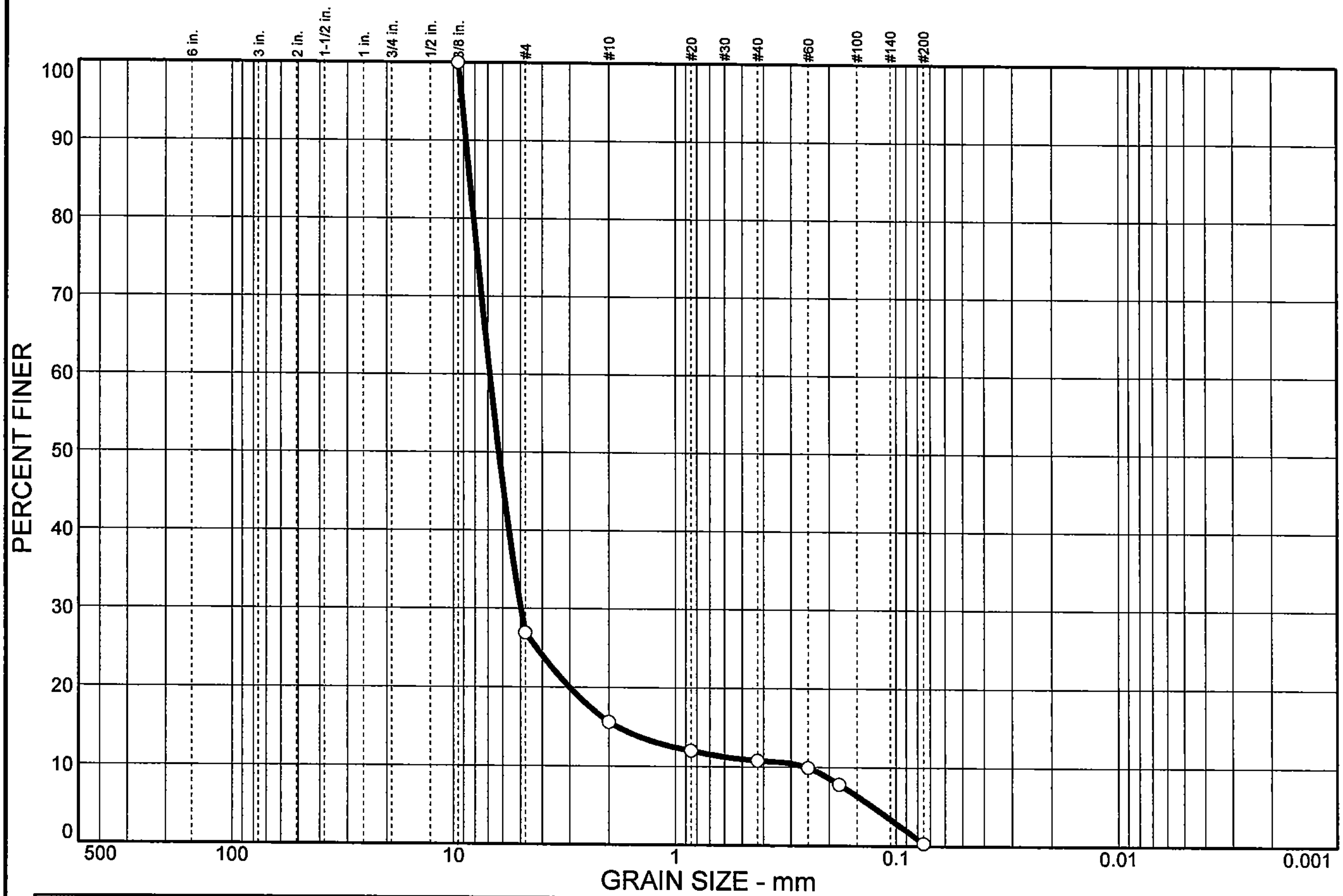
Remarks

Sample No.: 6097 **Source of Sample:** Client Samples **Date:**
Location: BIA-23 #6 **Elev./Depth:** 29 FT 8.7 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	73.1	11.2	4.9	10.5	0.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	26.9		
# 10	15.6		
# 20	12.0		
# 40	10.8		
# 60	9.9		
# 80	7.8		
# 200	0.3		

* (no specification provided)

Soil Description

Poorly graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 8.46 D_{60}= 6.86 D_{50}= 6.25
D_{30}= 4.98 D_{15}= 1.81 D_{10}= 0.256
C_u= 26.80 C_c= 14.11

Classification

USCS= GP AASHTO= A-1-a

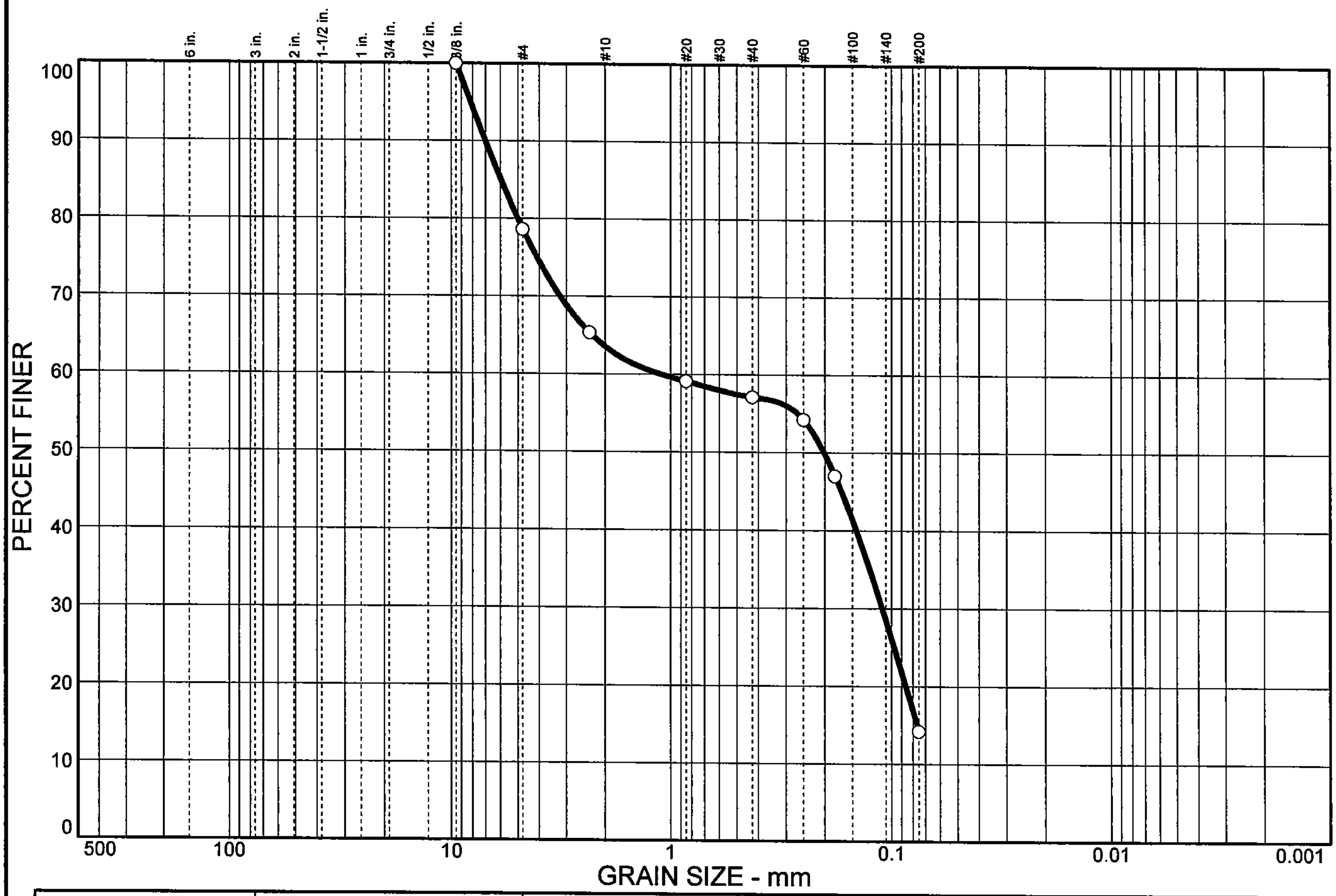
Remarks

Sample No.: 6098 **Source of Sample:** Client Samples **Date:**
Location: BIA-23 #7 **Elev./Depth:** 34 FT 10.2

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	21.4	15.1	6.4	42.9	14.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	78.6		
# 8	65.3		
# 20	59.1		
# 40	57.1		
# 60	54.2		
# 80	47.0		
# 200	14.2		

* (no specification provided)

Soil Description

Silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 5.97 D_{60}= 1.11 D_{50}= 0.202
D_{30}= 0.110 D_{15}= 0.0764 D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6099
Location: BIA-23 #8

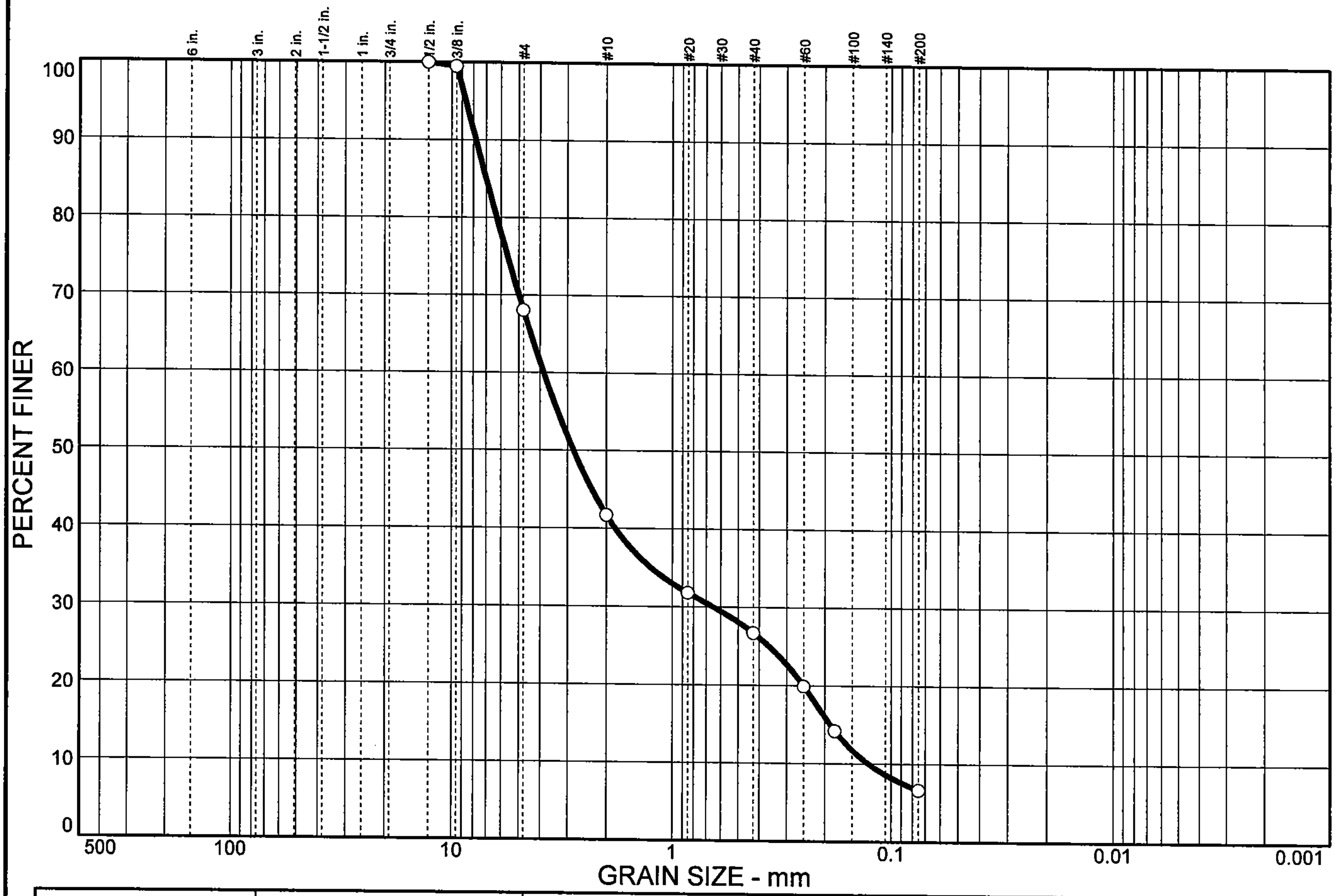
Source of Sample: Client Samples

Date:
Elev./Depth: 39 FT 11.7

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	32.0	26.3	15.0	20.1	6.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	99.5		
# 4	68.0		
# 10	41.7		
# 20	31.8		
# 40	26.7		
# 60	19.9		
# 80	14.2		
# 200	6.6		

* (no specification provided)

Soil Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 7.01
D_{60}= 3.85
D_{50}= 2.82
D_{30}= 0.649
D_{15}= 0.189
D_{10}= 0.127
C_u= 30.31
C_c= 0.86

Classification

USCS= SP-SM
AASHTO= A-1-a

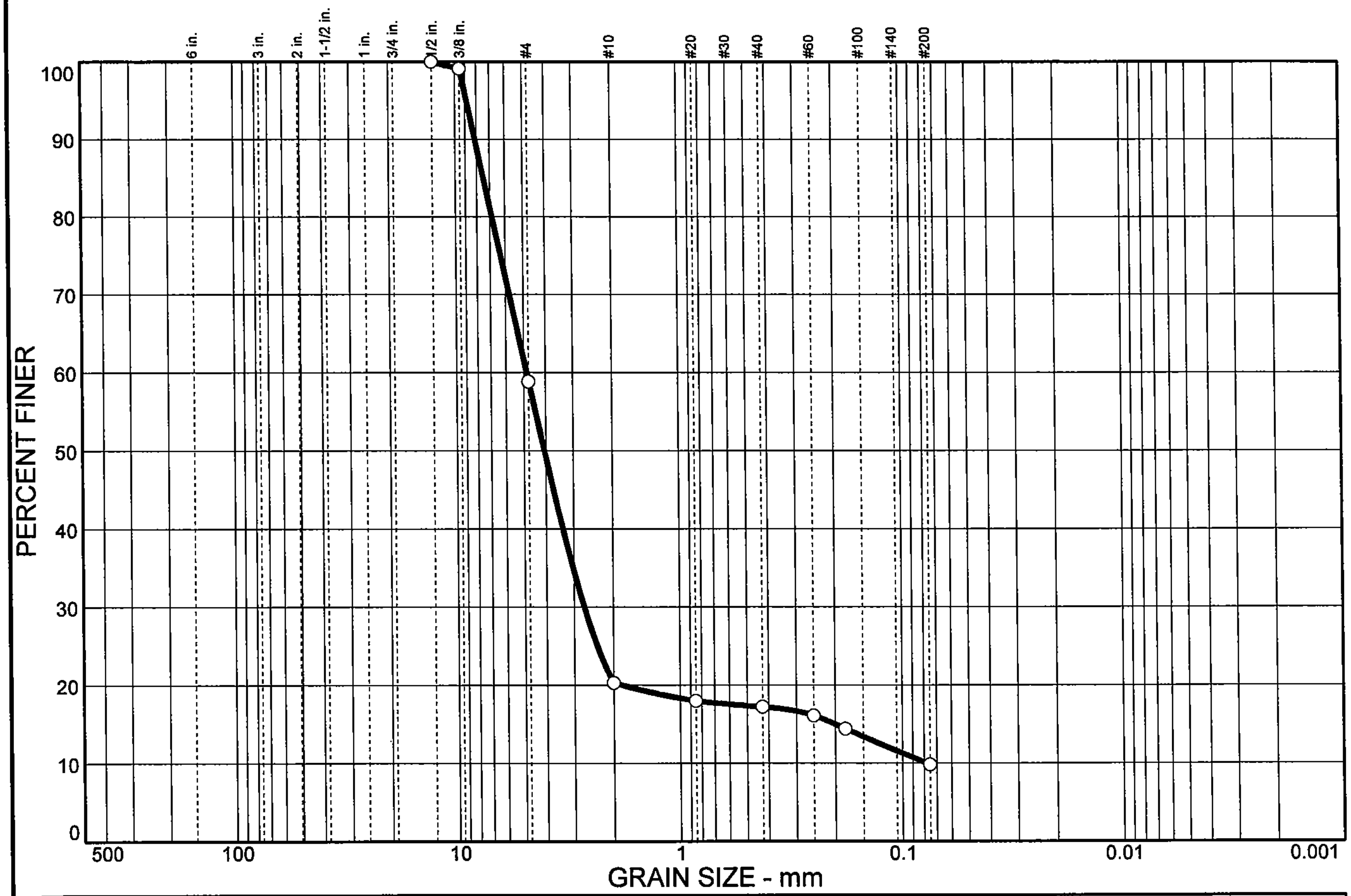
Remarks

Sample No.: 6100
Location: BIA-24 #4
Source of Sample: Client Samples
Date:
Elev./Depth: 20 FT 6 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	41.2	38.5	3.1	7.4	9.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	99.1		
# 4	58.8		
# 10	20.3		
# 20	18.0		
# 40	17.2		
# 60	16.1		
# 80	14.4		
# 200	9.8		

* (no specification provided)

Soil Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 7.48 D_{60}= 4.85 D_{50}= 4.06

D_{30}= 2.71 D_{15}= 0.200 D_{10}= 0.0780

C_u= 62.18 C_c= 19.35

Classification

USCS= SP-SM AASHTO= A-1-a

Remarks

Sample No.: 6101 **Source of Sample:** Client Samples **Date:**

Location: BIA-24 #5 **Elev./Depth:** 24 FT 7.2 m

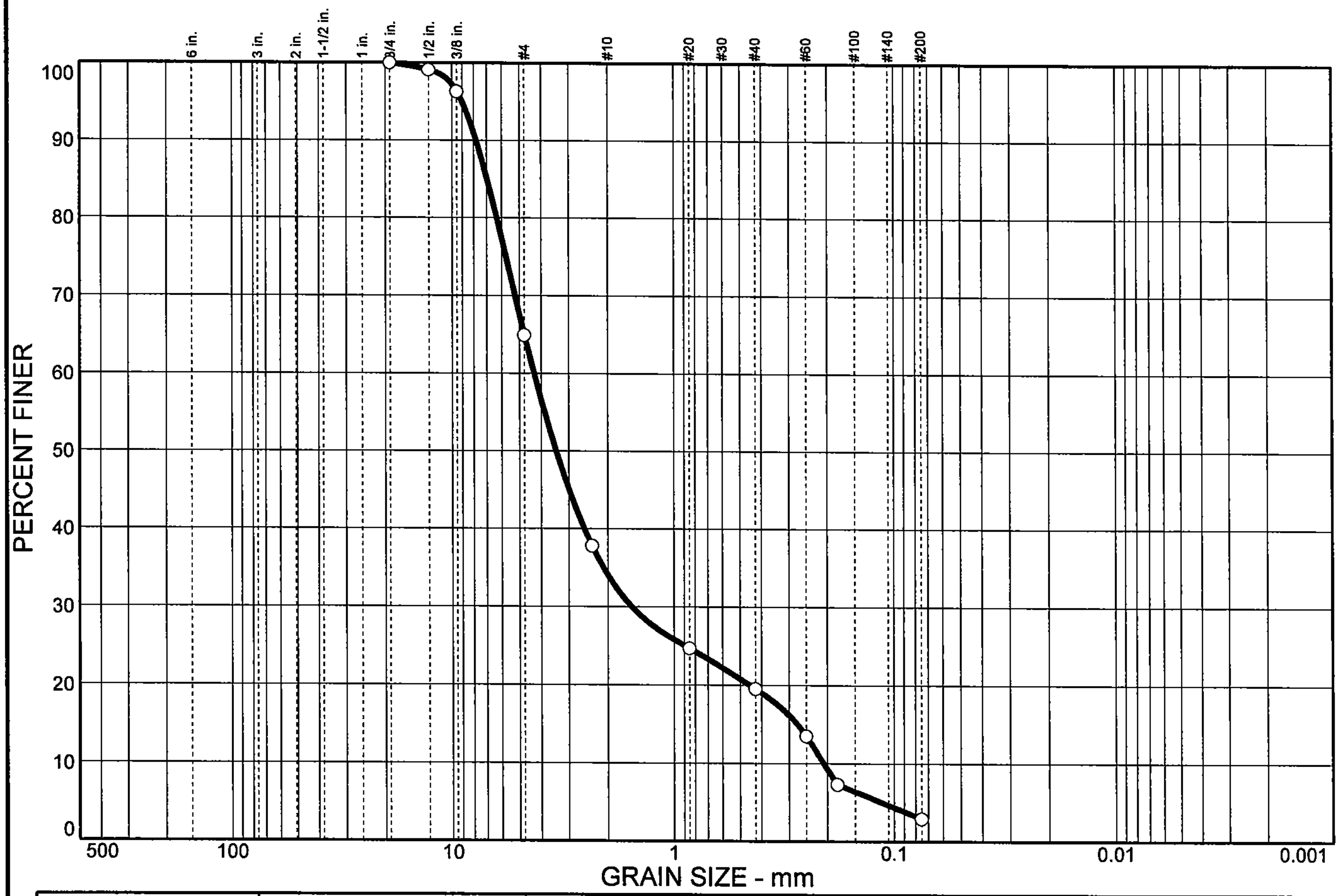
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	35.1	30.9	14.5	16.6	2.9	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	99.1		
3/8 in.	96.3		
# 4	64.9		
# 8	37.8		
# 20	24.7		
# 40	19.5		
# 60	13.5		
# 80	7.3		
# 200	2.9		

* (no specification provided)

Soil Description

Well-graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 6.98 D_{60}= 4.30 D_{50}= 3.42
D_{30}= 1.56 D_{15}= 0.275 D_{10}= 0.208
C_u= 20.65 C_c= 2.71

Classification

USCS= SW AASHTO= A-1-a

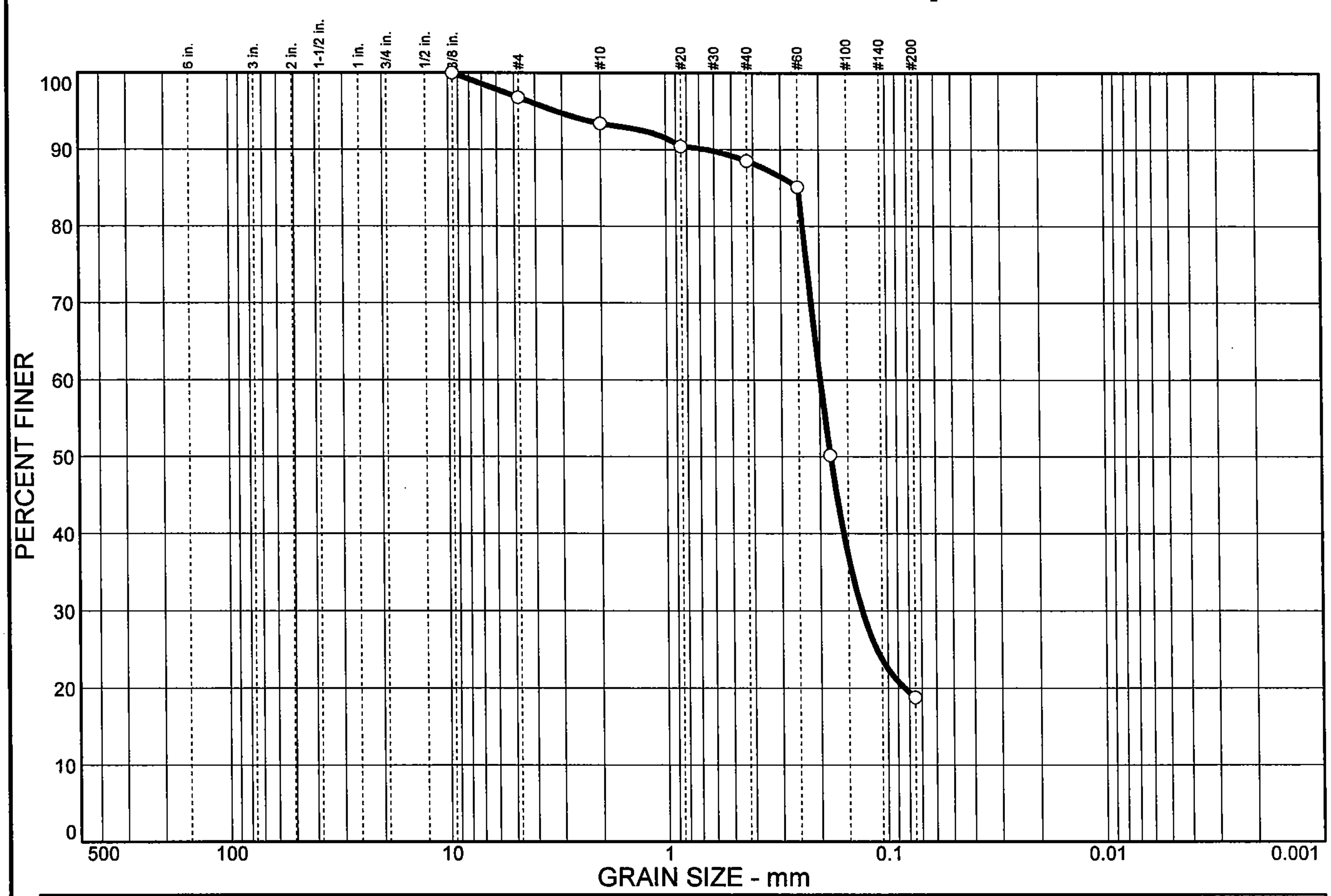
Remarks

Sample No.: 6102 **Source of Sample:** Client Samples **Date:**
Location: BIA-24 #6 **Elev./Depth:** 29 FT 8.7 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	3.2	3.4	4.9	69.7	18.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	96.8		
# 10	93.4		
# 20	90.4		
# 40	88.5		
# 60	85.1		
# 80	50.2		
# 200	18.8		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.250 D_{60}= 0.199 D_{50}= 0.180
D_{30}= 0.130 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

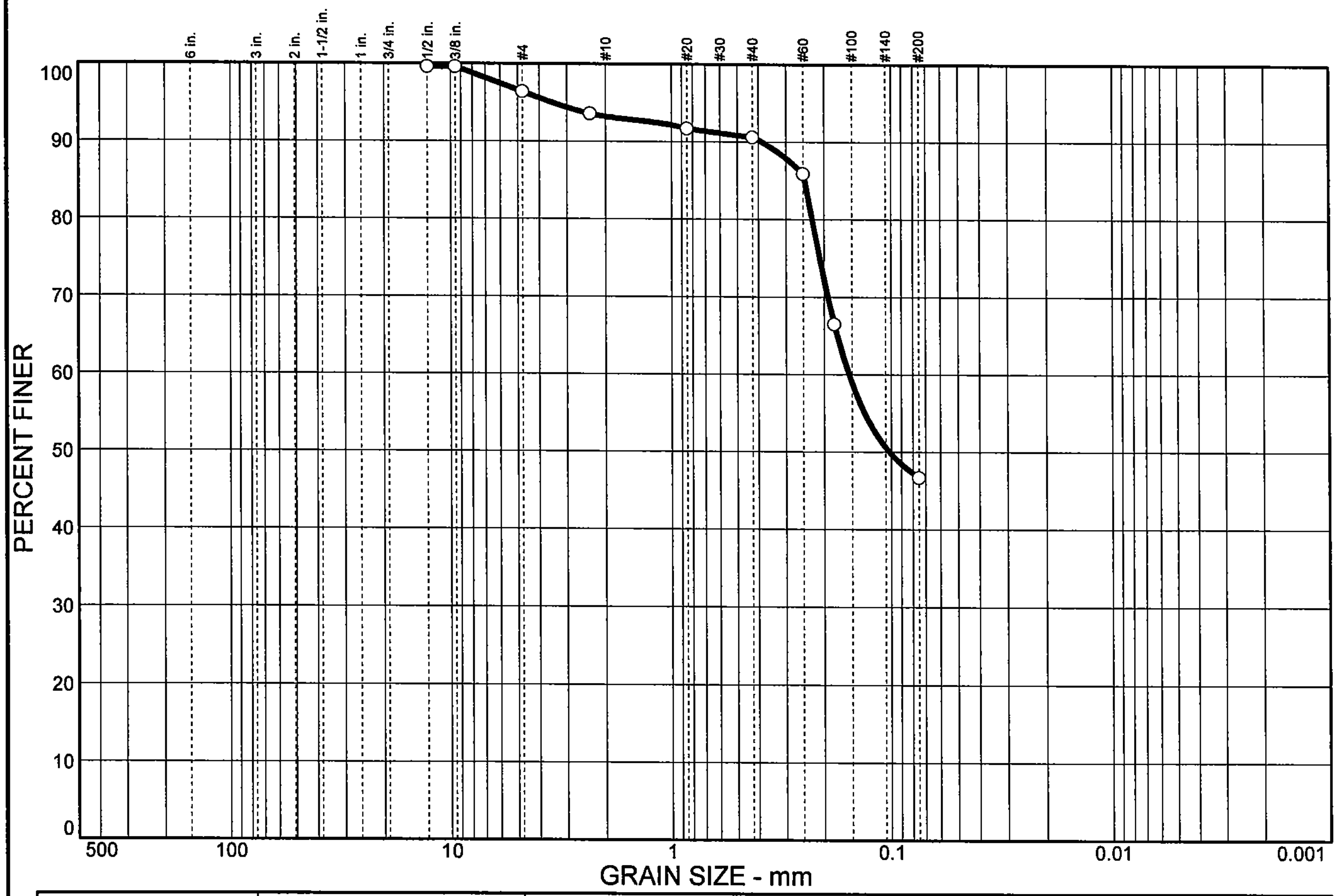
Remarks

Sample No.: 6103 **Source of Sample:** Client Samples **Date:**
Location: BIA-24 #7 **Elev./Depth:** 34 FT 10.2

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
			3.2	2.6	43.9	46.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	99.6		
3/8 in.	99.6		
# 4	96.4		
# 8	93.6		
# 20	91.7		
# 40	90.6		
# 60	85.9		
# 80	66.5		
# 200	46.7		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL=
LL=
PI=

Coefficients

D_{85}= 0.246
D_{60}= 0.155
D_{50}= 0.102
D_{30}=
D_{15}=
D_{10}=
C_u=
C_c=

Classification

USCS= SM
AASHTO= A-4(0)

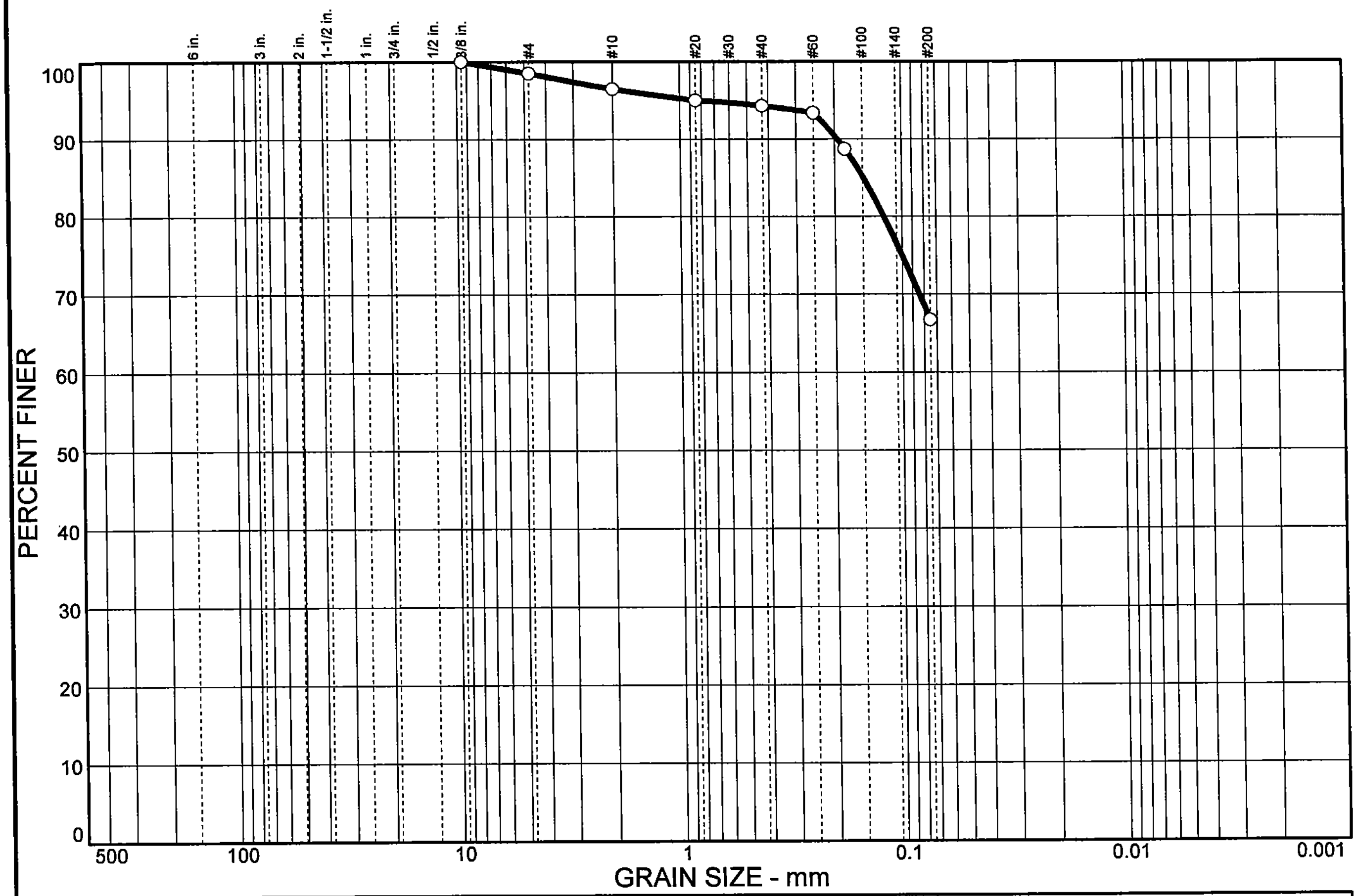
Remarks

Sample No.: 6104
Source of Sample: Client Samples
Date:
Location: BIA-25 #1
Elev./Depth: 5 FT 1.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	1.5	2.0	2.2	27.6	66.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	98.5		
# 10	96.5		
# 20	95.0		
# 40	94.3		
# 60	93.4		
# 80	88.7		
# 200	66.7		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.149 D_{60}= D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

Remarks

Sample No.: 6105
Location: BIA-25 #2

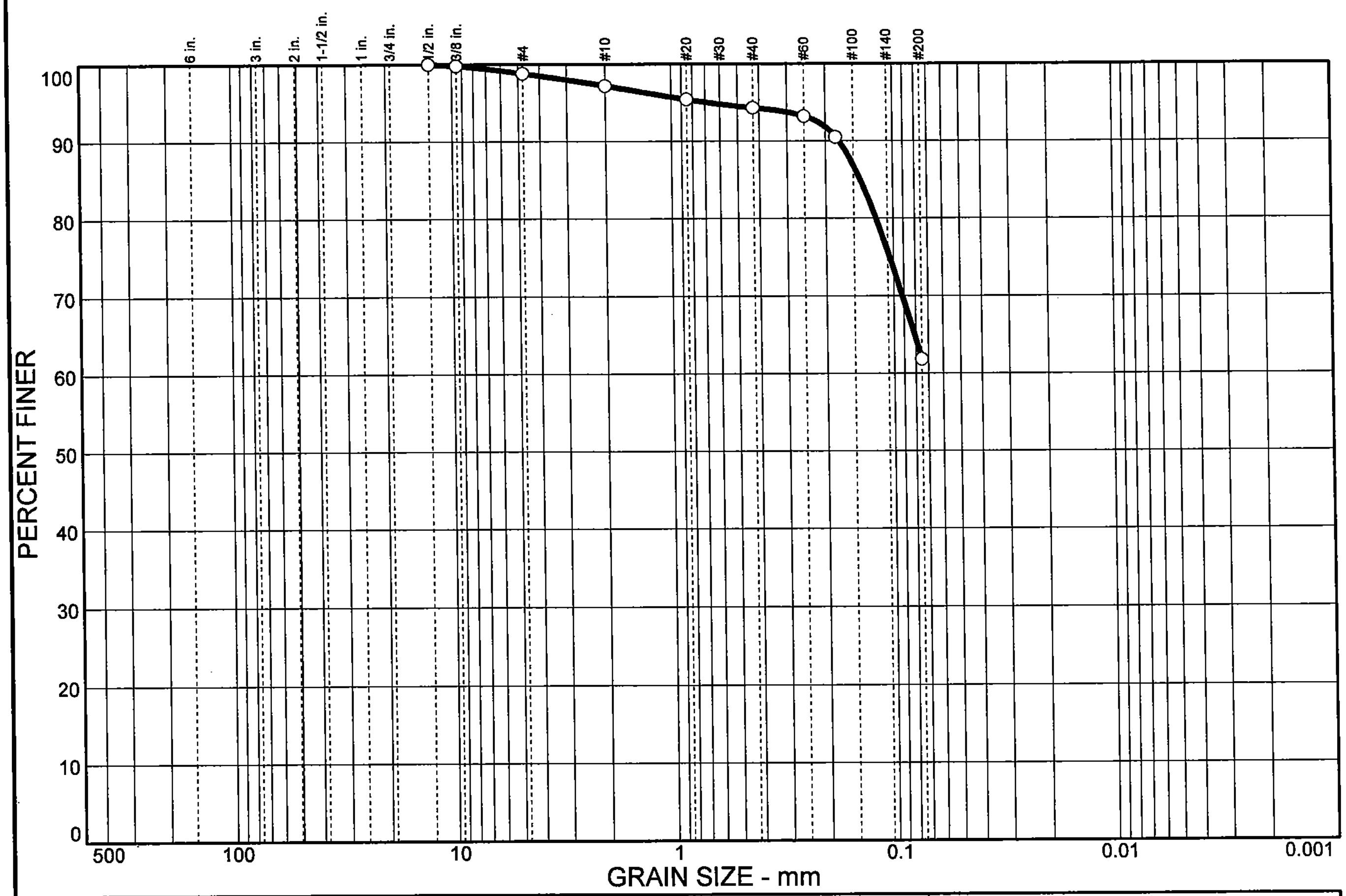
Source of Sample: Client Samples

Date:
Elev./Depth: 10 FT 3 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	1.2	1.6	2.9	32.5	61.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	99.8		
# 4	98.8		
# 10	97.2		
# 20	95.4		
# 40	94.3		
# 60	93.2		
# 80	90.5		
# 200	61.8		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.140 D_{60}= D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

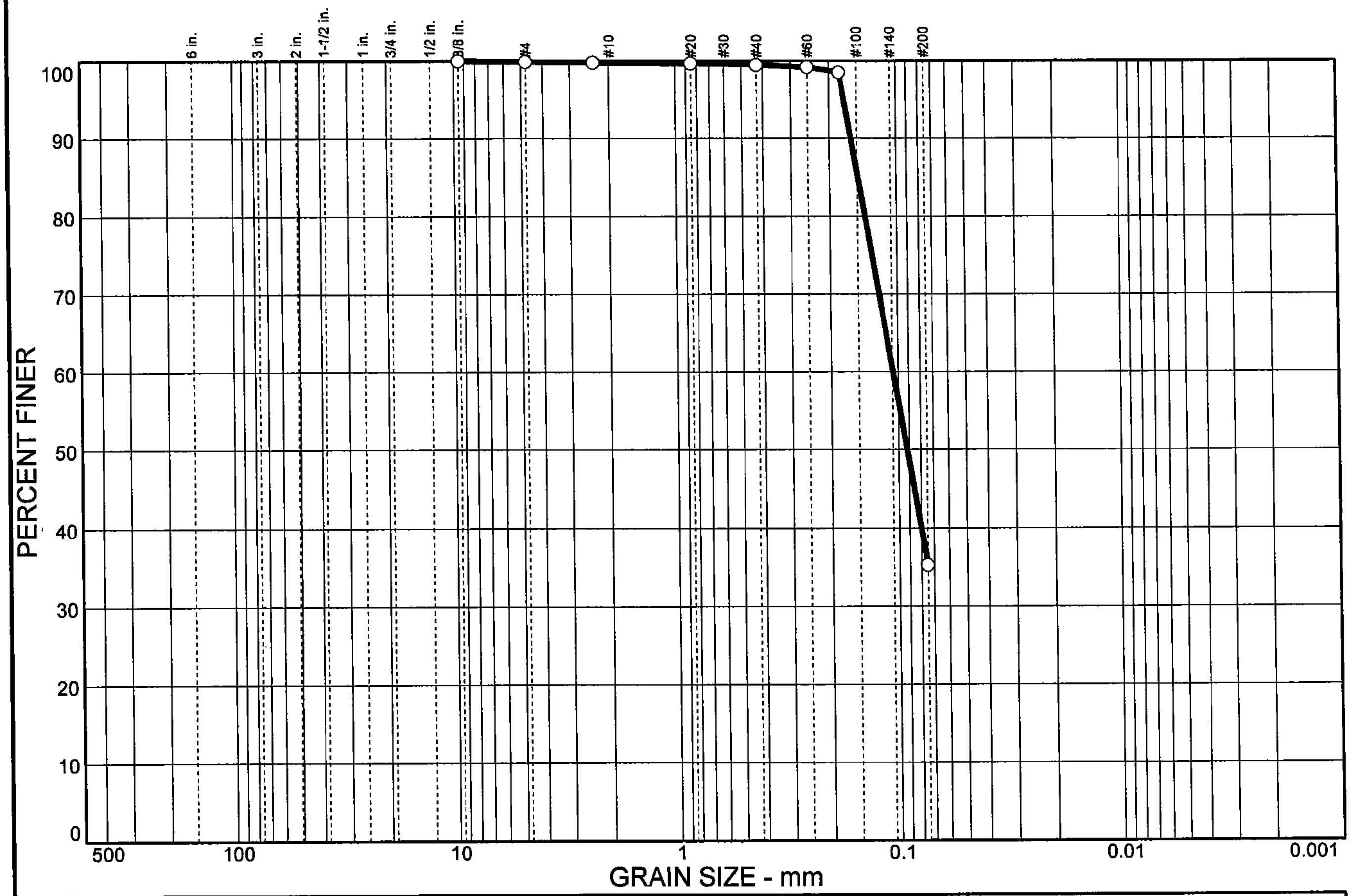
Remarks

Sample No.: 6106 **Source of Sample:** Client Samples **Date:**
Location: BIA-26 #1 **Elev./Depth:** 5 FT 1.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	0.1	0.1	0.3	64.2	35.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	99.9		
# 8	99.8		
# 20	99.7		
# 40	99.5		
# 60	99.2		
# 80	98.5		
# 200	35.3		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.149 D_{60}= 0.105 D_{50}= 0.0918

D_{30}= D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6107
Location: BIA-26 #2

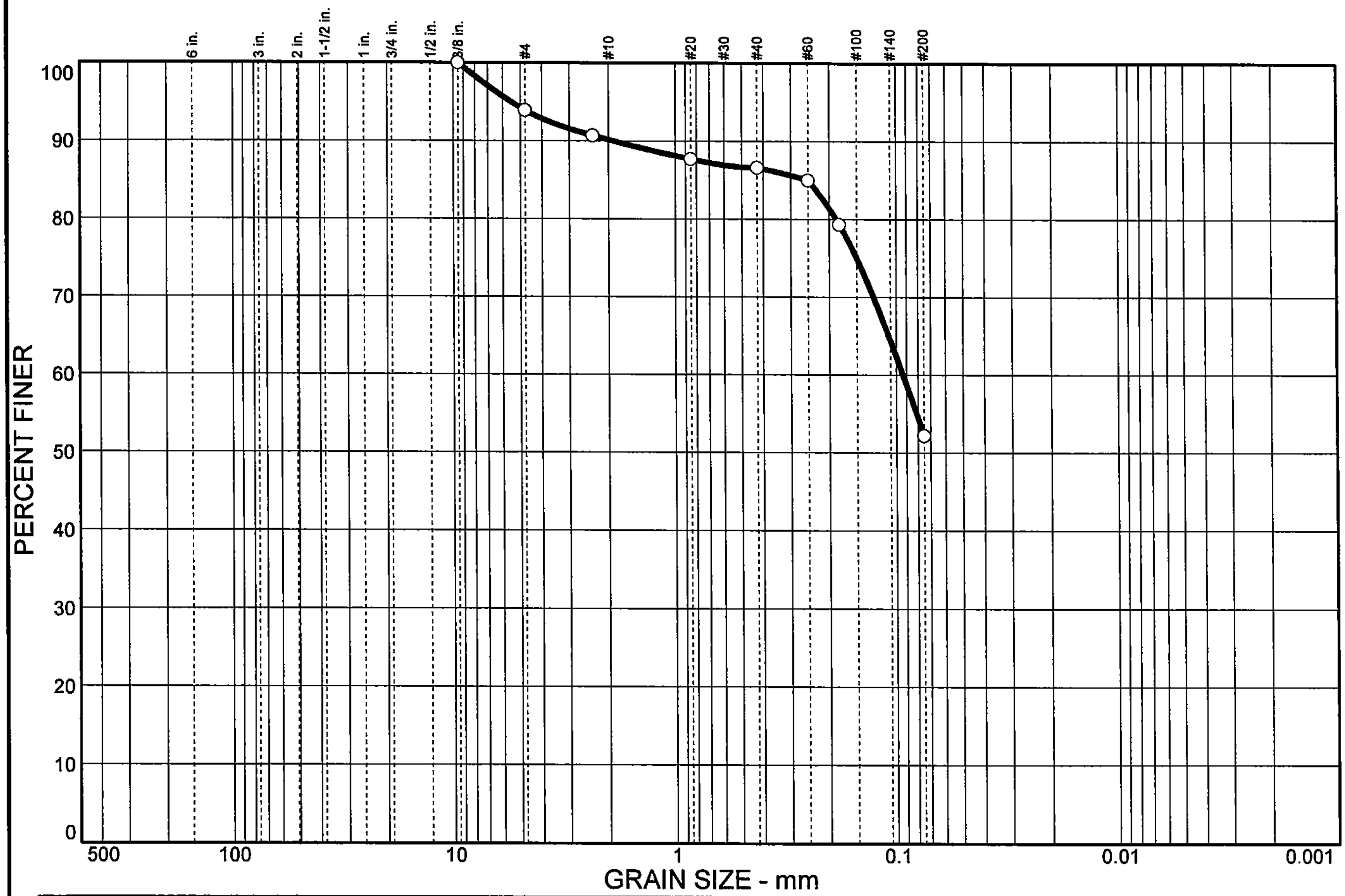
Source of Sample: Client Samples

Date:
Elev./Depth: 10 FT 3m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	6.1	3.7	3.6	34.4	52.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	93.9		
# 8	90.7		
# 20	87.7		
# 40	86.6		
# 60	85.0		
# 80	79.3		
# 200	52.2		

* (no specification provided)

Soil Description

Sandy silt

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.250 D_{60}= 0.0934 D_{50}=
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO= A-4(0)

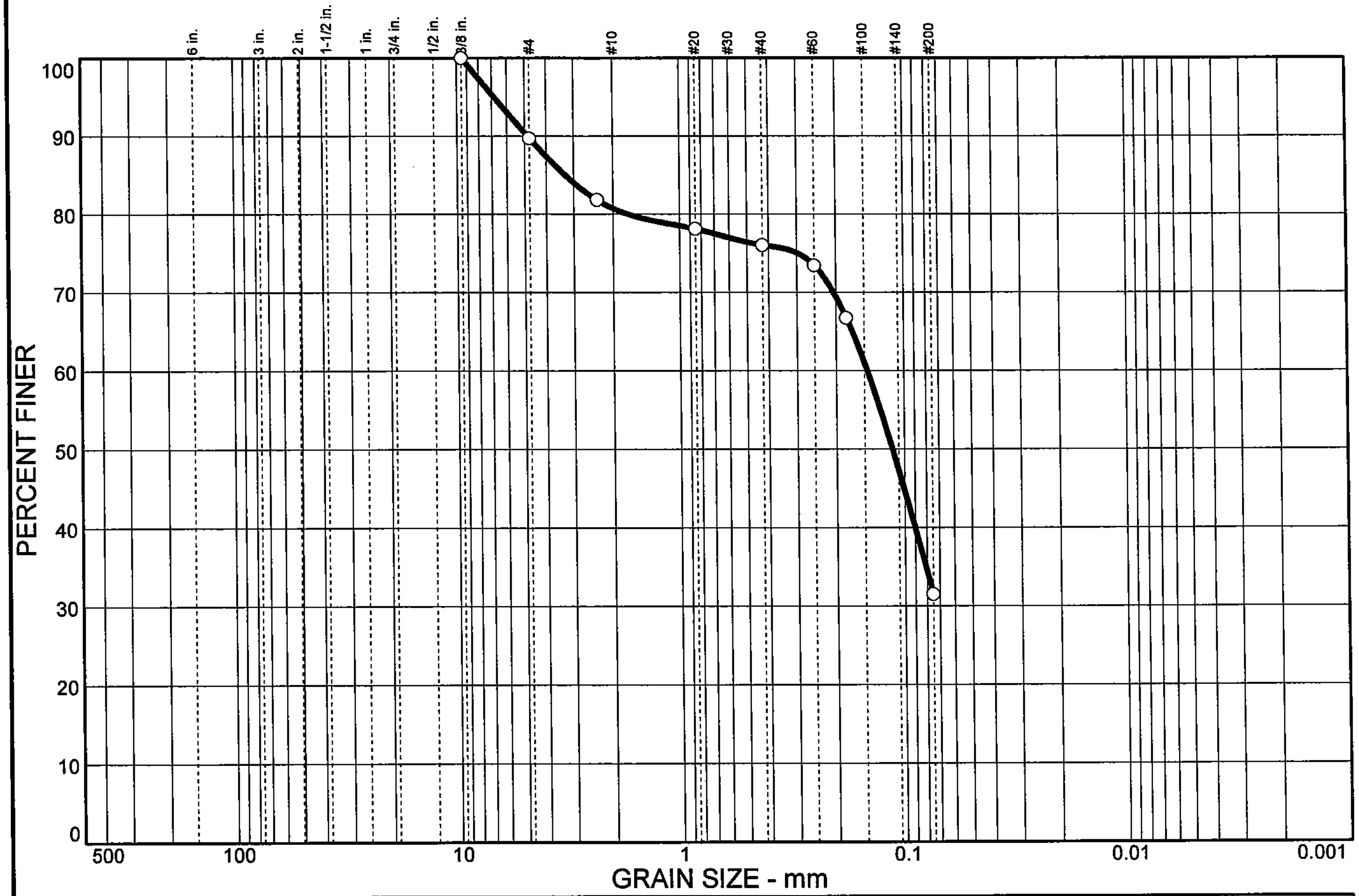
Remarks

Sample No.: 6108
Location: BIA-27 #2
Source of Sample: Client Samples
Date:
Elev./Depth: 10 FT 3m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	10.3	9.0	4.7	44.5	31.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8 in.	100.0		
# 4	89.7		
# 8	81.8		
# 20	78.1		
# 40	76.0		
# 60	73.4		
# 80	66.7		
# 200	31.5		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 3.29 D_{60}= 0.146 D_{50}= 0.113
D_{30}= D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

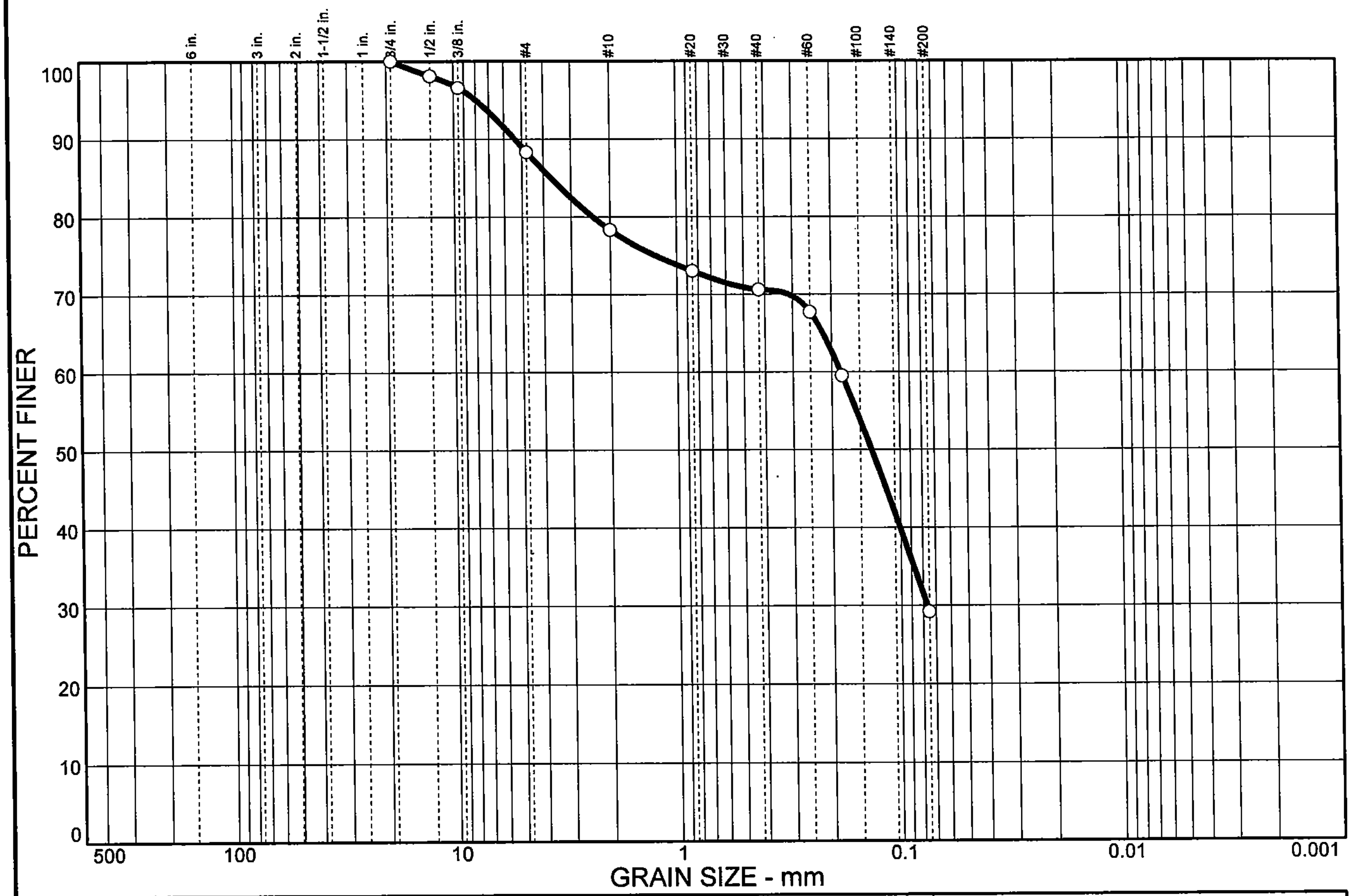
Remarks

Sample No.: 6109
Location: BIA-28 #2
Source of Sample: Client Samples
Date:
Elev./Depth: 10 FT 3 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	11.7	10.0	7.7	41.4	29.2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	98.1		
3/8 in.	96.6		
# 4	88.3		
# 10	78.3		
# 20	73.0		
# 40	70.6		
# 60	67.7		
# 80	59.5		
# 200	29.2		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 3.70 D_{60}= 0.183 D_{50}= 0.134
D_{30}= 0.0767 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

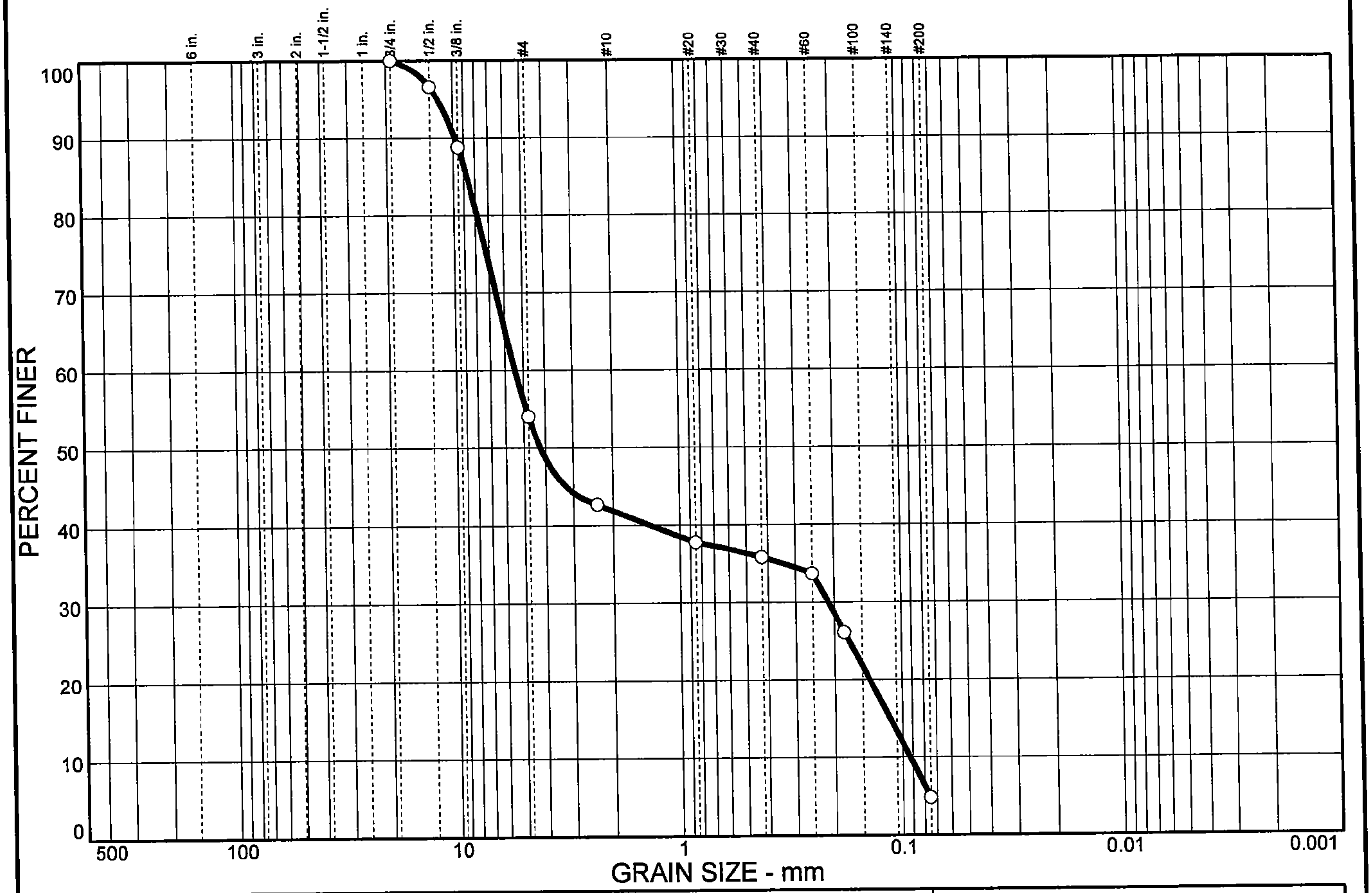
Remarks

Sample No.: 6110
Location: BIA-28 #3
Source of Sample: Client Samples
Date:
Elev./Depth: 15 FT 4.5 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	46.0	12.1	6.1	31.0	4.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	96.6		
3/8 in.	88.8		
# 4	54.0		
# 8	42.7		
# 20	37.8		
# 40	35.8		
# 60	33.7		
# 80	26.1		
# 200	4.8		

* (no specification provided)

Soil Description

Poorly graded sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 8.72 D_{60}= 5.44 D_{50}= 4.21

D_{30}= 0.213 D_{15}= 0.113 D_{10}= 0.0926

C_u= 58.75 C_c= 0.09

Classification

USCS= SP AASHTO= A-1-b

Remarks

Sample No.: 6111 **Source of Sample:** Client Samples **Date:**

Location: BIA-28 #4 **Elev./Depth:** 20 FT 6 m

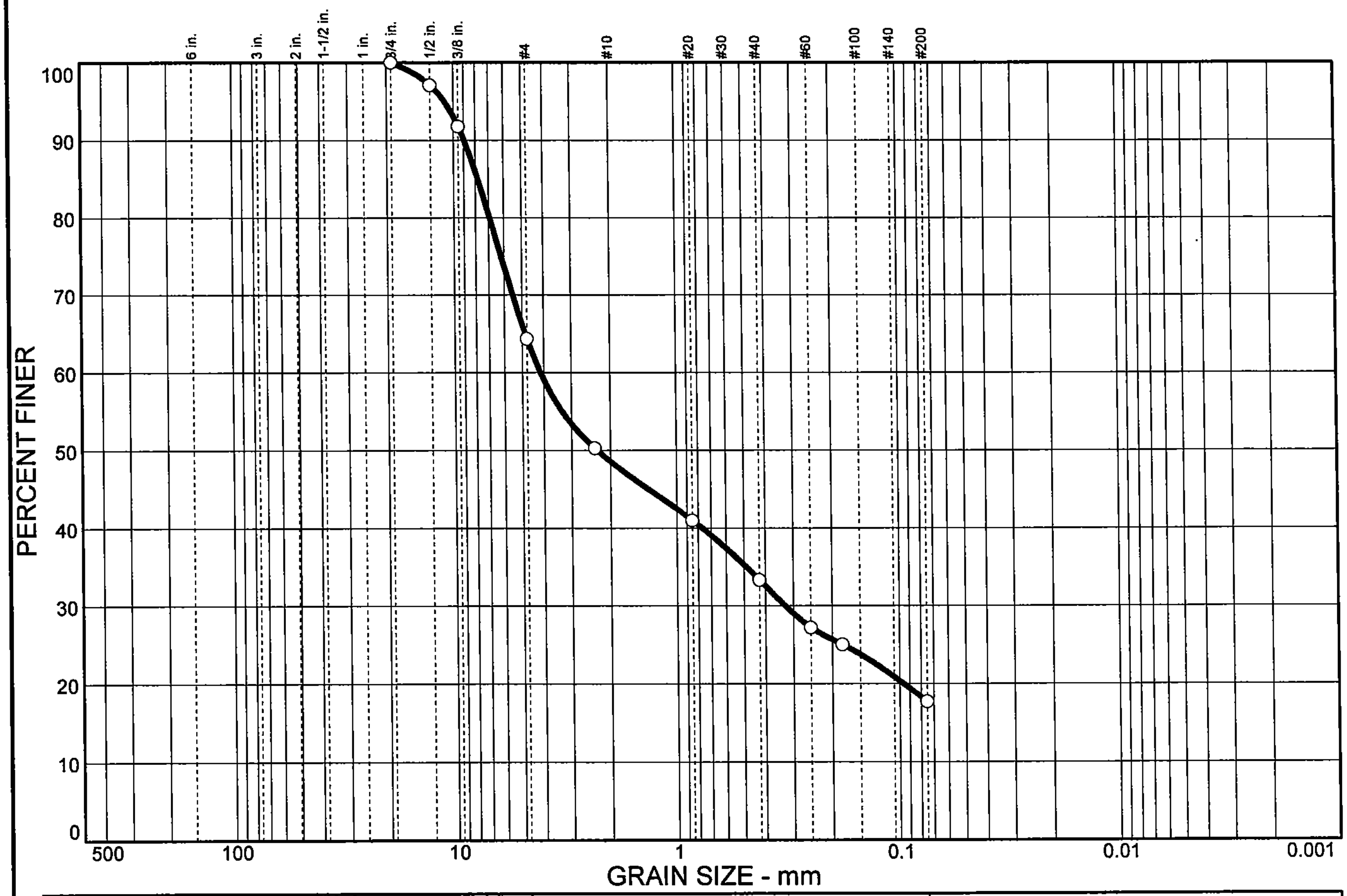
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	35.7	15.7	15.3	15.6	17.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	97.1		
3/8 in.	91.8		
# 4	64.3		
# 8	50.3		
# 20	41.0		
# 40	33.3		
# 60	27.2		
# 80	25.0		
# 200	17.7		

* (no specification provided)

Soil Description

Silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 7.82 D_{60}= 4.14 D_{50}= 2.30

D_{30}= 0.327 D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-1-b

Remarks

Sample No.: 6112 **Source of Sample:** Client Samples **Date:**

Location: BIA-29 #1 **Elev./Depth:** 5 FT 1.5 m

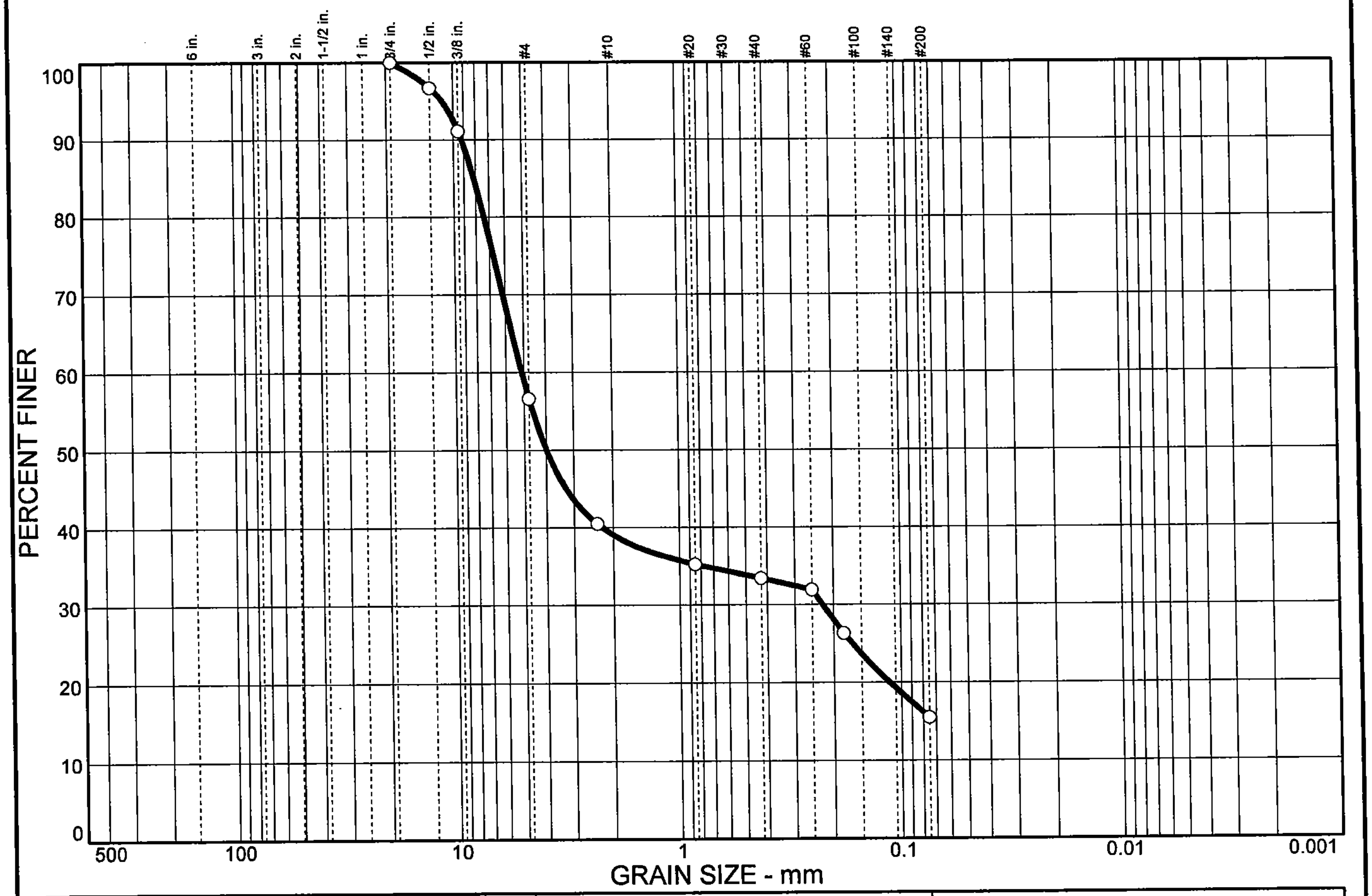
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	43.4	17.5	5.7	17.9	15.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	96.7		
3/8 in.	91.1		
# 4	56.6		
# 8	40.5		
# 20	35.2		
# 40	33.4		
# 60	31.9		
# 80	26.3		
# 200	15.5		

* (no specification provided)

Soil Description

Silty gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 8.17 D_{60}= 5.11 D_{50}= 3.98

D_{30}= 0.224 D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= GM AASHTO= A-1-b

Remarks

Sample No.: 6113 **Source of Sample:** Client Samples **Date:**

Location: BIA-30 #4 **Elev./Depth:** 20 FT 6 m

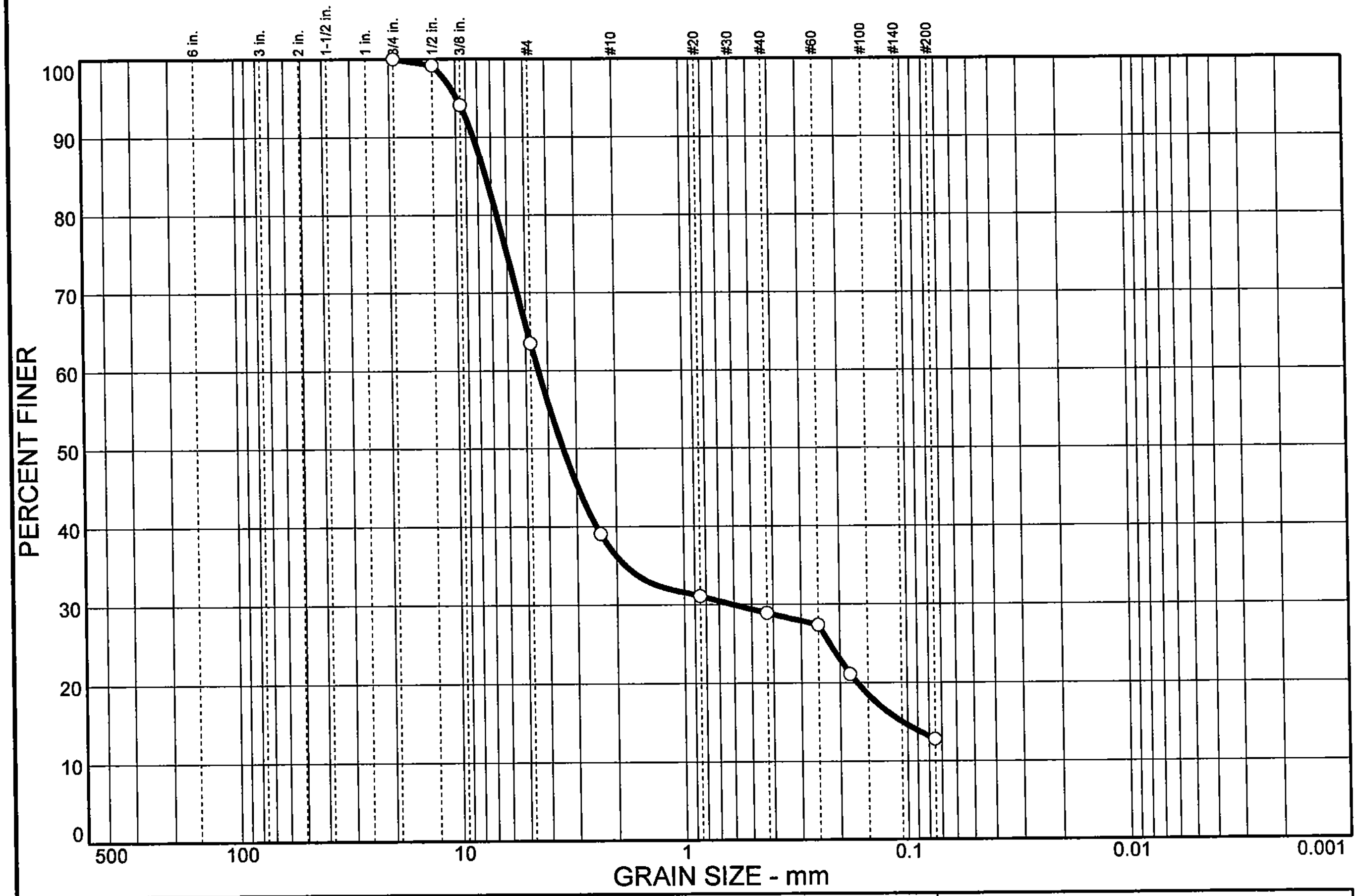
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	36.5	27.3	7.3	16.1	12.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	99.2		
3/8 in.	94.1		
# 4	63.5		
# 8	39.1		
# 20	31.1		
# 40	28.9		
# 60	27.4		
# 80	21.1		
# 200	12.8		

* (no specification provided)

Soil Description

Silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 7.40 D_{60}= 4.40 D_{50}= 3.44
D_{30}= 0.608 D_{15}= 0.105 D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-1-a

Remarks

Sample No.: 6114
Location: BIA-30 #5

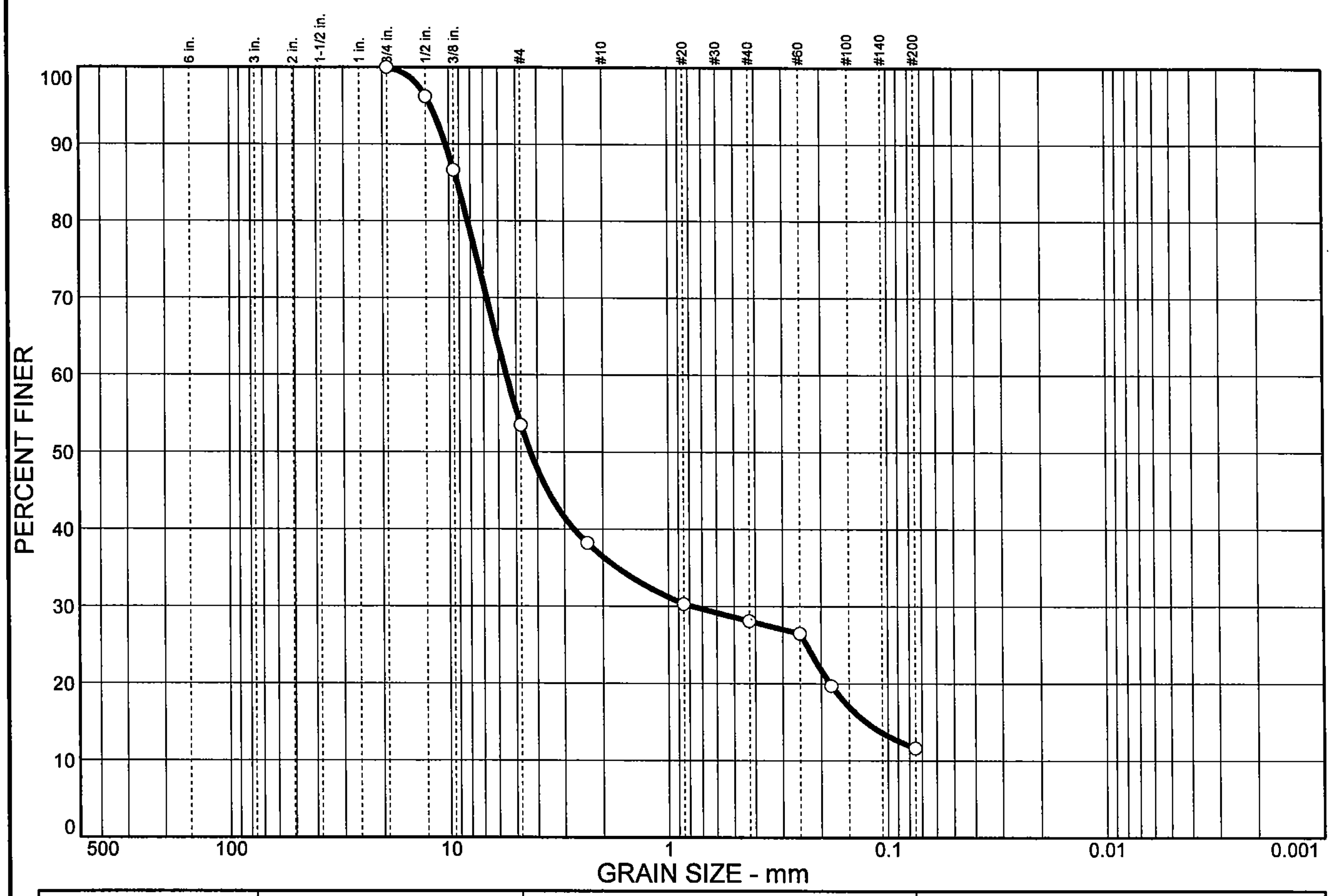
Source of Sample: Client Samples

Date:
Elev./Depth: 24 FT 7.2 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	46.5	17.1	8.3	16.5	11.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	96.2		
3/8 in.	86.6		
# 4	53.5		
# 8	38.2		
# 20	30.3		
# 40	28.1		
# 60	26.5		
# 80	19.7		
# 200	11.6		

* (no specification provided)

Soil Description

Poorly graded gravel with silt and sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 9.18 D_{60}= 5.53 D_{50}= 4.30
D_{30}= 0.775 D_{15}= 0.126 D_{10}=
C_u= C_c=

Classification

USCS= GP-GM AASHTO= A-1-a

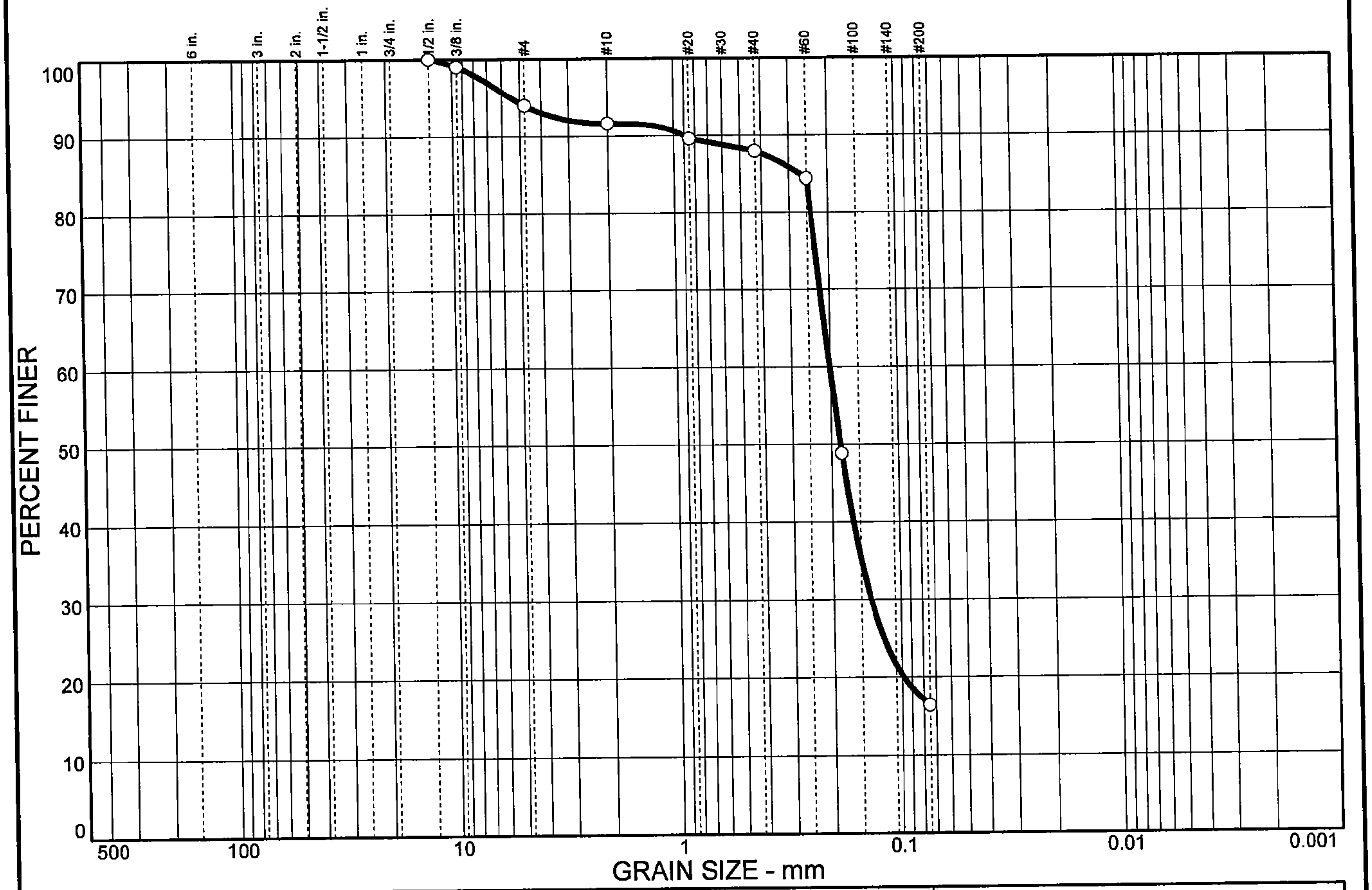
Remarks

Sample No.: 6115 **Source of Sample:** Client Samples **Date:**
Location: BIA-30 #6 **Elev./Depth:** 29 FT 8.7 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	6.0	2.4	3.6	71.6	16.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	99.0		
# 4	94.0		
# 10	91.6		
# 20	89.6		
# 40	88.0		
# 60	84.4		
# 80	48.8		
# 200	16.4		

* (no specification provided)

Soil Description

Silty sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 0.268 D_{60}= 0.202 D_{50}= 0.182
D_{30}= 0.136 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

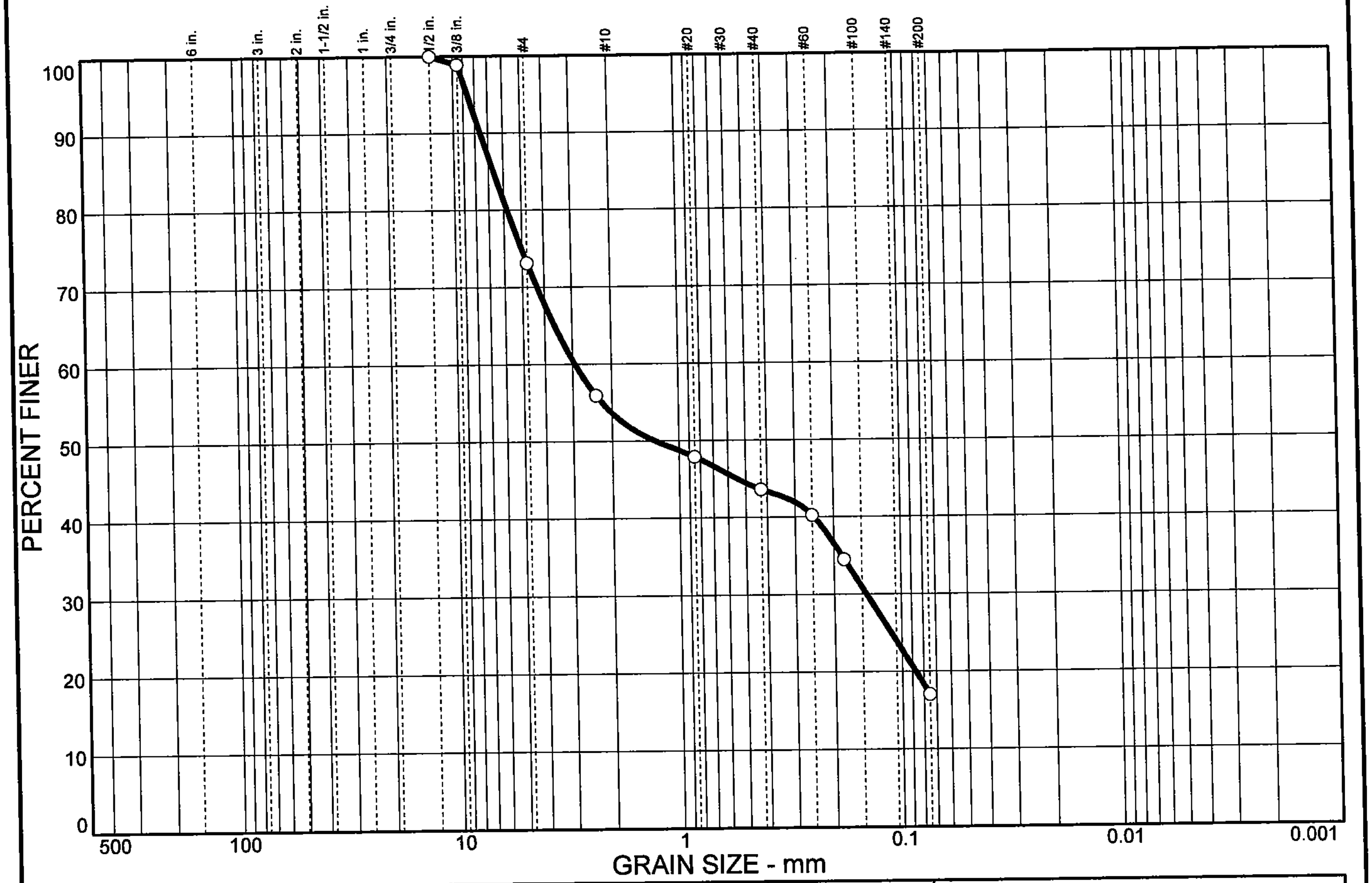
Remarks

Sample No.: 6116
Location: BIA-30 #7
Source of Sample: Client Samples
Date:
Elev./Depth: 34 FT 10.2 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148
Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	26.9	19.4	10.1	26.6	17.0	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	98.9		
# 4	73.1		
# 8	55.9		
# 20	47.9		
# 40	43.6		
# 60	40.2		
# 80	34.5		
# 200	17.0		

* (no specification provided)

Soil Description

Silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 6.66 D_{60}= 2.93 D_{50}= 1.27

D_{30}= 0.143 D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-1-b

Remarks

Sample No.: 6117 **Source of Sample:** Client Samples **Date:**

Location: BIA-31 #3 **Elev./Depth:** 15 FT 4.5 m

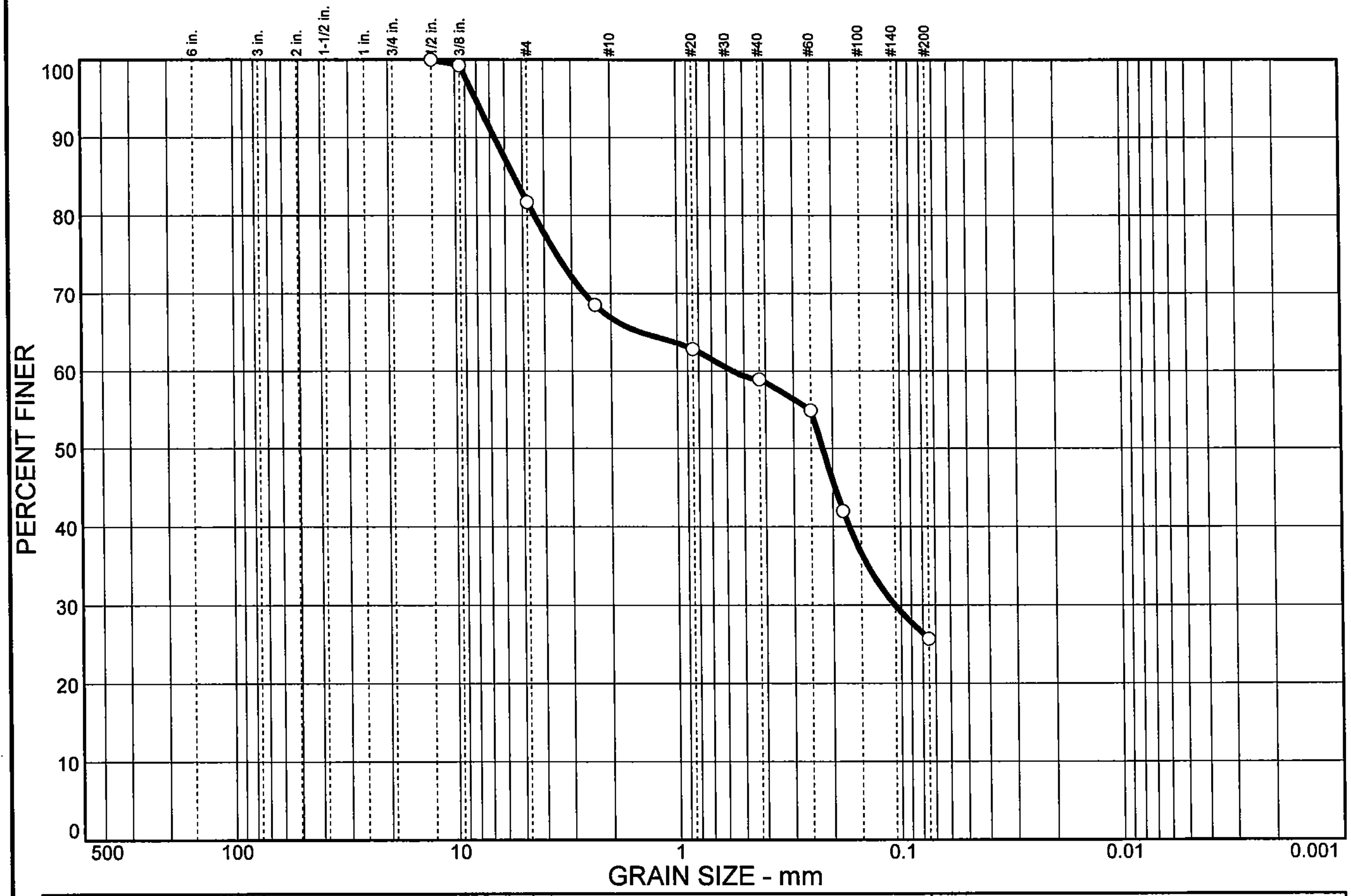
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	18.3	14.9	7.9	33.2	25.7	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1/2 in.	100.0		
3/8 in.	99.3		
# 4	81.7		
# 8	68.5		
# 20	62.8		
# 40	58.9		
# 60	54.9		
# 80	42.0		
# 200	25.7		

* (no specification provided)

Soil Description

Silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 5.45 D_{60}= 0.564 D_{50}= 0.222

D_{30}= 0.106 D_{15}= D_{10}=

C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6118 **Source of Sample:** Client Samples **Date:**

Location: BIA-31 #4 **Elev./Depth:** 19 FT 5.7 m

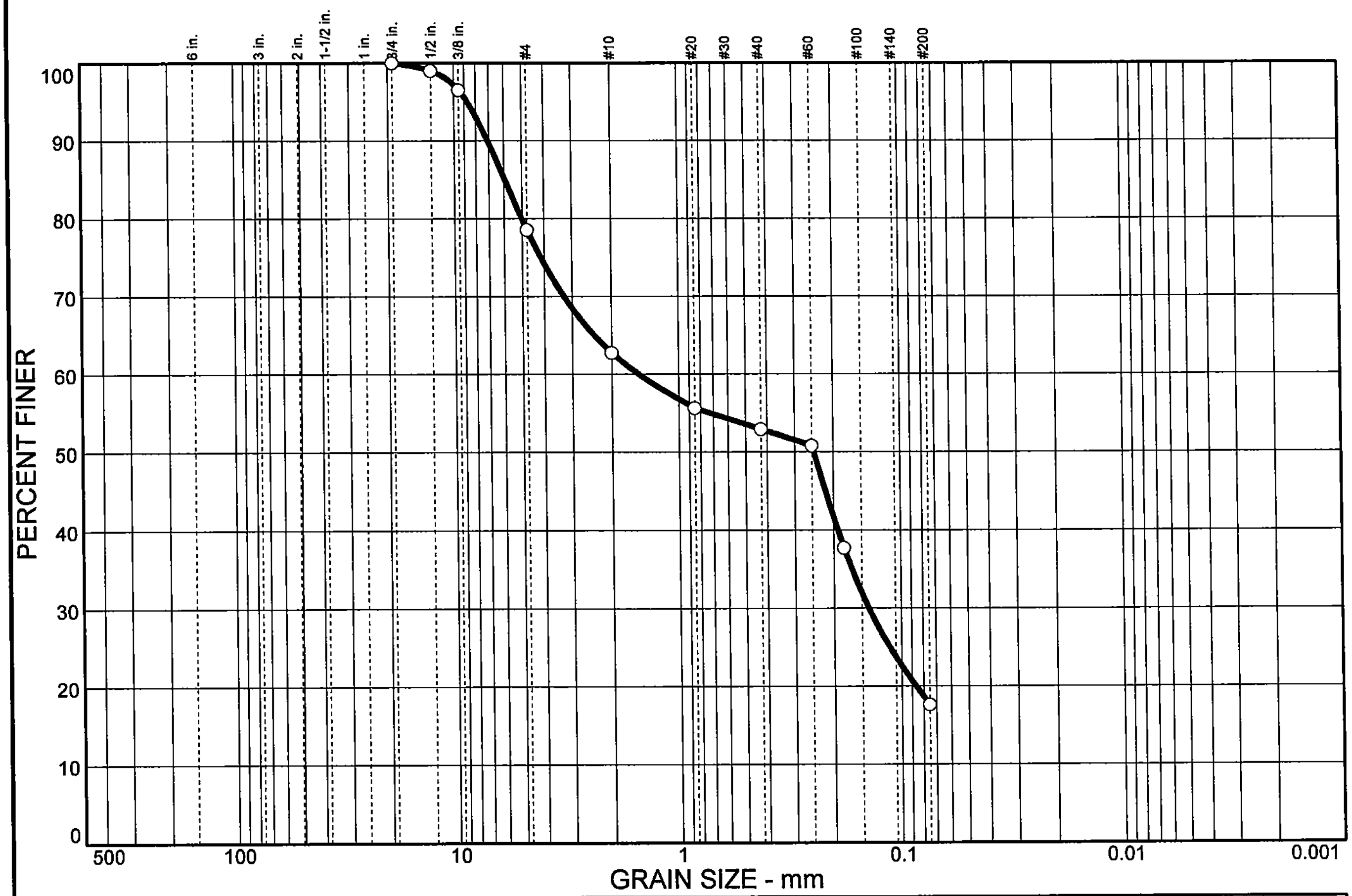
Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District

Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska

Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	21.5	15.8	9.8	35.3	17.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	99.0		
3/8 in.	96.5		
# 4	78.5		
# 10	62.7		
# 20	55.6		
# 40	52.9		
# 60	50.8		
# 80	37.7		
# 200	17.6		

* (no specification provided)

Soil Description

Silty sand with gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 5.95 D_{60}= 1.53 D_{50}= 0.245
D_{30}= 0.140 D_{15}= D_{10}=
C_u= C_c=

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Sample No.: 6119
Location: BIA-31 # 5

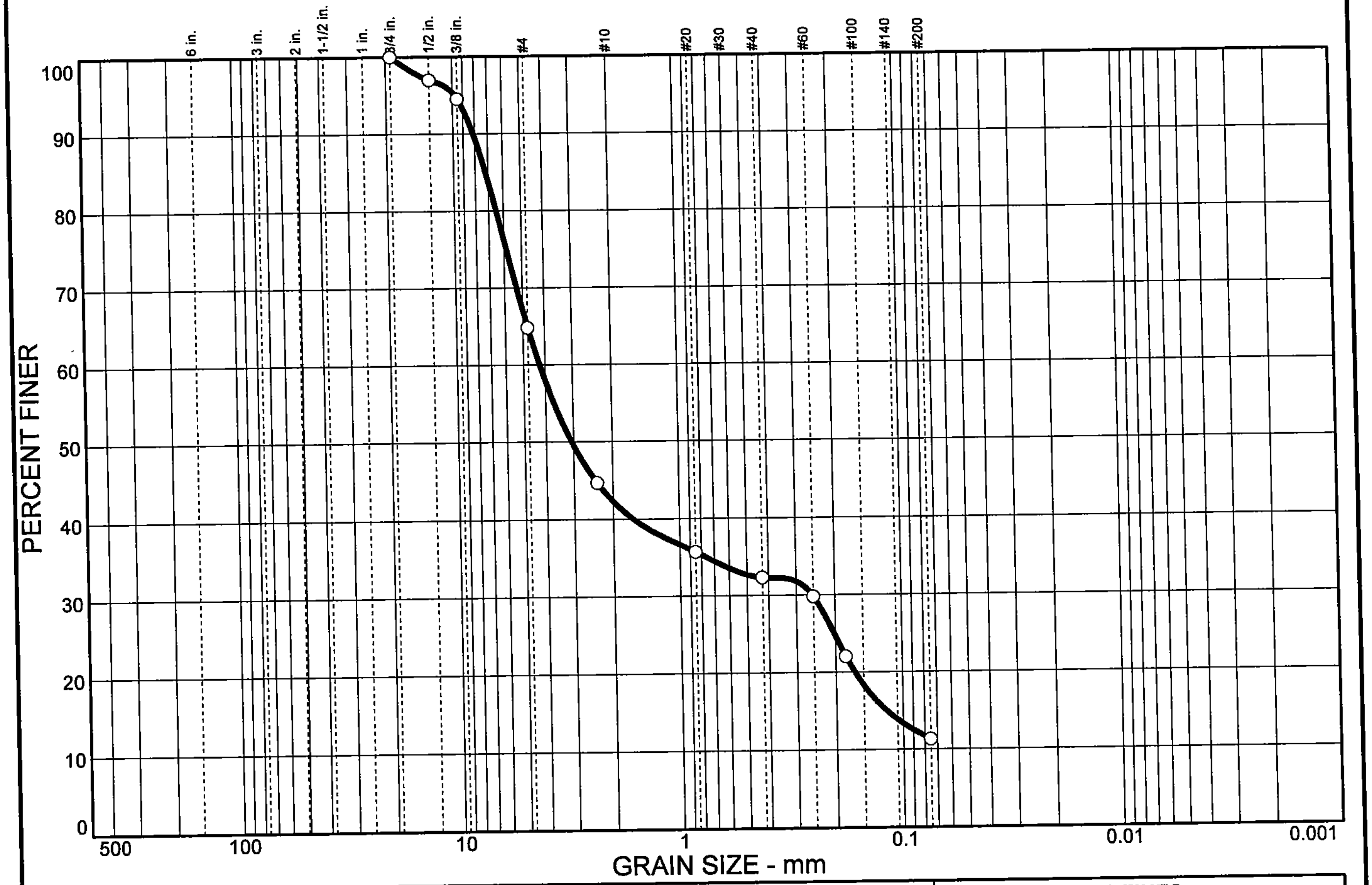
Source of Sample: Client Samples

Date:
Elev./Depth: 24 FT 7.2 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	35.2	22.5	10.0	21.0	11.3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	97.0		
3/8 in.	94.5		
# 4	64.8		
# 8	44.7		
# 20	35.7		
# 40	32.3		
# 60	29.8		
# 80	22.0		
# 200	11.3		

* (no specification provided)

Soil Description

Poorly graded sand with silt and gravel

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 7.21 D_{60}= 4.23 D_{50}= 3.07
D_{30}= 0.253 D_{15}= 0.119 D_{10}=
C_u= C_c=

Classification

USCS= SP-SM AASHTO= A-1-b

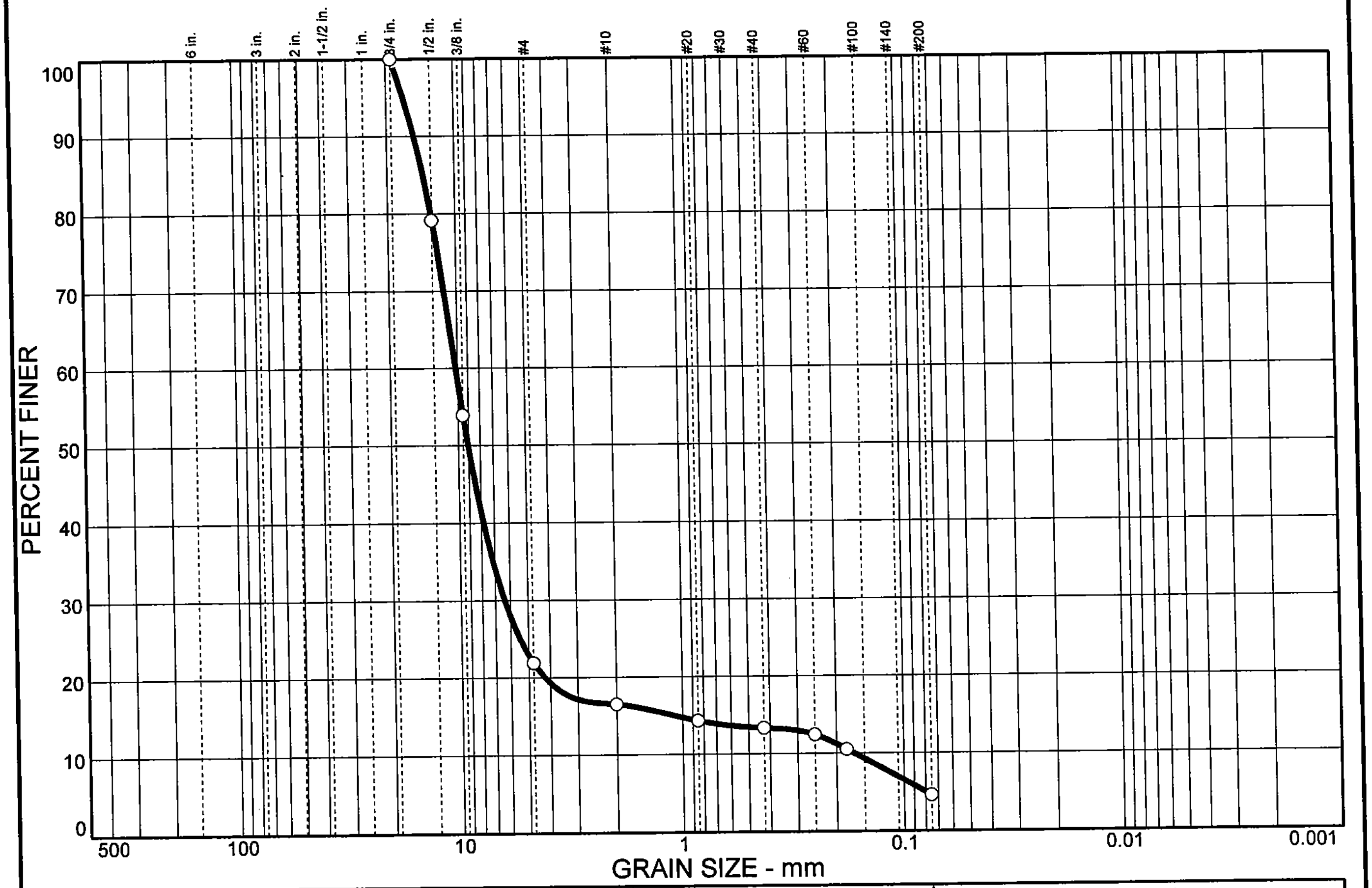
Remarks

Sample No.: 6120 **Source of Sample:** Client Samples **Date:**
Location: BIA-31 # 6 **Elev./Depth:** 29 FT 8.7 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL		% SAND			% FINES	
	CRS.	FINE	CRS.	MEDIUM	FINE	SILT	CLAY
0.0	0.0	78.1	5.4	3.2	8.7	4.6	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
1/2 in.	79.1		
3/8 in.	53.9		
# 4	21.9		
# 10	16.5		
# 20	14.3		
# 40	13.3		
# 60	12.4		
# 80	10.5		
# 200	4.6		

* (no specification provided)

Soil Description

Poorly graded gravel with sand

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 13.8 D_{60}= 10.2 D_{50}= 9.07
D_{30}= 6.36 D_{15}= 1.09 D_{10}= 0.167
C_u= 61.19 C_c= 23.69

Classification

USCS= GP AASHTO= A-1-a

Remarks

Sample No.: 6121 **Source of Sample:** Client Samples **Date:**
Location: BIA-31 # 7 **Elev./Depth:** 34 FT 10 m

Mappa TestLab

Client: U.S. Army Corps of Engineers, Alaska District
Project: Barrow Coastal Storm Damage Reduction Study
Barrow, Alaska
Project No: 2004-148 **Figure**

Appendix D

Test Boring Logs and Laboratory Data
Submerged Spit

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **8 Aug 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,379,800 ft. ±**
Easting: **687,029 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-1**

Permanent: **OS-01**

Operator: **Travis Coghill & Ryan Ralston**

Inspector: **Inocencio Roman/ Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NA**

Depth Drilled: **15.0 ft.**

Total Depth: **16.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **2.5 in.**

Size and Type of Bit: **3.875 in. Tri-Cone Bit**

Type of Equipment: **Nodwell B61 w/ autohammer**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Cloudy, 45 degrees**
2														
4														
6		1		F2	6 9 13	SP-SM	Poorly graded SAND with Silt	1	88	11	0.5		22	Dark gray, brown, and black, wet, fine sand, nonplastic (NP) fines
8														
10		2		F2	19 30 48	SP-SM	Poorly graded SAND with Silt		88	12			20	Dark gray and black, wet, fine sand, NP fines
12														
14														
16		3		F4	6 19 21	SM	Silty SAND		60	40			28	Dark gray to black, wet, fine sand, NP fines
18														Bottom of Hole 16.5 ft. Groundwater Measurement Not Applicable PID = (Cold/Hot) Photo Ionization Detector Depth to mudline - 50 feet
20														
22														
24														
26														
28														
30														
32														

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **OS-01**

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **11 Aug 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,353,974 ft. ±** Easting: **689,280 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **A-8** Permanent: **OS-02**

Operator: **Travis Coghill & Ryan Ralston**

Inspector: **Inocencio Roman/ Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NA**

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **2.5 in.**

Size and Type of Bit: **3.875 in. Tri-Cone Bit**

Type of Equipment: **Nodwell B61 w/ autohammer**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Fog, 45 degrees
2														
4														
6		1		F4	2 3 2	SM	Silty SAND	5	64	31	0.75		29	Black and gray, wet, fine sand, non plastic (NP) fines, trace of subangular gravel
8														
10		2		F2	5 7 12	SM	Silty SAND		87	13			21	Gray to brown, wet, fine sand, NP fines
12														
14														
16		3		F2	10 17 24	SP-SM	Poorly graded SAND with Silt		91	9			21	Gray, wet, fine sand, NP fines
18														
20		4		F2	8 13 20	SP-SM	Poorly graded SAND with Silt		88	12			21	Gray, wet, fine sand, NP fines, trace of shell fragments
22														
24														
26		5		F4	7 7 7	SM	Silty SAND	5	21	74	0.5		18	Gray, wet, fine sand, slightly plastic fines, some gravel and shells in sample that were washed down the hole and were not retrieved
28														
30		6		F4	2 5 6	ML	SILT		5	95			27	Dark gray, wet, fine sand, NP fines
32														Bottom of Hole 31.5 ft. Groundwater Measurement Not Applicable PID = (Cold/Hot) Photo Ionization Detector Depth to mudline - 25 feet

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **OS-02**

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section

EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **12 Aug 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,365,516 ft. ±** Easting: **689,013 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **A-5**

Permanent: **OS-03**

Operator: **Travis Coghill & Ryan Ralston**

Inspector: **Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NA**

Depth Drilled: **30.0 ft.**

Total Depth: **31.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **2.5 in.**

Size and Type of Bit: **3.875 in. Tri-Cone Bit**

Type of Equipment: **Nodwell B61 w/ autohammer**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Fog, 40 degrees**
2														
4														
6		1		**F4**	**3 7 8**	**ML**	**Sandy SILT**		**47**	**53**			**25**	**Dark gray, wet, fine sand**
8														
10		2		**F4**	**7 14 11**	**ML**	**Sandy SILT**		**50**	**50**			**24**	**Dark gray, wet, fine sand**
12														
14														
16		3		**F4**	**5 5 8**	**SM**	**Silty SAND**		**55**	**45**	**0.25**		**28**	**Dark gray, wet, subrounded gravel, fine sand, some shell fragments in sample**
18														
20		4		**F4**	**9 13 16**	**ML**	**Sandy SILT**	**1**	**30**	**69**	**0.375**		**29**	**Dark gray, wet, very fine sand, NP fines**
22														
24														
26		5		**F4**	**7 4 7**	**ML**	**Sandy SILT**	**1**	**25**	**74**	**0.2**		**30**	**Dark gray, wet, fine sand, NP fines**
28														
30		6		**F4**	**4 13 15**	**ML**	**SILT**		**14**	**86**			**28**	**Dark gray, wet, very fine sand, NP fines**
32														**Bottom of Hole 31.5 ft. Groundwater Measurement Not Applicable PID = (Cold/Hot) Photo Ionization Detector Depth to mudline - 40 feet**

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **OS-03**

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **12 Aug 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,384,905 ft. ±**
Easting: **699,822 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **TB-5**

Permanent: **OS-04**

Operator: **Travis Coghill & Ryan Ralston**

Inspector: **Inocencio Roman**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NA**

Depth Drilled: **9.0 ft.**

Total Depth: **9.8 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D.: **2.5 in.**

Size and Type of Bit: **3.875 in. Tri-Cone Bit**

Type of Equipment: **Nodwell B61 w/ autohammer**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size			Max Size (in.)	PID (ppm)	% Water	Description and Remarks Rain, 45 degrees
								%Gravel	%Sand	%Fines				
2														
4														
6		1		F4	16 19 21	SM	Silty SAND		70	30			13	Dark gray to black, wet, very fine sand, nonplastic (NP) fines
8		2		F2	20 51/4"	SP-SM	Poorly graded SAND with Silt		89	11			20	Dark gray to black, wet, very fine sand, NP fines
10														Bottom of Hole 9.8 ft. Groundwater Measurement Not Applicable PID = (Cold/Hot) Photo Ionization Detector Depth to mudline - 40 feet
12														
14														
16														
18														
20														
22														
24														
26														
28														
30														
32														

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **OS-04**

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **12 Aug 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,353,696 ft. ±** Easting: **668,124 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **A-11** Permanent: **OS-05**

Operator: **Travis Coghill & Ryan Ralston**

Inspector: **Inocencio Roman/ Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NA**

Depth Drilled: **30.0 ft.**

Total Depth: **33.0 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D.: **2.5 in.**

Size and Type of Bit: **3.875 in. Tri-Cone Bit**

Type of Equipment: **Nodwell B61 w/ autohammer**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	%Sand	%Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks Rain, 45 degrees
2														
4														
6		1		F4	3 3 3	ML	SILT with Sand		25	75			29	Dark gray, wet, very fine sand, NP fines
8														
10		2		F4	3 3 3	ML	SILT		14	86			37	Dark gray, wet, very fine sand, slightly plastic fines
12														
14														
16		3		F4	2 2 2	ML	Sandy SILT		31	69			27	Dark gray, wet, fine sand, slightly plastic fines
18														
20		4		F4	2 3 2	ML	SILT		8	92			33	Dark gray, wet, very fine sand, slightly to NP fines
22														
24														
26		5		F4	4 12 12	ML	Sandy SILT		38	62			20	Dark gray, wet, fine sand, trace shell fragments in sample
28														
30		6		F2	11 25 29	ML	Sandy SILT		42	58			19	Dark gray, wet, fine sand
32		7		F4	12 13 40	SP-SM	Poorly graded SAND with Silt		92	8			25	Dark gray, wet, fine sand
34														Bottom of Hole 33.0 ft. Groundwater Measurement Not Applicable PID = (Cold/Hot) Photo Ionization Detector Depth to mudline - 28 feet
36														

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **OS-05**

EXPLORATION LOG BARROWSTORMDAMAGEREDUCTION.GPJ ACE_ANC.GDT 3/11/05

ALASKA DISTRICT
CORPS OF ENGINEERS
ENGINEERING SERVICES

Soils and Geology Section
EXPLORATION LOG

Project: **Coastal Storm Damage Reduction**
Barrow, Alaska

Page 1 of 1

Date: **14 Aug 2004**

Drilling Agency: ☐ Alaska District ☒ Other **Denali Drilling**

Elevation Datum: ☐ MSL ☐ other

Location: Northing: **6,370,184 ft. ±** Easting: **676,954 ft. ±**

Top of Hole Elevation:

Hole Number, Field: **A-1** Permanent: **OS-06**

Operator: **Travis Coghill & Ryan Ralston**

Inspector: **Inocencio Roman/ Aaron Banks**

Type of Hole: ☒ other **Auger**
☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: **NA**

Depth Drilled: **22.0 ft.**

Total Depth: **23.5 ft.**

Hammer Weight: **340 lbs**

Split Spoon I.D: **2.5 in.**

Size and Type of Bit: **3.875 in. Tri-Cone Bit**

Type of Equipment: **Nodwell B61 w/ autohammer**

Type of Samples: **Grab and Drive**

Depth (ft.)	Lithology	Sample	Frozen ASTM D 4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	Grain Size %Gravel	Grain Size %Sand	Grain Size %Fines	Max Size (in.)	PID (ppm)	% Water	Description and Remarks **Sunny, 45 degrees**
8		1		**F4**	**13 20 22**	**SM**	**Silty SAND**		**78**	**22**			**21**	**Black to gray, wet, very fine sand, nonplastic (NP) fines**
12		2		**F4**	**4 9 16**	**ML**	**Sandy SILT**		**35**	**65**			**20**	**Black to gray, wet, very fine sand, NP fines**
18		3		**F4**	**6 6 8**	**ML**	**Sandy SILT**		**27**	**73**			**21**	**Black to gray, wet, very fine sand, NP fines**
22		4		**F4**	**7 11 15**	**ML**	**Sandy SILT**		**42**	**58**			**18**	**Black to gray, wet, very fine sand, NP fines**

Bottom of Hole 23.5 ft.
Groundwater Measurement Not Applicable
PID = (Cold/Hot) Photo Ionization Detector
Depth to mudline - 40 feet

NPA Form 19-E
May 94 Prev. Ed. Obsolete

Project: **Coastal Storm Damage Reduction**

Hole Number: **OS-06**

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terrafirma@alaska.com

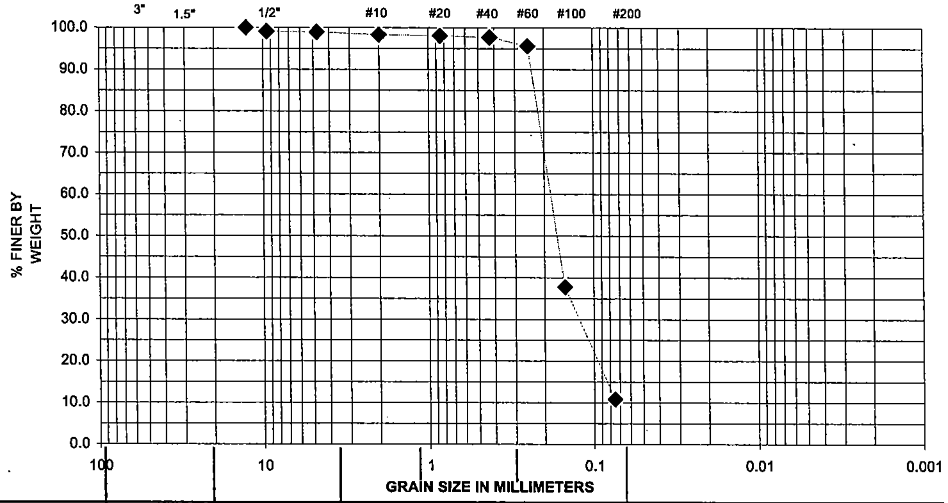
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**TB1**
SAMPLE NO/ DEPTH	**TB1-1 (5.0' - 6.5' Depth)**
DESCRIPTION:	**Poorly grd. sand w/ silt.**
DATE TESTED:	**8/24/2004**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T.**

% GRAVEL: **1.1** USC: **SP-SM**
% SAND: **88.1** FC:
% SILT/CLAY: **10.8** .02 mm:

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**21.5**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



COBBLES	GRAVEL		SAND			SILT or CLAY
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

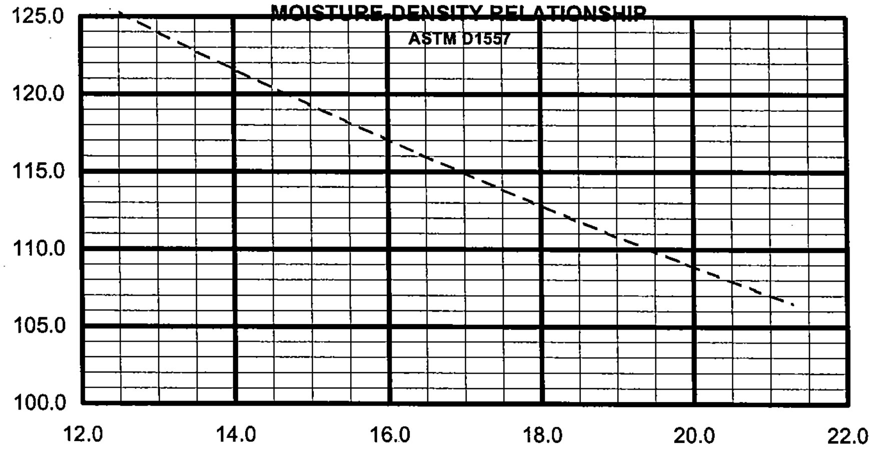
SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"	**100**	
9.5	3/8"	**99**	
4.75	# 4	**99**	
2	#10	**98**	
0.85	#20	**98**	
0.425	#40	**98**	
0.25	# 60	**96**	
0.015	#100	**38**	
0.075	#200	**10.8**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

MOISTURE-DENSITY RELATIONSHIP

ASTM D1557



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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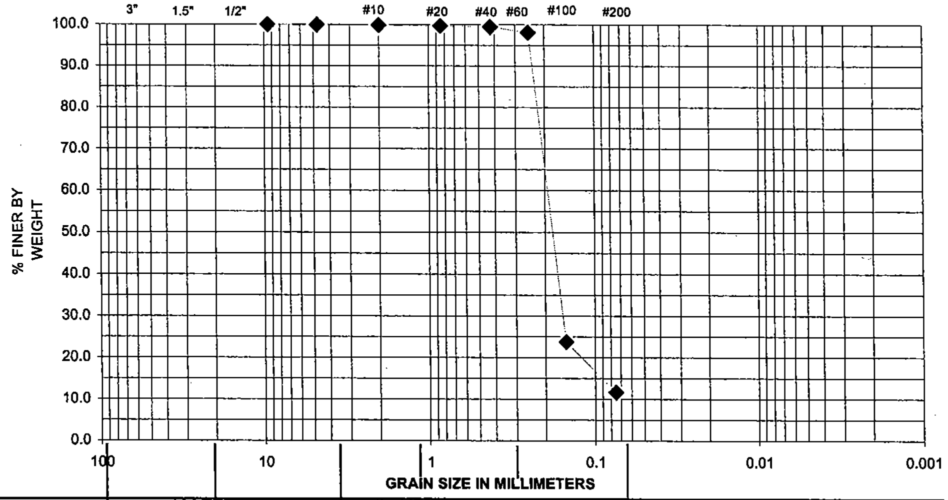
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**TB1**
SAMPLE NO/ DEPTH	**TB1-2 (-10.0' Depth)**
DESCRIPTION:	**Poorly grd. sand w/ silt.**
DATE TESTED:	**8/24/2004**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T.**

% GRAVEL: **0.0** USC: **SP-SM**
% SAND: **88.3** FC:
% SILT/CLAY: **11.7** .02 mm:

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**20.2**

PARTICLE SIZE ANALYSIS
ASTM D422/ C136



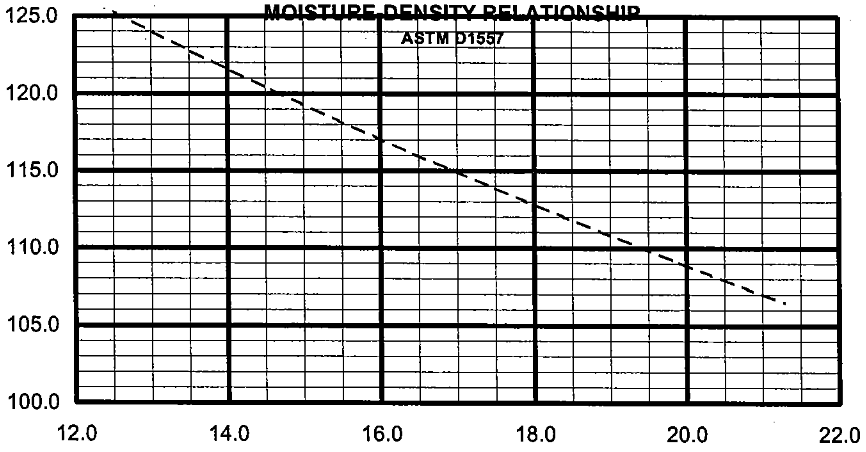
COBBLES	**GRAVEL**		**SAND**			**SILT or CLAY**
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"	**100**	
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**100**	
0.425	#40	**99**	
0.25	# 60	**98**	
0.015	#100	**24**	
0.075	#200	**11.7**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		


MOISTURE DENSITY RELATIONSHIP
ASTM D1557

Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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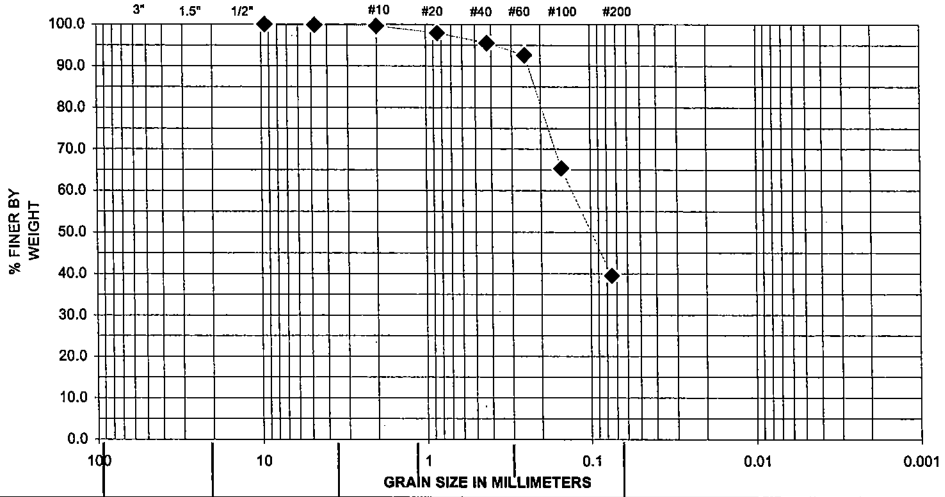
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**TB1**
SAMPLE NO/ DEPTH	**TB1-3 (-15.0' Depth)**
DESCRIPTION:	**Silty sand.**
DATE TESTED:	**8/24/2004**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.1**	USC:	**SM**
% SAND:	**60.4**	FC:	
% SILT/CLAY:	**39.5**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**27.7**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



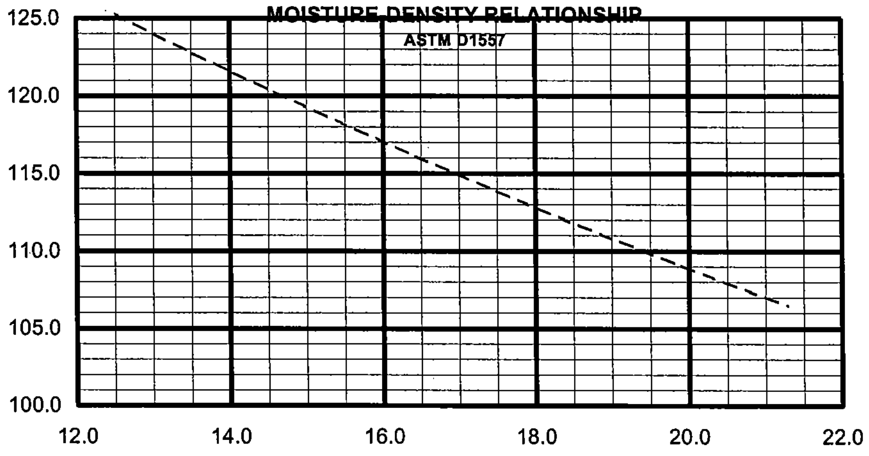
COBBLES	GRAVEL		SAND			SILT or CLAY
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"	**100**	
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**98**	
0.425	#40	**96**	
0.25	# 60	**93**	
0.015	#100	**65**	
0.075	#200	**39.5**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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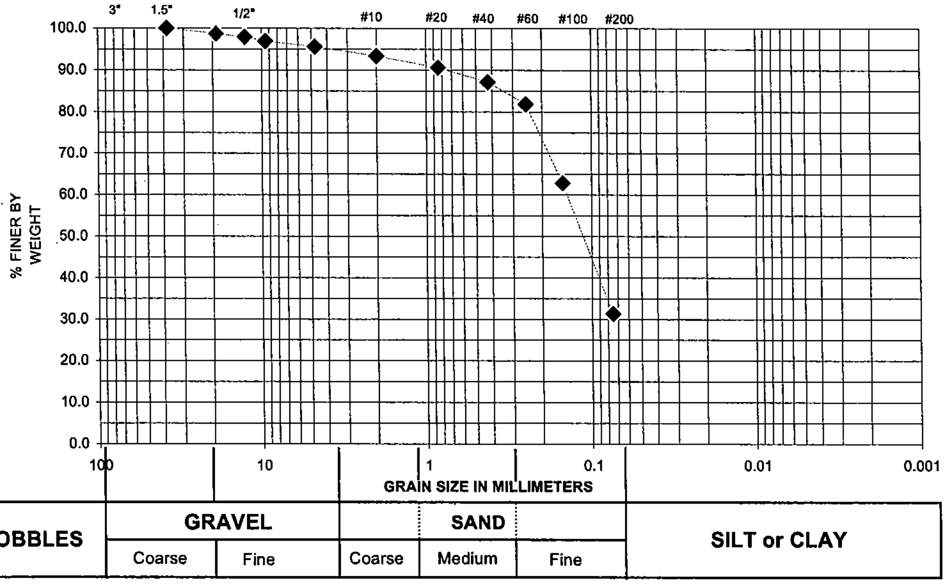
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reductioon**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A8**
SAMPLE NO/ DEPTH	**A8-1 (-5.0' - 6.5' Depth)**
DESCRIPTION:	**Silty sand.**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**4.4**	USC:	**SM**
% SAND:	**64.3**	FC:	
% SILT/CLAY:	**31.3**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**28.9**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136

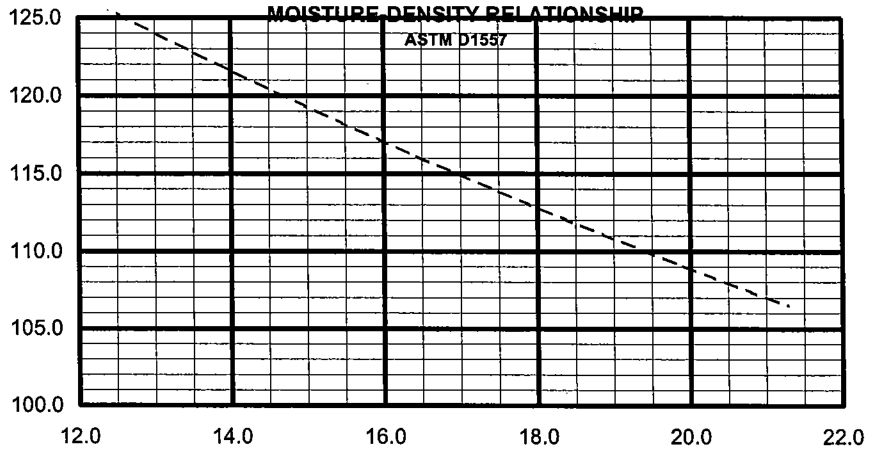


SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"	**100**	
19.05	3/4"	**99**	
12.7	1/2"	**98**	
9.5	3/8"	**97**	
4.75	# 4	**96**	
2	#10	**93**	
0.85	#20	**91**	
0.425	#40	**87**	
0.25	# 60	**82**	
0.015	#100	**63**	
0.075	#200	**31.3**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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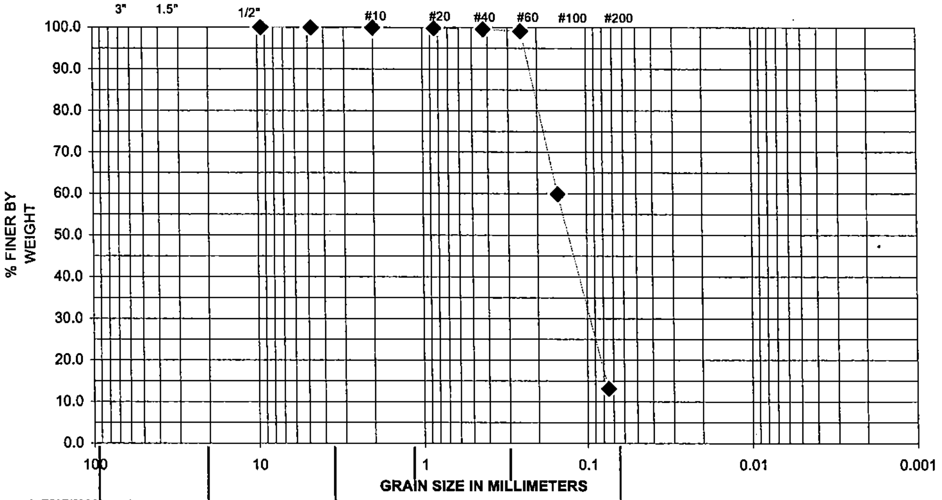
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A8**
SAMPLE NO/ DEPTH	**A8-2 (-10.0' - 11.5' Depth)**
DESCRIPTION:	**Silty sand.**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.0**	USC:	**SM**
% SAND:	**86.8**	FC:	
% SILT/CLAY:	**13.2**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**21.3**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



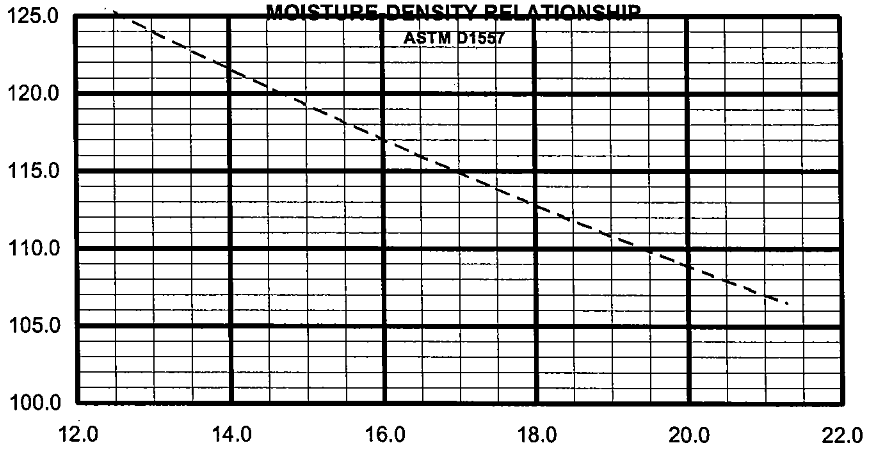
COBBLES	**GRAVEL**		**SAND**			**SILT or CLAY**
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"	**100**	
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**100**	
0.425	#40	**100**	
0.25	# 60	**99**	
0.015	#100	**60**	
0.075	#200	**13.2**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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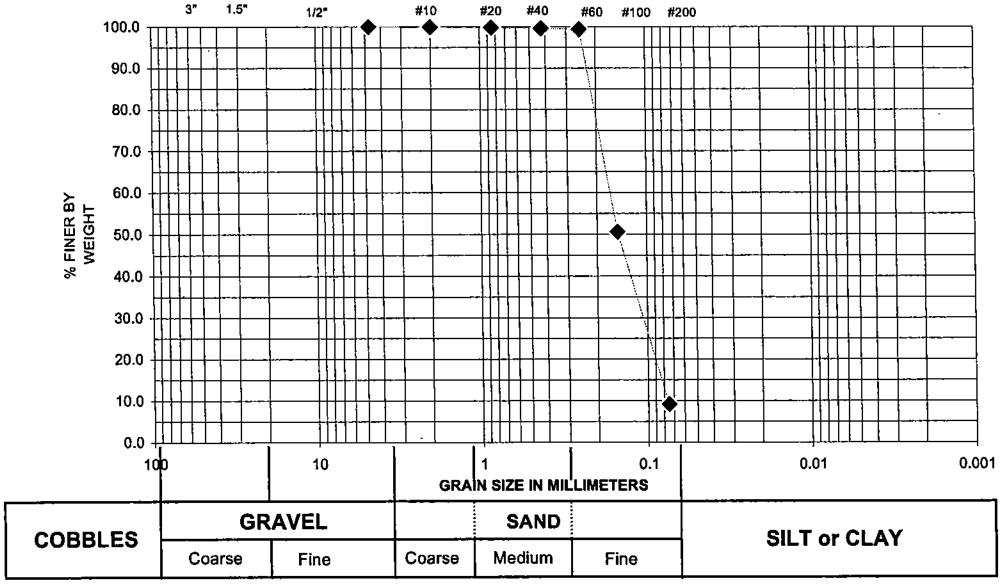
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A8**
SAMPLE NO/ DEPTH	**A8-3 (-15.0' - 16.5' Depth)**
DESCRIPTION:	**Poorly grd. sand w/ silt.**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.0**	USC:	**SP-SM**
% SAND:	**90.9**	FC:	
% SILT/CLAY:	**9.1**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**21.2**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136

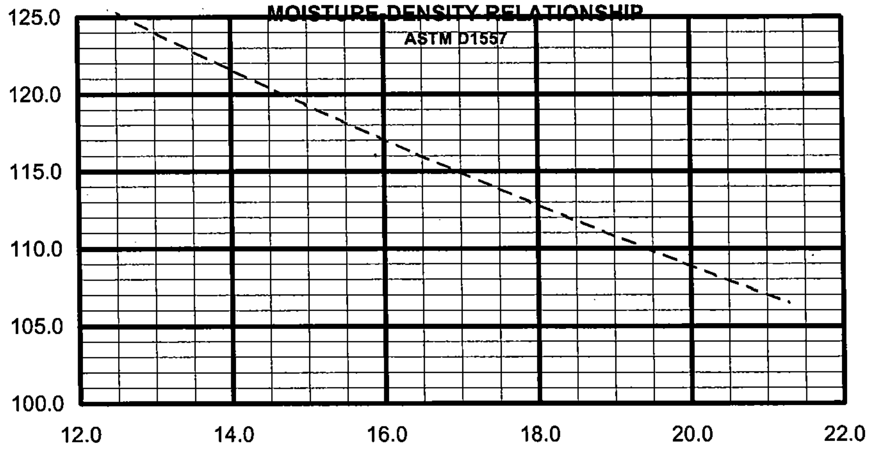


SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**100**	
0.425	#40	**100**	
0.25	# 60	**99**	
0.015	#100	**51**	
0.075	#200	**9.1**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A8**
SAMPLE NO/ DEPTH	**A8-4 (-20.0' - 21.5' Depth)**
DESCRIPTION:	**Poorly grd. sand w/ silt.**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

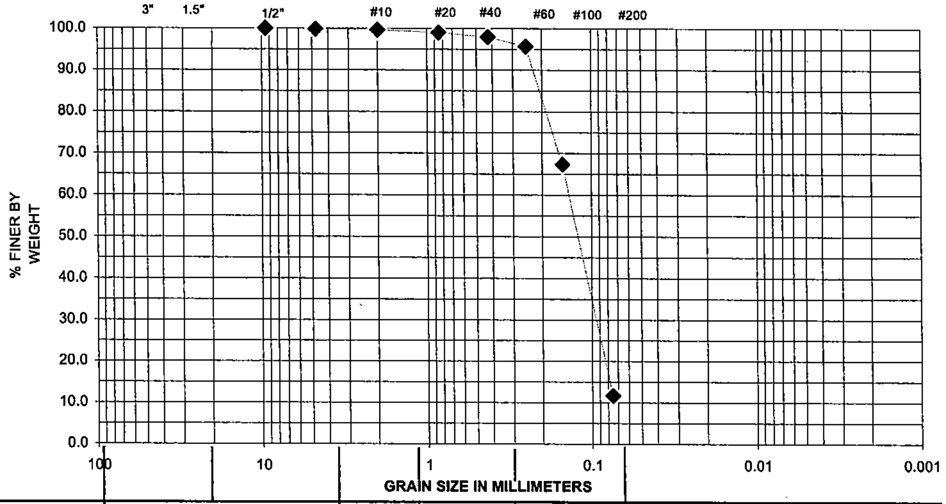
% GRAVEL: **0.1**
% SAND: **88.2**
% SILT/CLAY: **11.7**

USC: **SP-SM**
FC:
.02 mm:

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**21.2**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



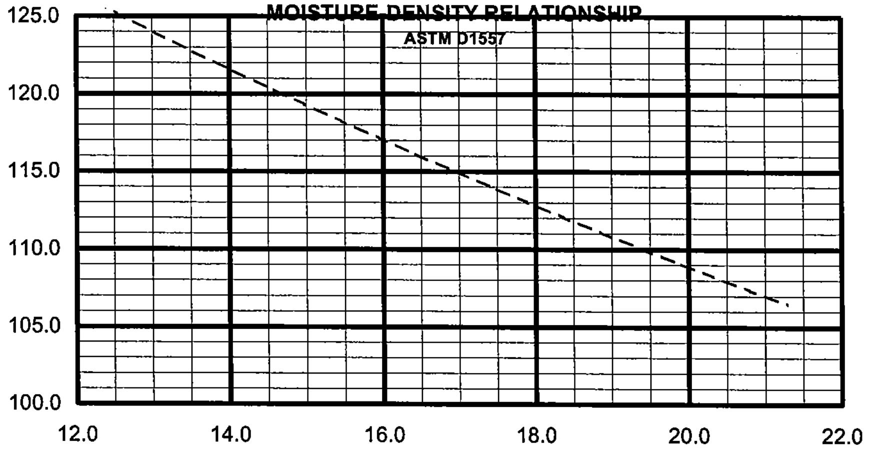
COBBLES	**GRAVEL**			**SAND**		**SILT or CLAY**
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"	**100**	
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**99**	
0.425	#40	**98**	
0.25	# 60	**96**	
0.015	#100	**67**	
0.075	#200	**11.7**	

HYDROMETER RESULT

ELAPSED / TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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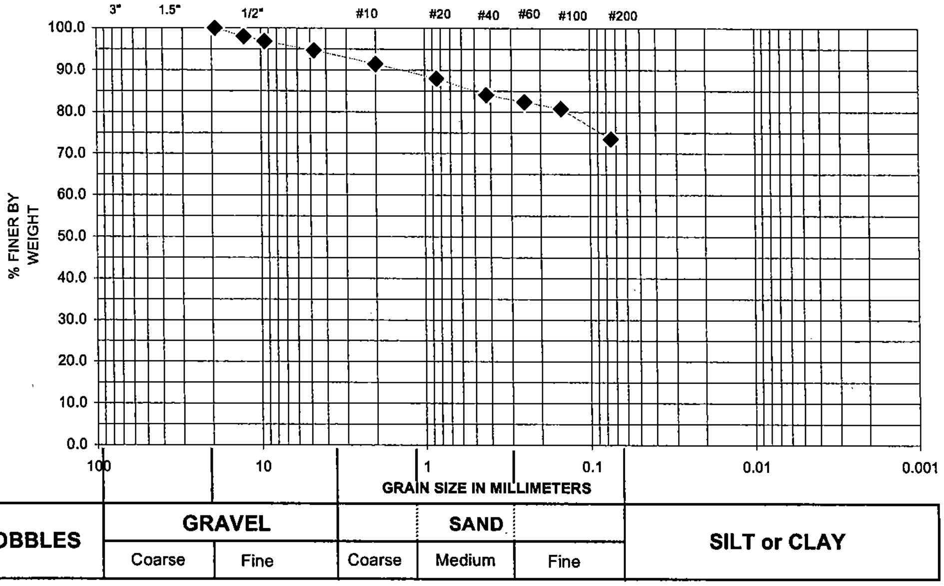
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A8**
SAMPLE NO/ DEPTH	**A8-5 (-25.0' - 26.5' Depth)**
DESCRIPTION:	**Silty sand.**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL: **5.3**
% SAND: **21.2**
% SILT/CLAY: **73.5**
USC: **SM**
FC:
.02 mm:

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**18.2**

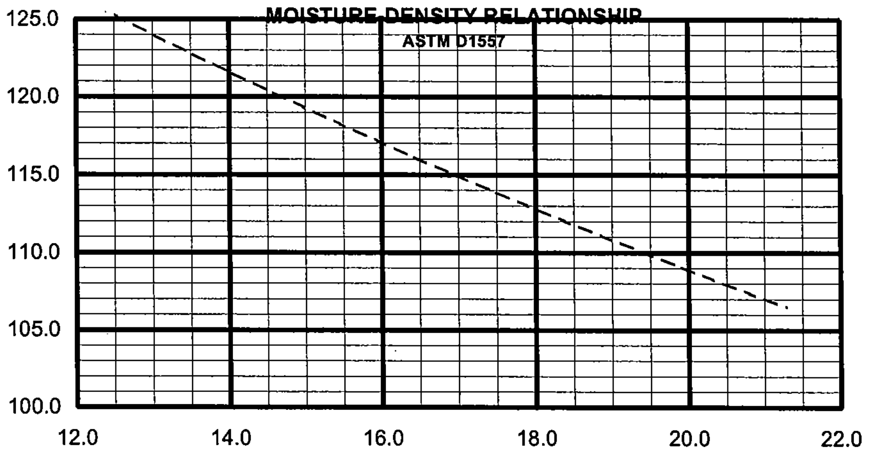
PARTICLE SIZE ANALYSIS

ASTM D422/ C136



SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"	**100**	
12.7	1/2"	**98**	
9.5	3/8"	**97**	
4.75	# 4	**95**	
2	#10	**91**	
0.85	#20	**88**	
0.425	#40	**84**	
0.25	# 60	**82**	
0.015	#100	**81**	
0.075	#200	**73.5**	



HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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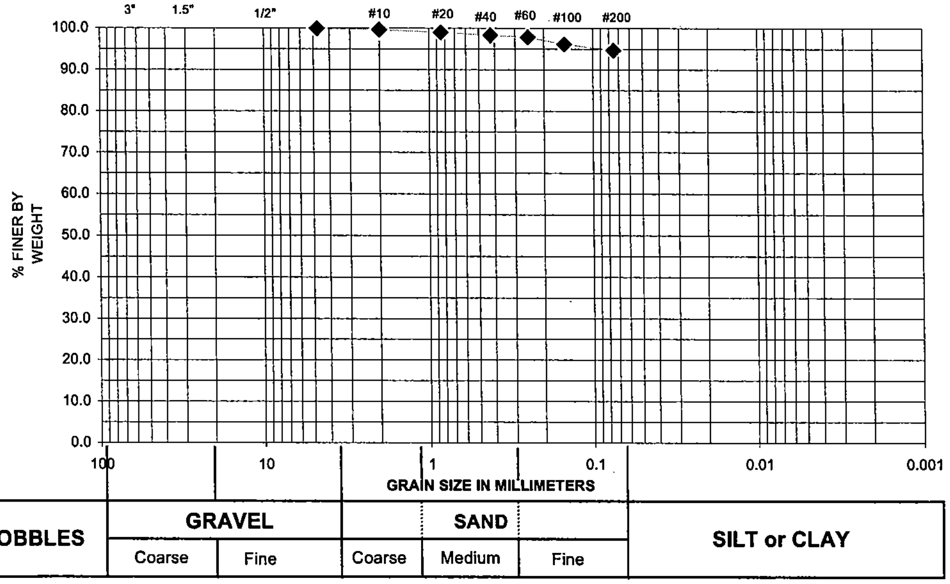
PROJECT CLIENT: **COE - Alaska District**
PROJECT NAME: **Barrow Storm Damage Reductioon**
PROJECT NO.: **COE 1594**
SAMPLE LOCATION: **A8**
SAMPLE NO/ DEPTH **A8-6 (-30.0' - 31.5' Depth)**
DESCRIPTION: **Silt**
DATE TESTED: **08/28/04**
TESTED BY: **D.P.**
REVIEWED BY: **Ron Caron C.E.T. / T. Selmer**

% GRAVEL: **0.0** USC: **ML**
% SAND: **5.3** FC:
% SILT/CLAY: **94.7** .02 mm:

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**26.7**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



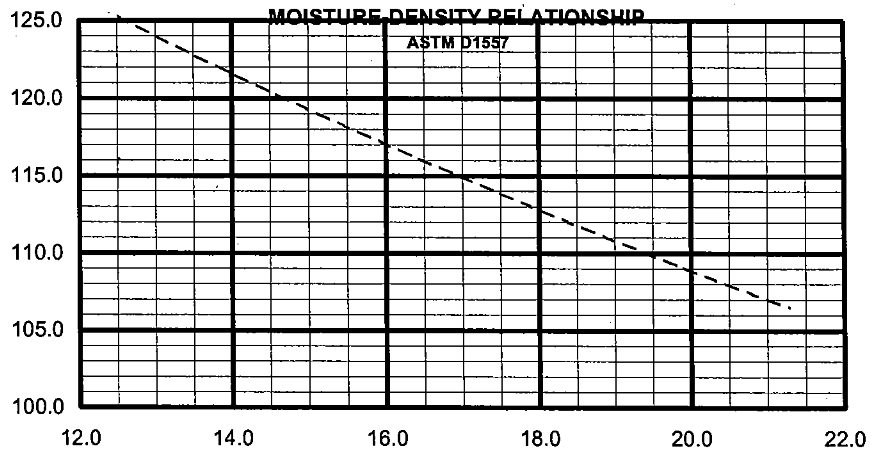
SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**99**	
0.425	#40	**98**	
0.25	# 60	**98**	
0.015	#100	**96**	
0.075	#200	**94.7**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	



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PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A5**
SAMPLE NO/ DEPTH	**A5-1 (-5.0' - 6.5' Depth)**
DESCRIPTION:	**Sandy Silt**
DATE TESTED:	**08/24/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

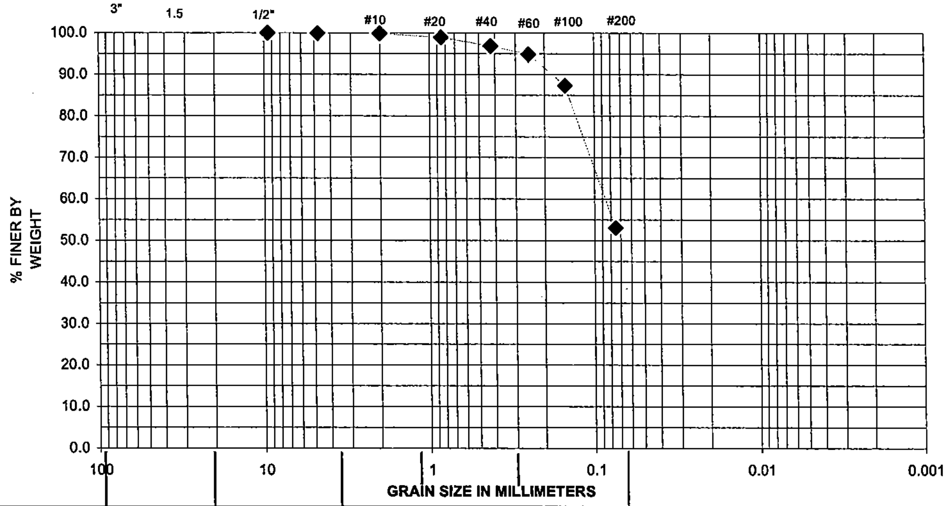
% GRAVEL: **0.0**
% SAND: **46.9**
% SILT/CLAY: **53.1**

USC: **ML**
FC:
.02 mm:

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**24.7**

PARTICLE SIZE ANALYSIS

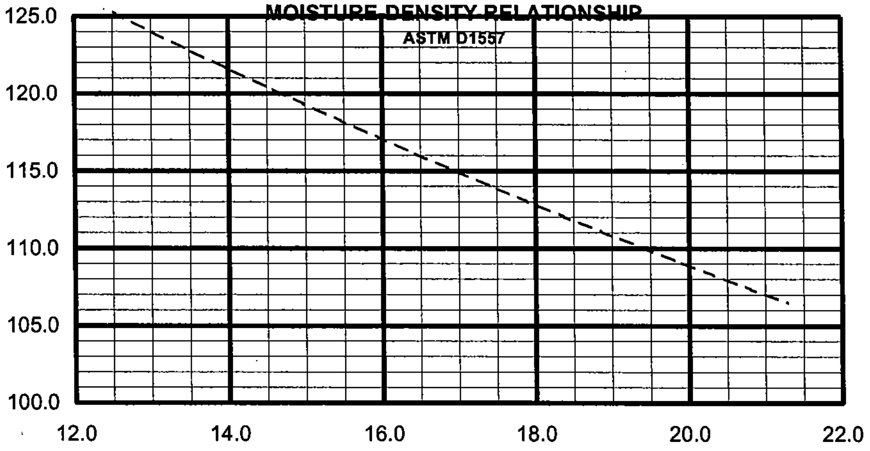
ASTM D422/ C136



COBBLES	GRAVEL		SAND			SILT or CLAY
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"	**100**	
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**99**	
0.425	#40	**97**	
0.25	# 60	**95**	
0.015	#100	**87**	
0.075	#200	**53.1**	



HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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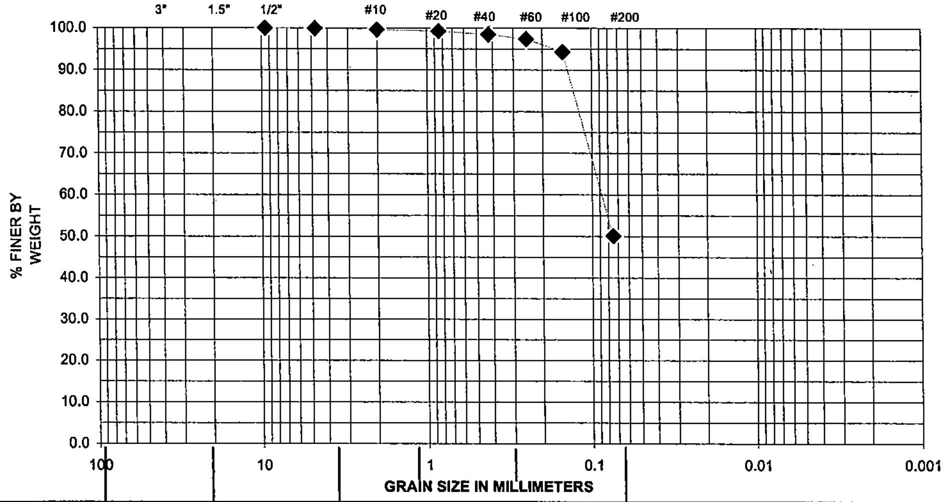
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A5**
SAMPLE NO/ DEPTH	**A5-2 (-10.0' - 11.5' Depth)**
DESCRIPTION:	**Sandy Silt**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.1**	USC:	**ML**
% SAND:	**49.8**	FC:	
% SILT/CLAY:	**50.1**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**24.3**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



COBBLES	GRAVEL		SAND			SILT or CLAY
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

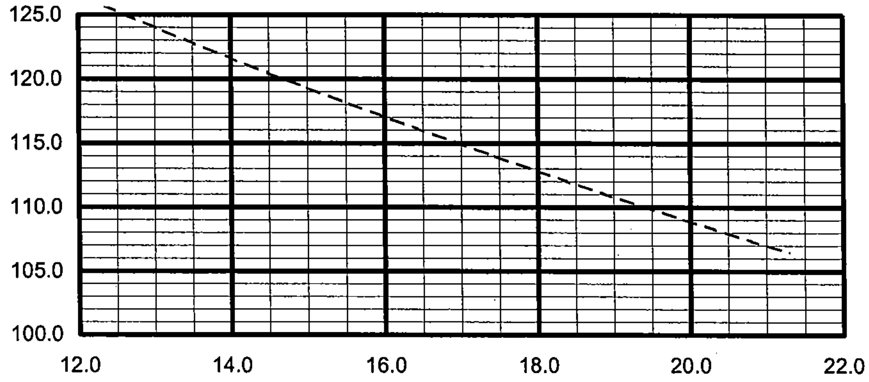
SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"	**100**	
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**99**	
0.425	#40	**98**	
0.25	# 60	**97**	
0.015	#100	**94**	
0.075	#200	**50.1**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

MOISTURE-DENSITY RELATIONSHIP

ASTM D1557



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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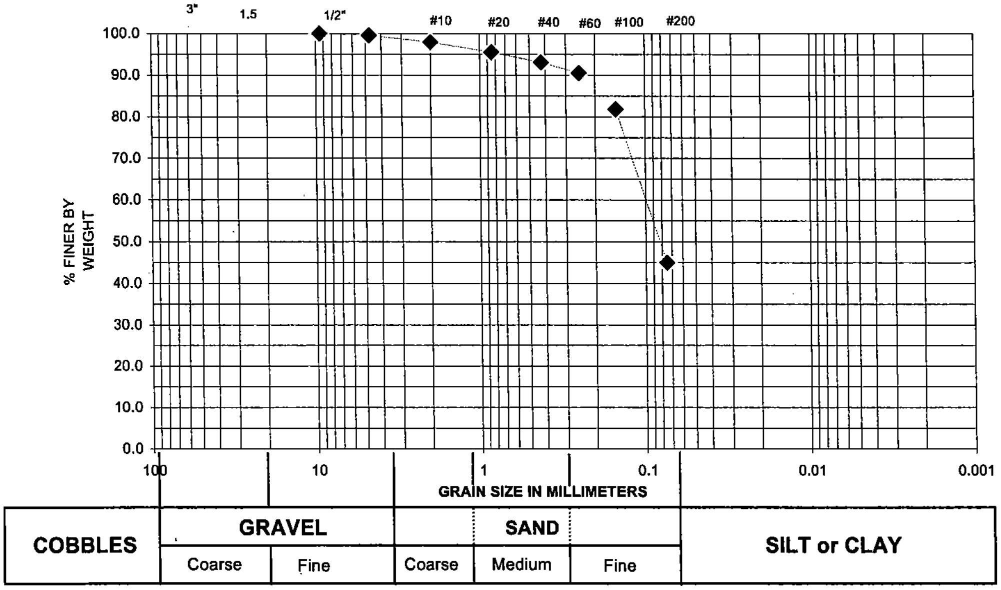
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A5**
SAMPLE NO/ DEPTH	**A5-3 (-15.0' - 16.5' Depth)**
DESCRIPTION:	**Silty sand.**
DATE TESTED:	**08/24/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.5**	USC:	**SM**
% SAND:	**54.5**	FC:	
% SILT/CLAY:	**45.0**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**27.8**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



SIEVE ANALYSIS RESULT

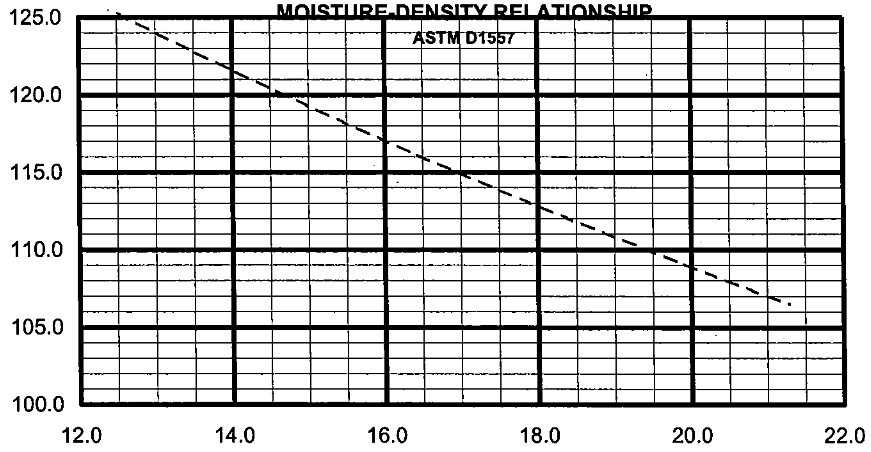
SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"	**100**	
4.75	# 4	**100**	
2	#10	**98**	
0.85	#20	**96**	
0.425	#40	**93**	
0.25	# 60	**91**	
0.015	#100	**82**	
0.075	#200	**45.0**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

MOISTURE-DENSITY RELATIONSHIP

ASTM D1557



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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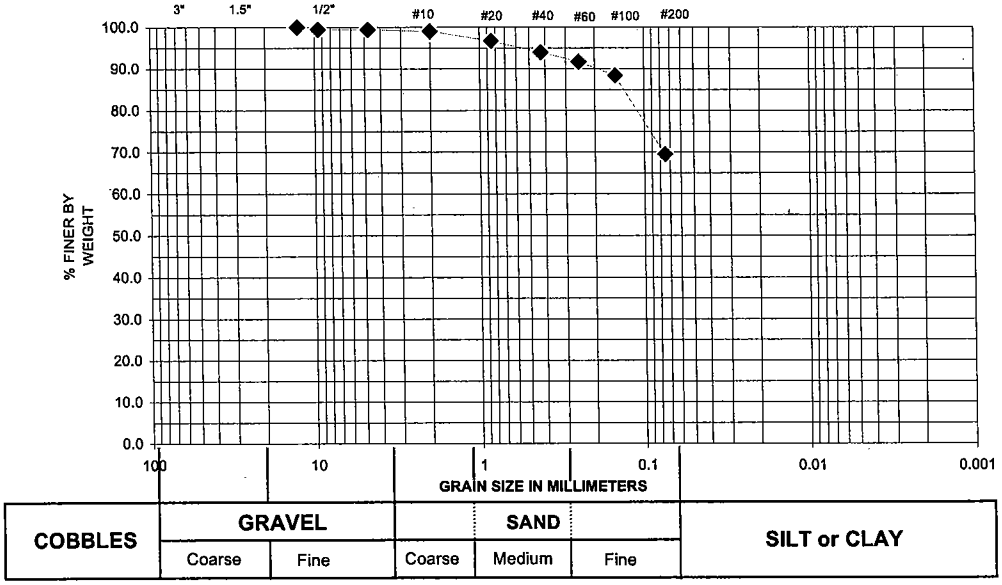
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A5**
SAMPLE NO/ DEPTH	**A5-4 (-20.0' - 21.5' Depth)**
DESCRIPTION:	**Sandy silt**
DATE TESTED:	**08/24/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.6**	USC:	**ML**
% SAND:	**29.9**	FC:	
% SILT/CLAY:	**69.5**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**29.3**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136

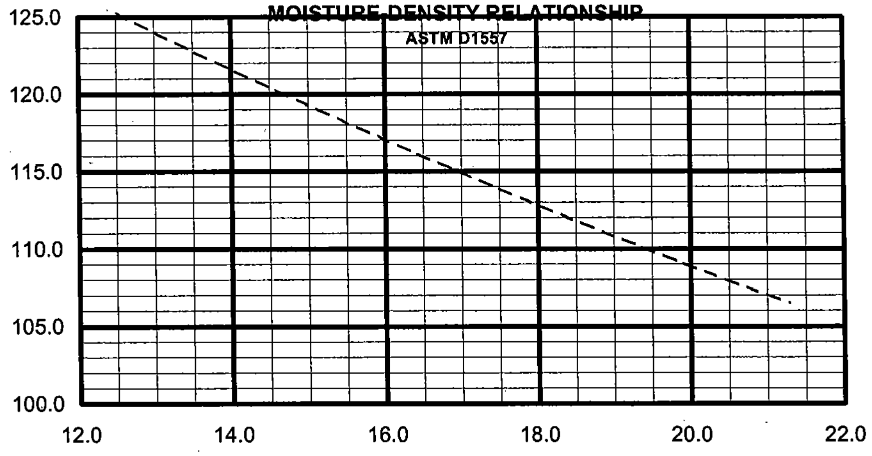


SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"	**100**	
9.5	3/8"	**99**	
4.75	# 4	**99**	
2	#10	**99**	
0.85	#20	**97**	
0.425	#40	**94**	
0.25	# 60	**92**	
0.015	#100	**88**	
0.075	#200	**69.5**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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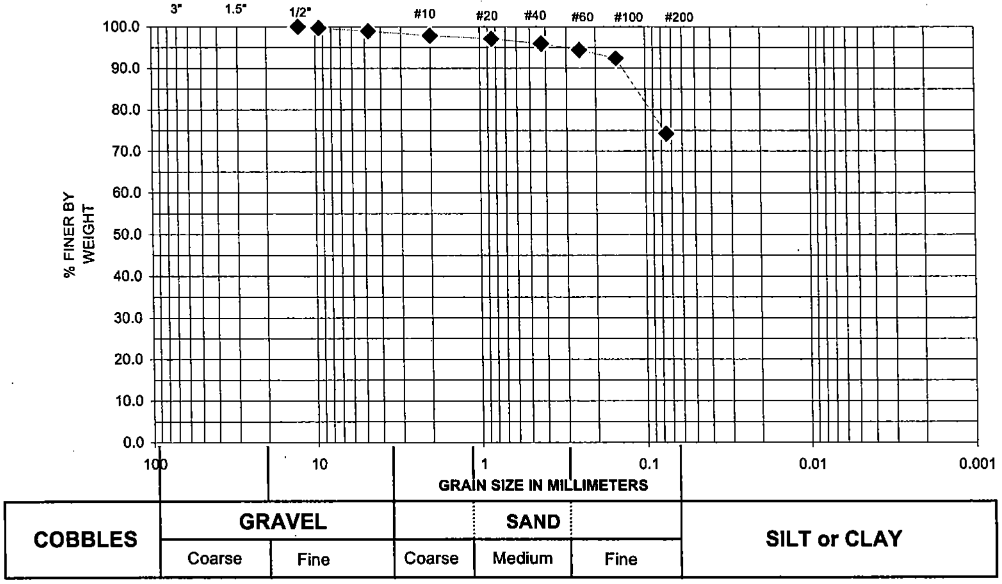
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A5**
SAMPLE NO/ DEPTH	**A5-5 (-25.0' - 26.5' Depth)**
DESCRIPTION:	**Silty sand.**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**1.0**	USC:	**SM**
% SAND:	**24.8**	FC:	
% SILT/CLAY:	**74.2**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**29.9**

PARTICLE SIZE ANALYSIS
ASTM D422/ C136



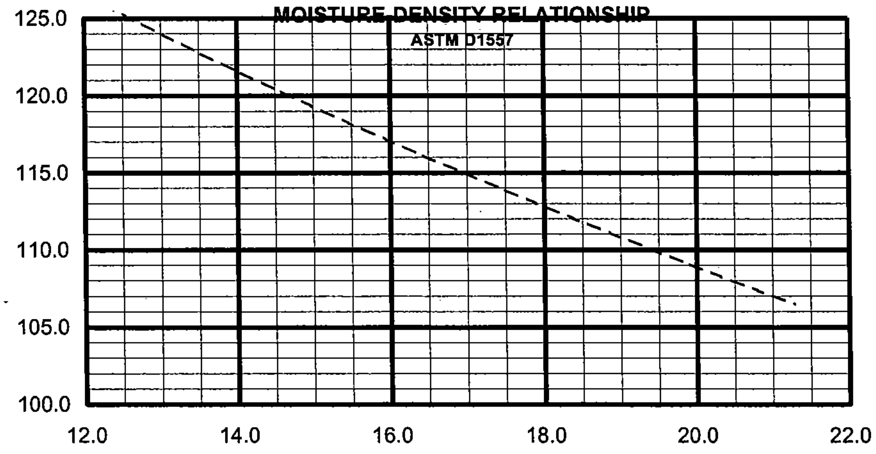
SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"	**100**	
9.5	3/8"	**100**	
4.75	# 4	**99**	
2	#10	**98**	
0.85	#20	**97**	
0.425	#40	**96**	
0.25	# 60	**94**	
0.015	#100	**92**	
0.075	#200	**74.2**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

MOISTURE DENSITY RELATIONSHIP
ASTM D1557



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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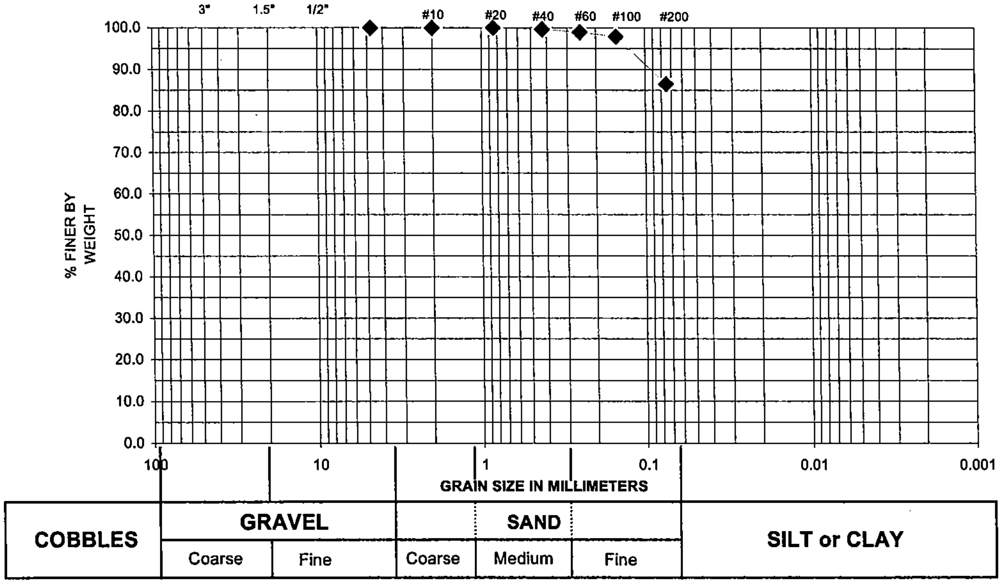
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A5**
SAMPLE NO/ DEPTH	**A5-6 (-30.0' - 31.5' Depth)**
DESCRIPTION:	**Silt**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.0**	USC:	**ML**
% SAND:	**13.5**	FC:	
% SILT/CLAY:	**86.5**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**27.6**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



SIEVE ANALYSIS RESULT

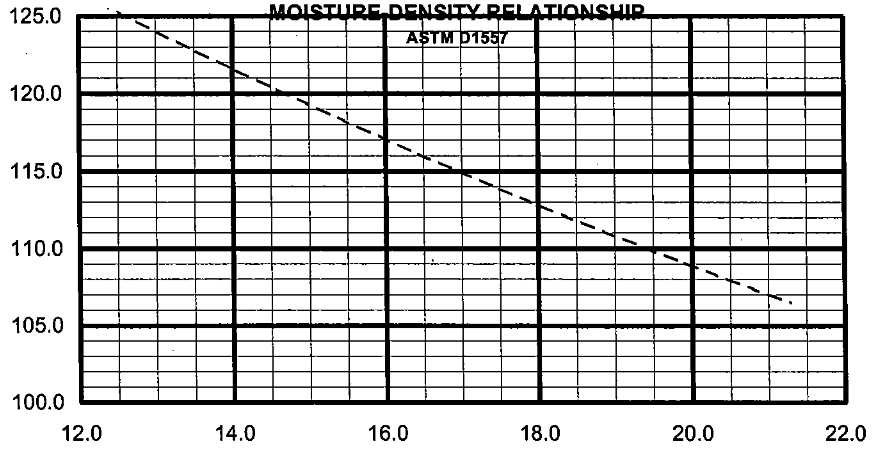
SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**100**	
0.425	#40	**100**	
0.25	# 60	**99**	
0.015	#100	**98**	
0.075	#200	**86.5**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

MOISTURE-DENSITY RELATIONSHIP

ASTM D1557



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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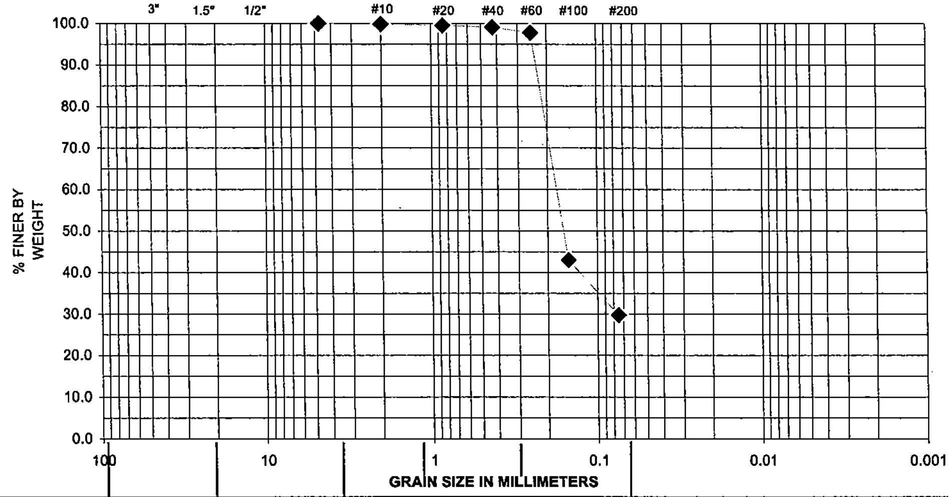
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Valdez Harbor Lab Testing**
PROJECT NO.:	**COE 1583**
SAMPLE LOCATION:	**TB5**
SAMPLE NO/ DEPTH	**TB5-5a (-5.0' - 6.5' Depth)**
DESCRIPTION:	**Silty sand.**
DATE TESTED:	**8/24/2004**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.0**	USC:	**SM**
% SAND:	**70.3**	FC:	
% SILT/CLAY:	**29.7**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**13.3**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



COBBLES	GRAVEL		SAND			SILT or CLAY
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

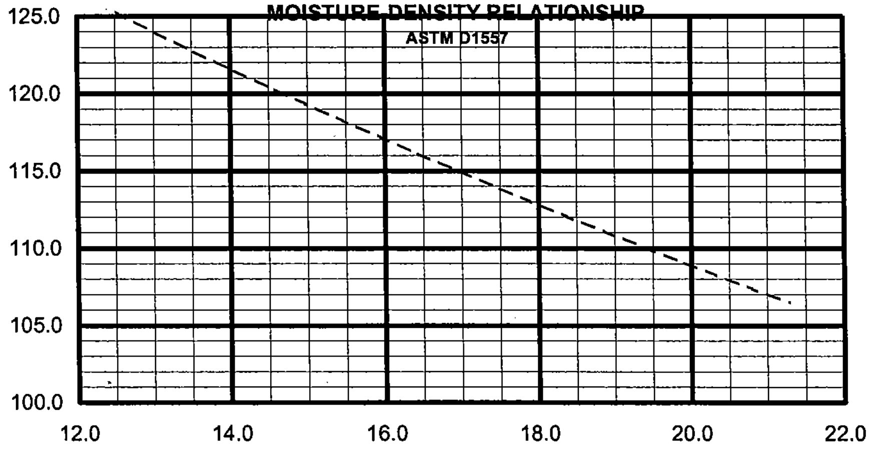
SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**100**	
0.425	#40	**99**	
0.25	# 60	**98**	
0.015	#100	**43**	
0.075	#200	**29.7**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

MOISTURE DENSITY RELATIONSHIP

ASTM D1557



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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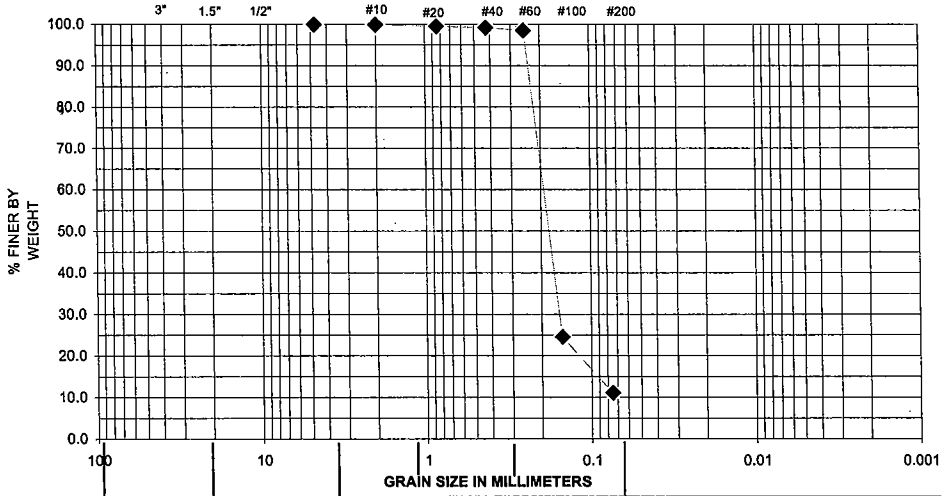
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Valdez Harbor Lab Testing**
PROJECT NO.:	**COE 1583**
SAMPLE LOCATION:	**TB5**
SAMPLE NO/ DEPTH	**TB5-S2 (-10.0' - 11.5' Depth)**
DESCRIPTION:	**Poorly grd. sand w/ silt.**
DATE TESTED:	**8/24/2004**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.0**	USC:	**SP-SM**
% SAND:	**88.9**	FC:	
% SILT/CLAY:	**11.1**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**20.3**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



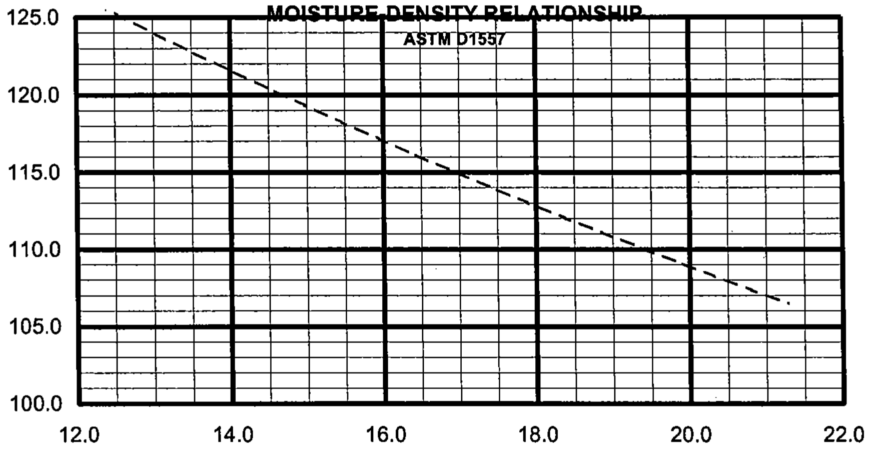
COBBLES	GRAVEL		SAND			SILT or CLAY
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**99**	
0.425	#40	**99**	
0.25	# 60	**99**	
0.015	#100	**25**	
0.075	#200	**11.1**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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TERRA FIRMA INC.

Laboratory Testing / Construction Monitoring

Telephone: (907) 344-5934
Fax: (907) 344-5993
terrafirma@alaska.com

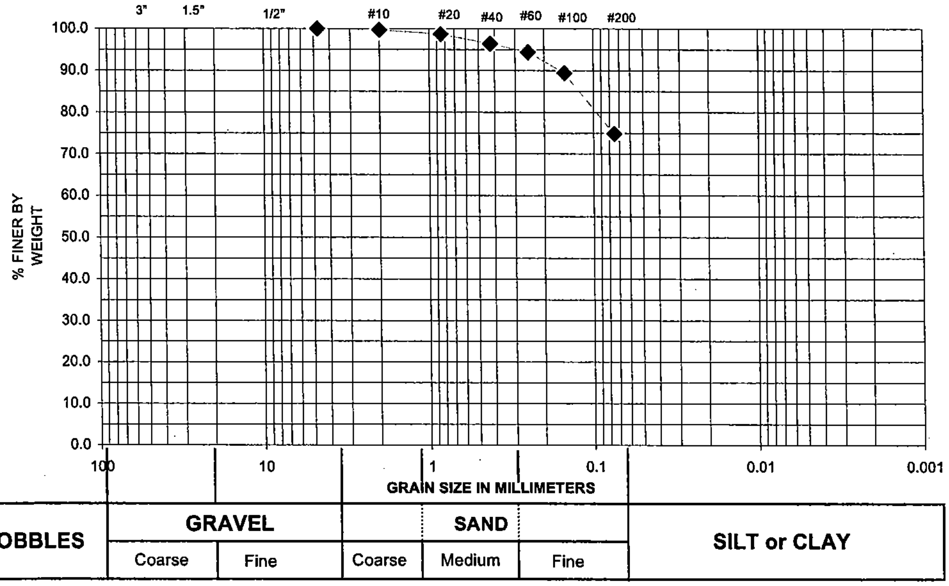
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A11**
SAMPLE NO/ DEPTH	**A11-1 (-5.0.0' - 6.5' Depth)**
DESCRIPTION:	**Silt w/ sand**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.0**	USC:	**ML**
% SAND:	**25.1**	FC:	
% SILT/CLAY:	**74.9**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**29.3**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



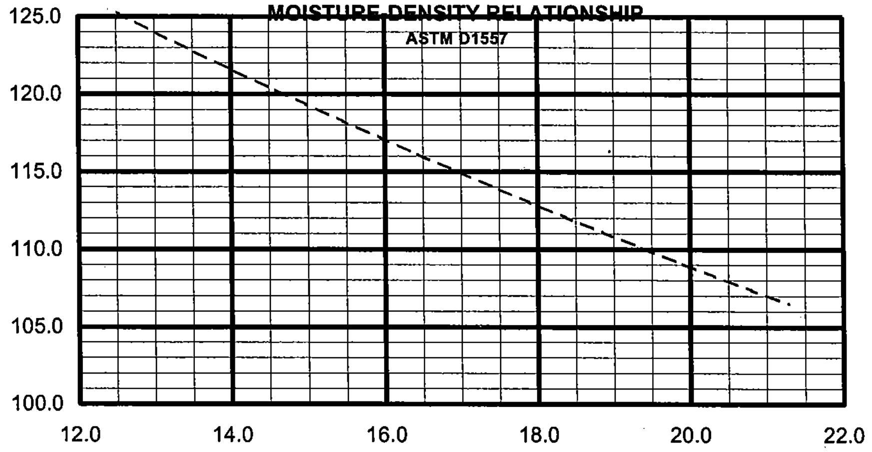
SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**99**	
0.425	#40	**96**	
0.25	# 60	**94**	
0.015	#100	**89**	
0.075	#200	**74.9**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	



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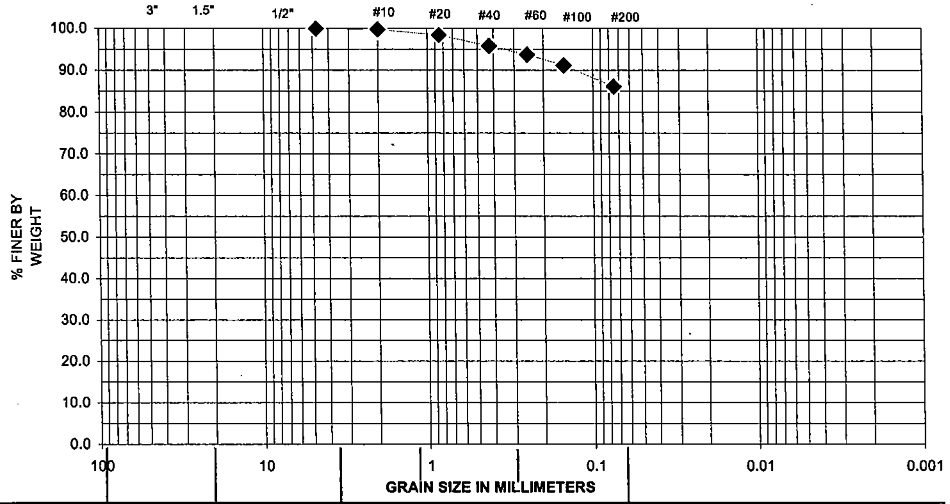
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A11**
SAMPLE NO/ DEPTH	**A11-2 (-10.0' - 11.5' Depth)**
DESCRIPTION:	**Silt**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.0**	USC:	**ML**
% SAND:	**13.9**	FC:	
% SILT/CLAY:	**86.1**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**36.5**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



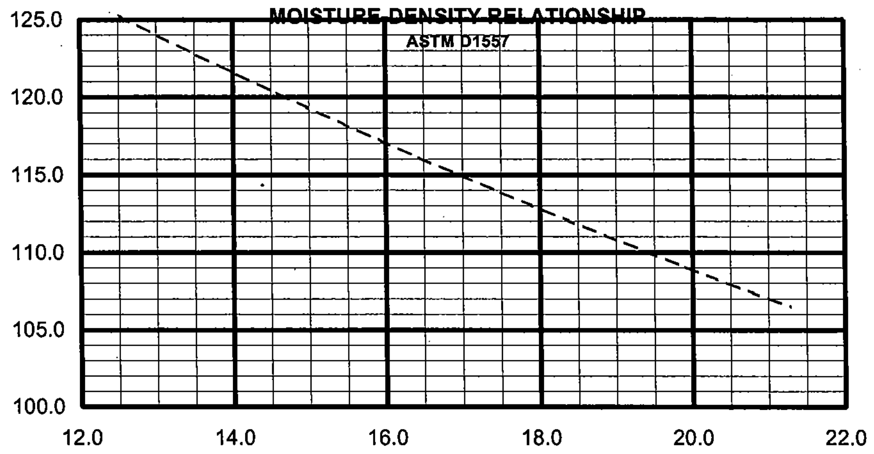
COBBLES	GRAVEL		SAND			SILT or CLAY
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**98**	
0.425	#40	**96**	
0.25	# 60	**94**	
0.015	#100	**91**	
0.075	#200	**86.1**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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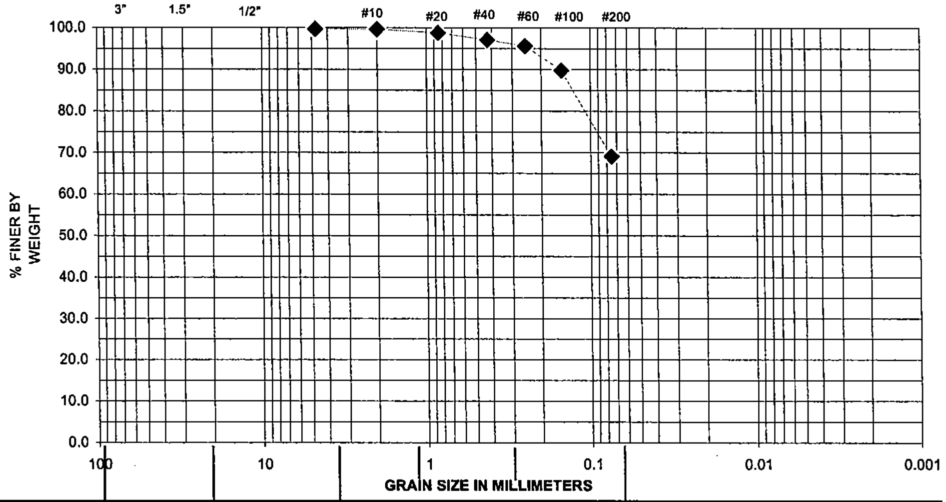
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A11**
SAMPLE NO/ DEPTH	**A11-3 (-15.0.0' -16.5' Depth)**
DESCRIPTION:	**Sandy silt**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL: **0.3** USC: **ML**
% SAND: **30.6** FC:
% SILT/CLAY: **69.1** .02 mm:

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**26.5**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



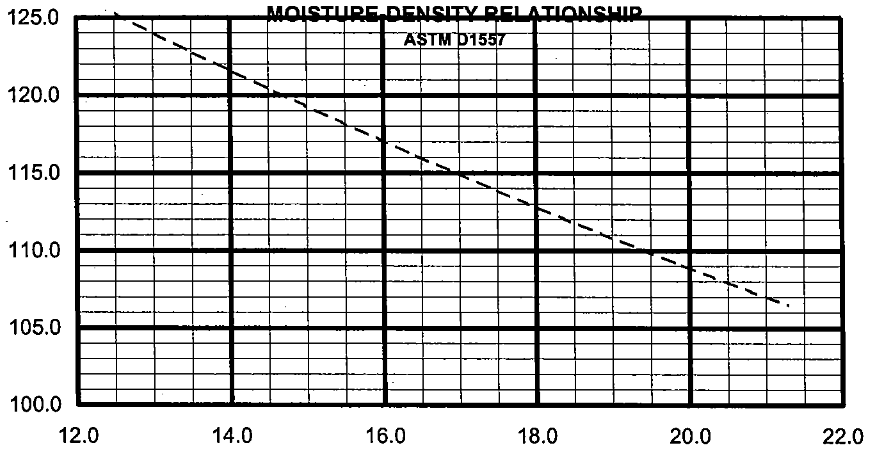
COBBLES	GRAVEL		SAND			SILT or CLAY
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**99**	
0.425	#40	**97**	
0.25	# 60	**96**	
0.015	#100	**90**	
0.075	#200	**69.1**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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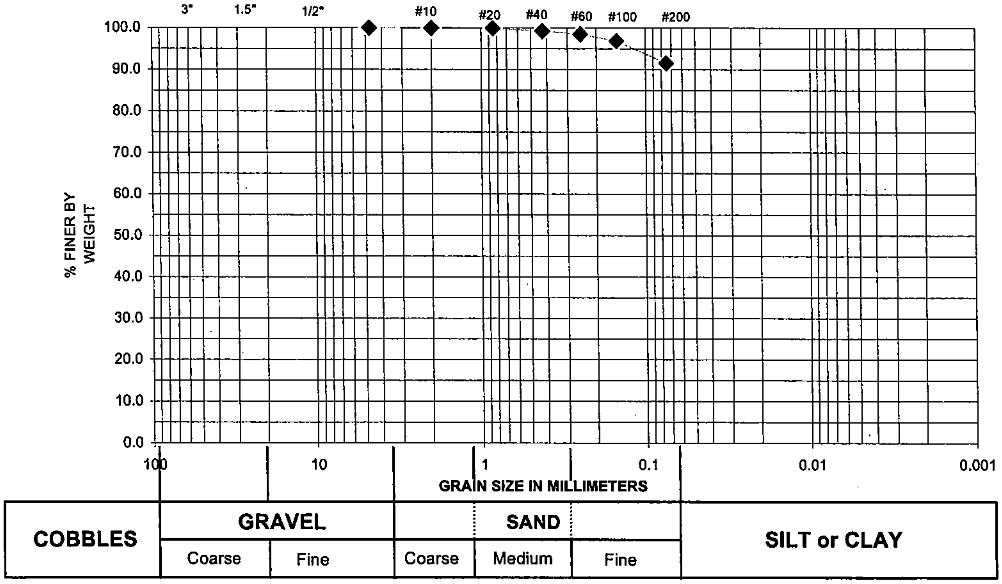
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A11**
SAMPLE NO/ DEPTH	**A11-4 (-20.0.0' -21.5' Depth)**
DESCRIPTION:	**Silt**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.0**	USC:	**ML**
% SAND:	**8.5**	FC:	
% SILT/CLAY:	**91.5**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**32.5**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136

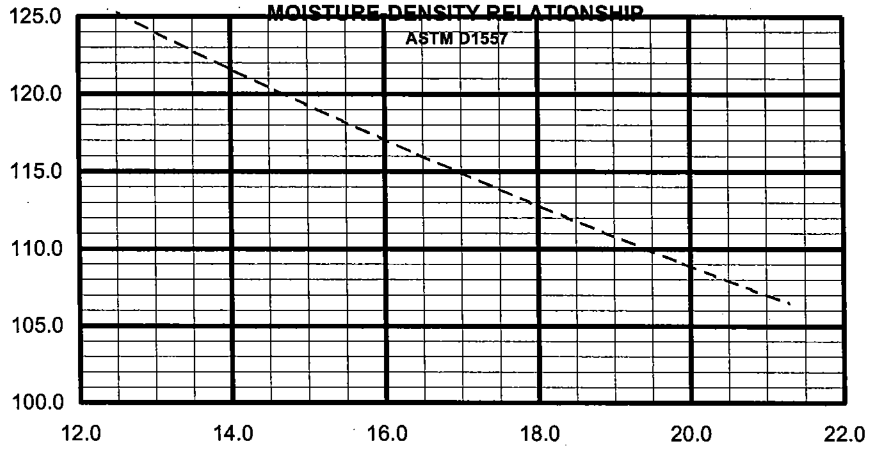


SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**100**	
0.425	#40	**99**	
0.25	# 60	**99**	
0.015	#100	**97**	
0.075	#200	**91.5**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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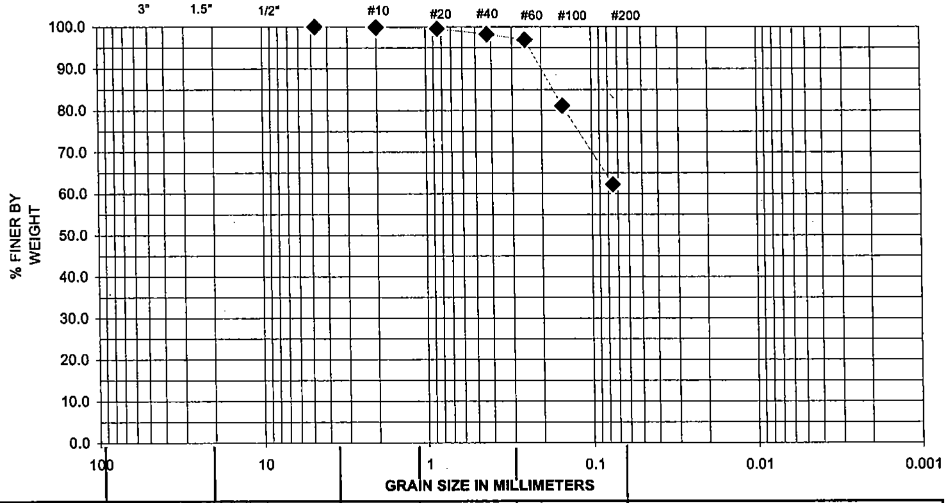
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A11**
SAMPLE NO/ DEPTH	**A11-5 (-25.0.0' -26.5' Depth)**
DESCRIPTION:	**Sandy silt**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL: **0.0** USC: **ML**
% SAND: **37.7** FC:
% SILT/CLAY: **62.3** .02 mm:

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**19.7**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



COBBLES	GRAVEL		SAND			SILT or CLAY
	Coarse	Fine	Coarse	Medium	Fine	

SIEVE ANALYSIS RESULT

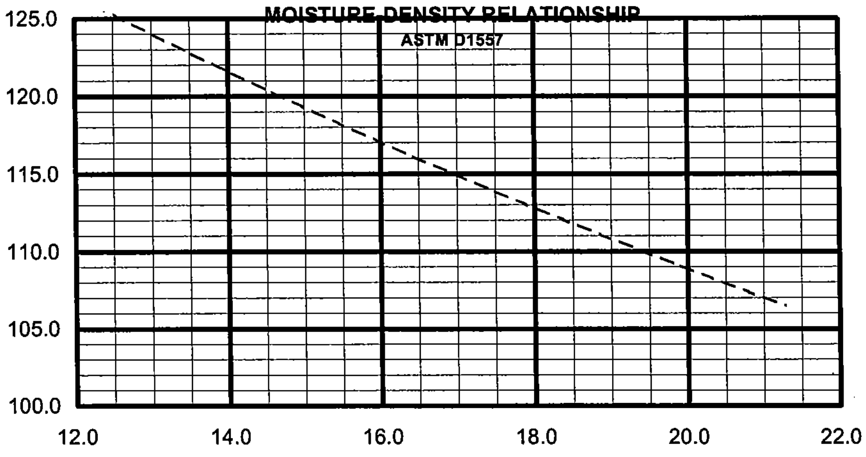
SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**100**	
0.425	#40	**98**	
0.25	# 60	**97**	
0.015	#100	**81**	
0.075	#200	**62.3**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

MOISTURE DENSITY RELATIONSHIP

ASTM D1557



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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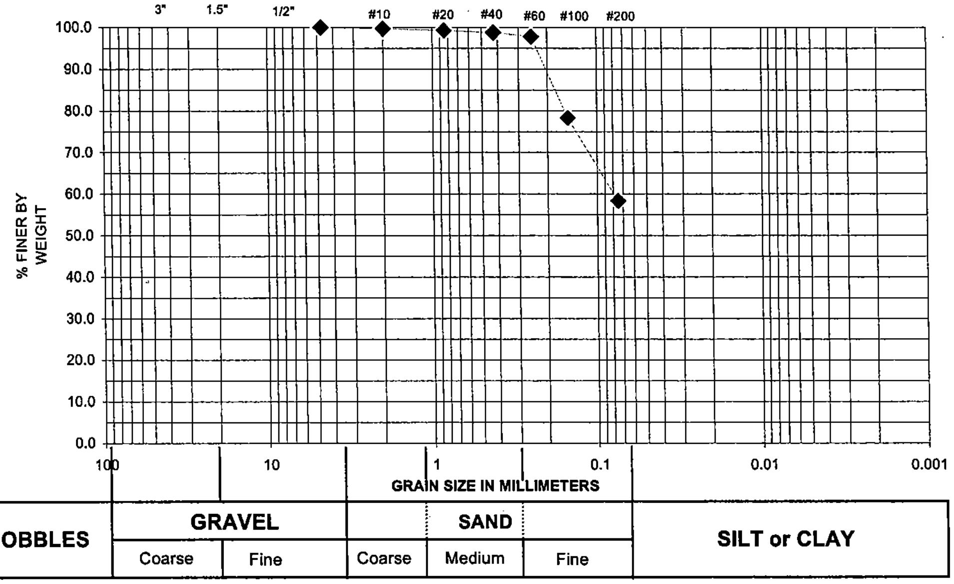
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A11**
SAMPLE NO/ DEPTH	**A11-6 (-30.0' -31.5' Depth)**
DESCRIPTION:	**Sandy silt**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL: **0.0** USC: **ML**
% SAND: **41.7** FC:
% SILT/CLAY: **58.3** .02 mm:

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**25.3**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136

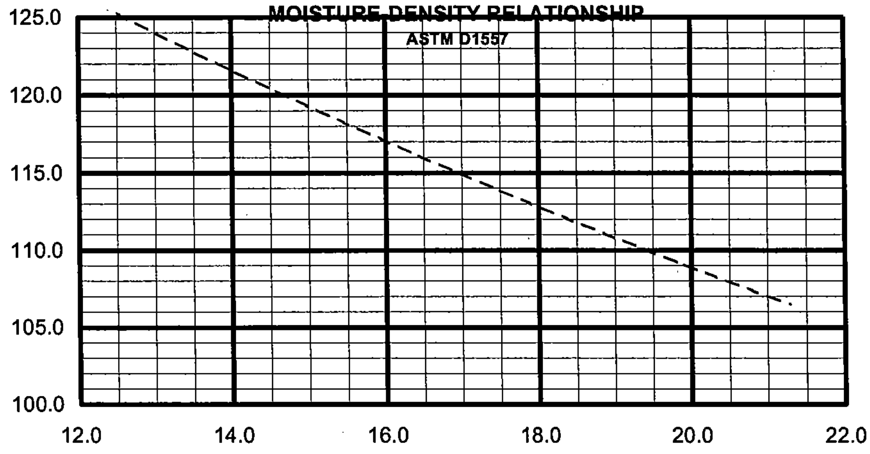


SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**99**	
0.425	#40	**99**	
0.25	# 60	**98**	
0.015	#100	**78**	
0.075	#200	**58.3**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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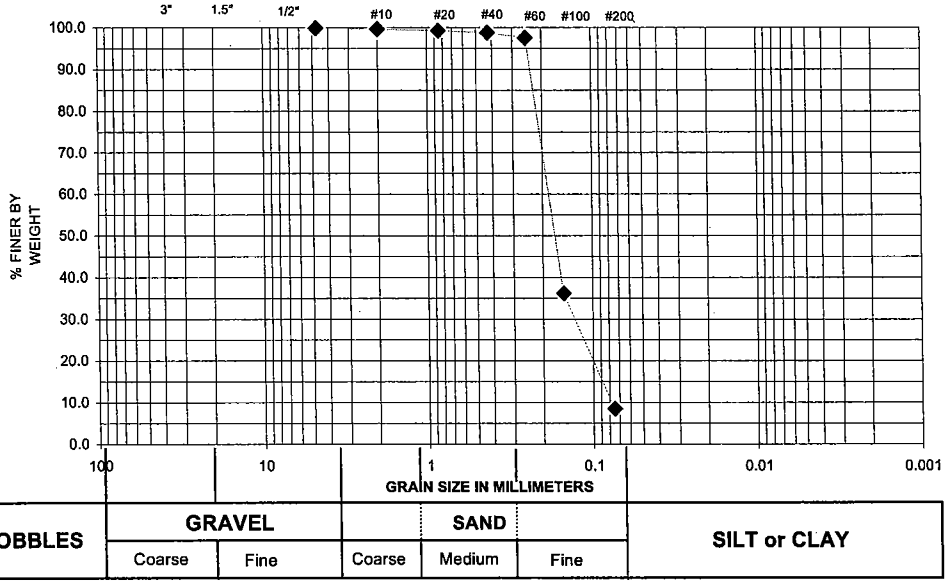
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1549**
SAMPLE LOCATION:	**A11**
SAMPLE NO/ DEPTH	**A11-7 (-31.5' -33.0' Depth)**
DESCRIPTION:	**Poorly grd. sand w/ silt.**
DATE TESTED:	**08/28/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.1**	USC:	**SP-SM**
% SAND:	**91.5**	FC:	
% SILT/CLAY:	**8.4**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**19.2**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136



SIEVE ANALYSIS RESULT

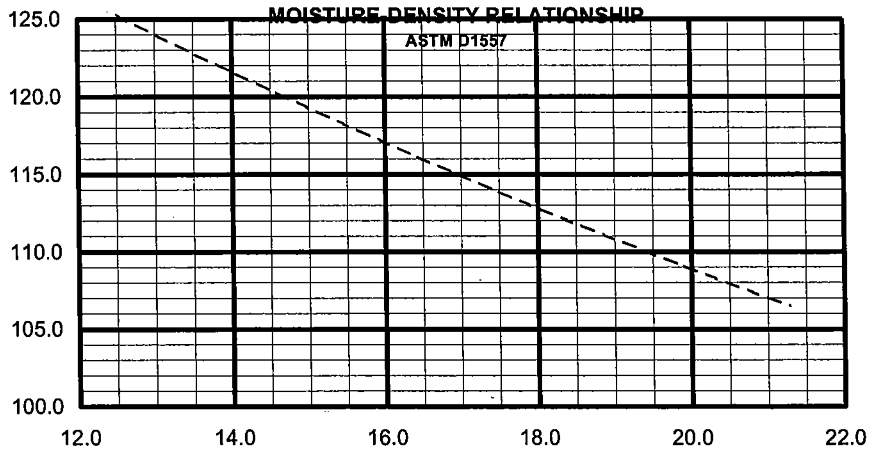
SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**99**	
0.425	#40	**99**	
0.25	# 60	**98**	
0.015	#100	**36**	
0.075	#200	**8.4**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		

MOISTURE-DENSITY RELATIONSHIP

ASTM D1557



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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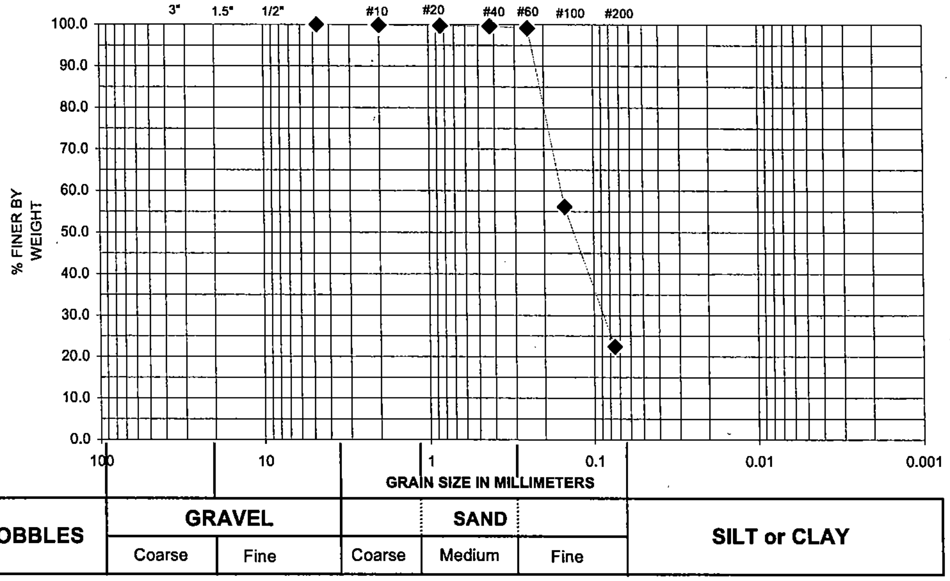
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A1**
SAMPLE NO/ DEPTH	**A1-1 (-7.0' - 8.5' Depth)**
DESCRIPTION:	**Silty sand.**
DATE TESTED:	**8/24/2004**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.0**	USC:	**SM**
% SAND:	**77.6**	FC:	
% SILT/CLAY:	**22.4**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**20.9**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136

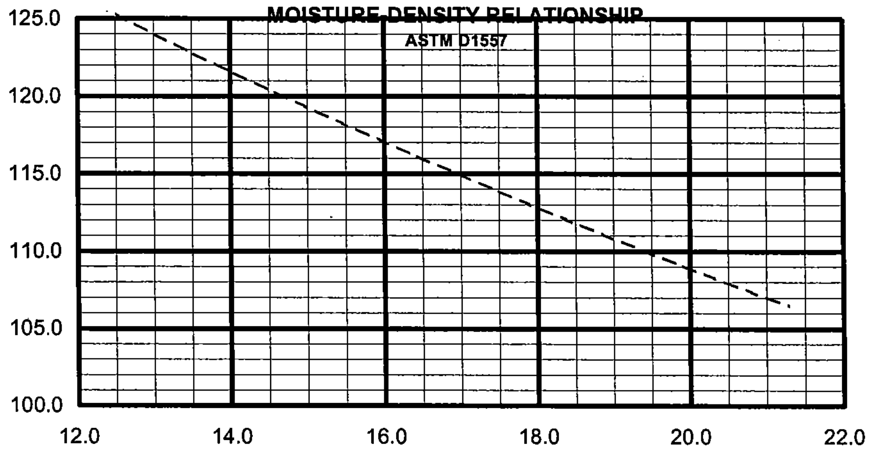


SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**100**	
0.425	#40	**100**	
0.25	# 60	**99**	
0.015	#100	**56**	
0.075	#200	**22.4**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

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terrafirma@alaska.com

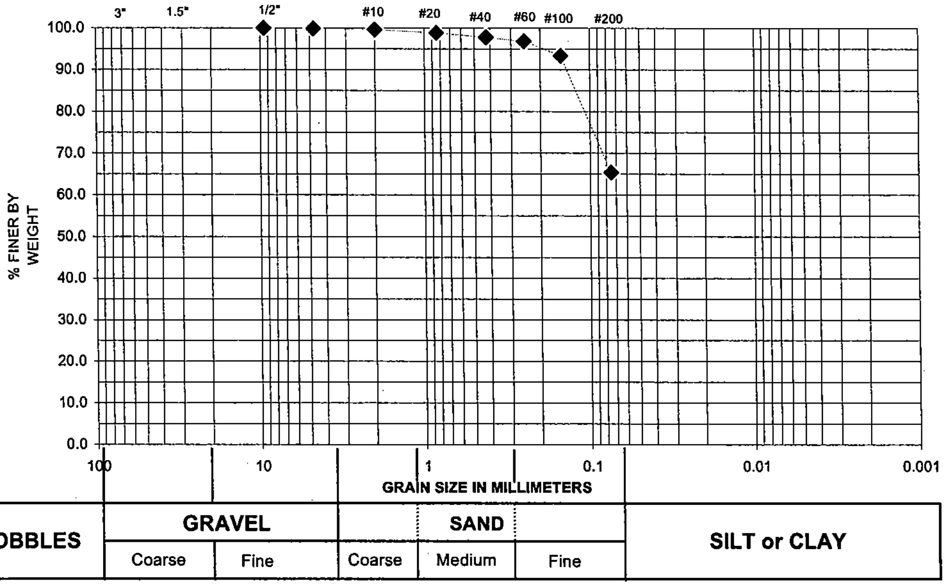
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**CPE 1594**
SAMPLE LOCATION:	**A1**
SAMPLE NO/ DEPTH	**A1-2 (-12.0' - 13.5' Depth)**
DESCRIPTION:	**Sandy Silt**
DATE TESTED:	**8/24/2004**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.1**	USC:	**M:**
% SAND:	**34.5**	FC:	
% SILT/CLAY:	**65.4**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**19.6**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136

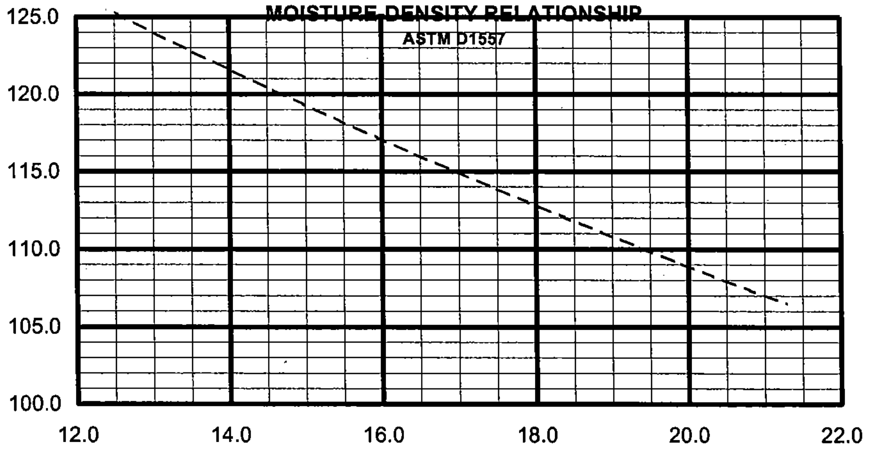


SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"	**100**	
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**99**	
0.425	#40	**98**	
0.25	# 60	**97**	
0.015	#100	**93**	
0.075	#200	**65.4**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

The testing services reported herein have been performed to recognized industry standards, unless otherwise noted. No other warranty is made. Should engineering interpretation or opinion be required, TFI will provide upon written request.

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Telephone: (907) 344-5934
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terrafirma@alaska.com

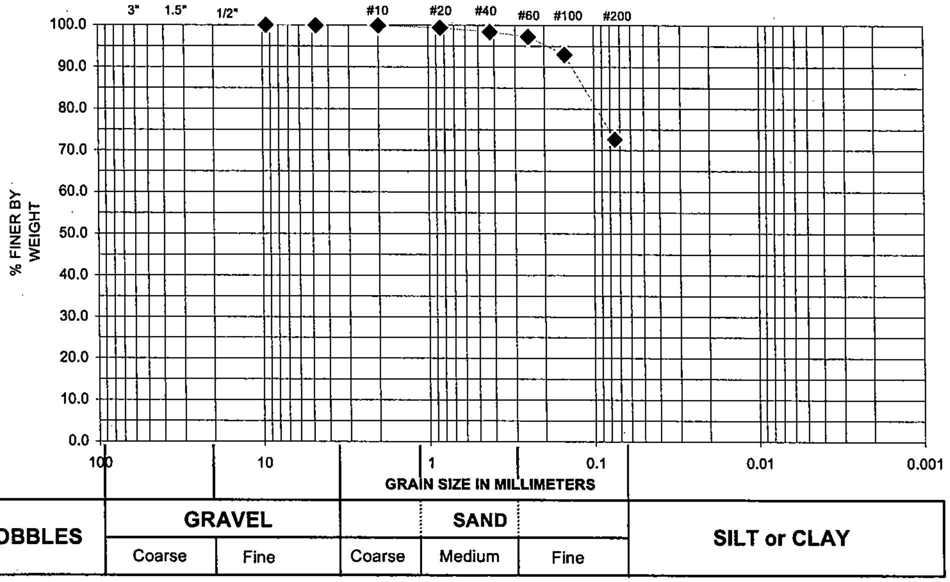
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A1**
SAMPLE NO/ DEPTH	**A1-3 (-17.0' - 18.5' Depth)**
DESCRIPTION:	**Silt w/ sand**
DATE TESTED:	**8/24/2004**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL:	**0.0**	USC:	**ML**
% SAND:	**27.3**	FC:	
% SILT/CLAY:	**72.7**	.02 mm:	

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**20.5**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136

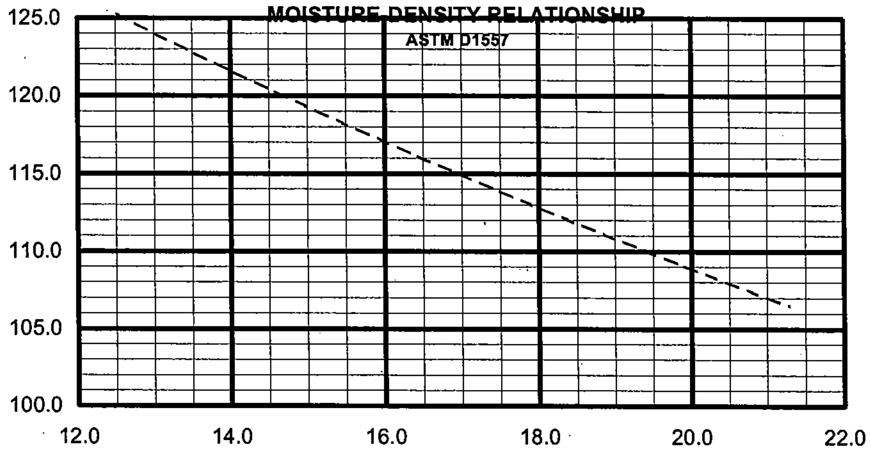


SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"	**100**	
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**99**	
0.425	#40	**98**	
0.25	# 60	**97**	
0.015	#100	**93**	
0.075	#200	**72.7**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	

801 East 82nd Avenue, #A-9
Anchorage, AK 99518

TERRA FIRMA INC.

Laboratory Testing / Construction Monitoring

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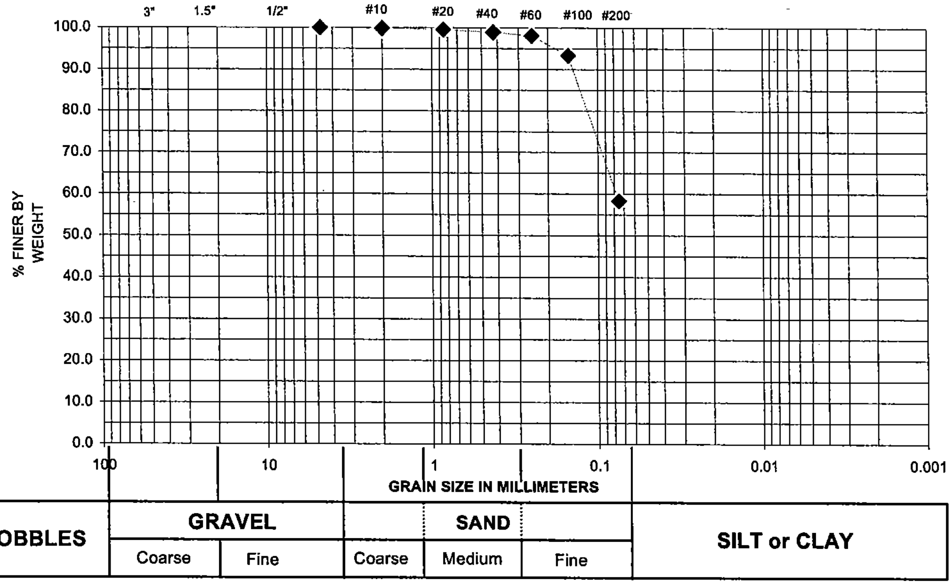
PROJECT CLIENT:	**COE - Alaska District**
PROJECT NAME:	**Barrow Storm Damage Reduction**
PROJECT NO.:	**COE 1594**
SAMPLE LOCATION:	**A1**
SAMPLE NO/ DEPTH	**A1-4 (-22.0' - 23.5' Depth)**
DESCRIPTION:	**Sandy Silt**
DATE TESTED:	**08/24/04**
TESTED BY:	**D.P.**
REVIEWED BY:	**Ron Caron C.E.T. / T. Selmer**

% GRAVEL: **0.0**
% SAND: **41.7**
% SILT/CLAY: **58.3**
USC: **ML**
FC:
.02 mm:

ASTM D1557(uncorrected)	pcf
ASTM D4718 (corrected)	pcf
OPTIMUM M.C.% (corrected)	
NATURAL M.C. %	**17.9**

PARTICLE SIZE ANALYSIS

ASTM D422/ C136

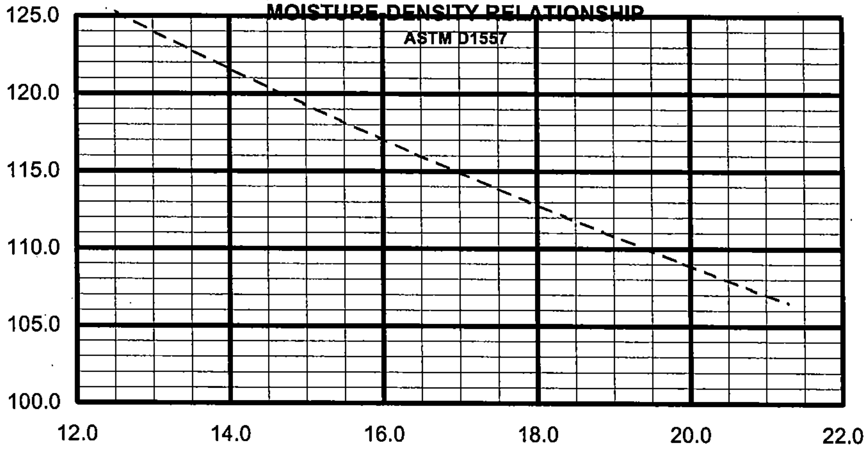


SIEVE ANALYSIS RESULT

SIEVE SIZE (mm)	SIEVE SIZE (in.)	TOTAL % PASSING	SPEC
152.4	6"		
76.2	3"		
38.1	1.5"		
19.05	3/4"		
12.7	1/2"		
9.5	3/8"		
4.75	# 4	**100**	
2	#10	**100**	
0.85	#20	**100**	
0.425	#40	**99**	
0.25	# 60	**98**	
0.015	#100	**93**	
0.075	#200	**58.3**	

HYDROMETER RESULT

ELAPSED TIME	DIAMETER (mm)	TOTAL % PASSING
0		
0.5		
1		
2		
4		
8		
15		
30		
60		
250		
1440		



Perm. (ASTM D2438)	
Degradation (ATM T-13)	
Atterberg Limit ASTM 4318	