US Army Corps of Engineers
Alaska District

Draft Feasibility Report

Barrow Alaska Coastal Erosion
Barrow, Alaska

September 6, 2018

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Prepared by
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EXECUTIVE SUMMARY

Barrow is the political and economic hub of the North Slope Borough (NSB), providing important services to the communities in Northern Alaska. This report examines the need for a coastal storm risk management study at Barrow, Alaska addressing coastal erosion and flooding to determine the feasibility of Federal participation in a potential project. This study utilizes Alaska Coastal Erosion Federal funds which determined the study title.

Barrow experiences frequent and severe coastal storms, resulting in flooding and erosion that threaten public health and safety, the economy of the community, over $1 billion of critical infrastructure, access to subsistence areas, and cultural and historical resources. This threat to life-sustaining infrastructure is crucial to the preservation of the community. Barrow is an arctic environment with approximately 300 days a year below freezing. 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.

This coastal storm risk management study evaluated a number of alternatives based on economic, engineering, environmental, and other factors. The Tentatively Selected Plan (TSP), which would protect approximately 5 miles of coastline, includes a combination of rock revetment at the bluff area, armored berm, and both armoring and raising Stevenson Street. The TSP maximizes the net National Economic Development (NED) benefits and would reduce erosion along the bluffs in front of the Barrow neighborhood and reduce flooding due to wave run-up during storm events.

The coastline would be altered to some degree with the TSP. Sacrificial berms will no longer be necessary to protect infrastructure and the community. There will be boat ramps and access points along the revetments to allow for boating and beach access for subsistence, recreational and social activities. In addition, interior drainage points are being considered throughout the proposed project. The U.S. Army Corps of Engineers (Corps) is working with the non-Federal Sponsor and community to collect feedback on optimal locations for access points, boat ramps and interior drainage points. This design will be finalized in subsequent phases of this project. The non-Federal Sponsor (NSB) supports this recommended plan.

The TSP has a construction cost of $193 million (M) and an annual operations and maintenance (O&M) cost of $670,000. NED benefits are $1.5M and the benefits to cost ratio is 0.18 for the preferred plan. This study is being conducted under Section 116 Authority, which affords this study the ability to select a plan based on Other Social Effects, with selection supported by a Cost Effective/Incremental Cost Analysis (CE/ICA). This analysis resulted in community resilience units (CRUs) based on feedback from the community and current knowledge. The output from this analysis determined the best buy plan to be the TSP.

The NSB would be required to pay the non-Federal share of 35 percent of the costs assigned to the coastal storm risk management features of the study as specified by the Section 116 Authority, as amended. The estimated non-Federal share of construction is approximately

$125.5M and the Federal share of construction is approximately $67.5M. Actual cost break-out, including considerations for land, easements, rights-of-way, relocation, and disposal (LERRD), will be calculated during the preconstruction engineering and design (PED) phase.

PERTINENT DATA

Alternative 2

2a. Rock Revetment at bluff and Berm in front of Stevenson St. * all volumes are based on idealized cross-sections and are subject to change once LiDAR is collected and new storm surge calculations are performed												
Armored Revetment Coverage Area	**Type of Protection**	**Armor [cy]**	**B Rock [cy]**	**Core [cy]**	**Gravel [cy]**	**Filter Fabric [sy]**	**Excavation [cy]**	**Local Material [cy]**	**Maintenance Interval / Length**	**Maintenance Armor [cy]**	**Maintenance B Rock [cy]**	**Maintenance Core [cy]**
Bluffs: Revetment	Armor sized for waves	25,800	23,200	8,000	8,700	26,900	19,700	21,900	5 yrs/2000 ft	8,700	7,900	3,500
Low Lying Areas: Revetted Berm	Armor sized for waves	111,300	108,900	35,600	43,400	135,700	191,800	NA	5 yrs/2000 ft	8,700	7,900	3,500
2b. Rock Revetment at bluff and Raise Stevenson St. * all volumes are based on idealized cross-sections and are subject to change once LiDAR is collected and new storm surge calculations are performed												
Armored Revetment Coverage Area	**Type of Protection**	**Armor [cy]**	**B Rock [cy]**	**Core [cy]**	**Gravel [cy]**	**Filter Fabric [sy]**	**Excavation [cy]**	**Local Material [cy]**	**Maintenance Interval / Length**	**Maintenance Armor [cy]**	**Maintenance B Rock [cy]**	**Maintenance Core [cy]**
Bluffs: Revetment	Armor sized for waves	25,800	23,200	8,000	8,700	26,900	19,700	21,900	5 yrs/2000 ft	8,700	7,900	3,500
Low Lying Areas: Raise Stevenson St.	Armor sized for waves	90,500	113,100	41,500	45,600	142,900	129,100	174,600	5 yrs/2000 ft	8,700	7,900	3,500

Economics			
Item	**Federal ($)**	**Non-Federal ($)**	**Total ($)**
Total Annual NED Cost	$5,541,250	$2,983,750	$8,525,000
Total Annual NED Benefit	$974,683	$524,830	$1,499,513
Net Annual NED Benefits	$26,313,693	$14,168,911	$40,482,605
Benefit/Cost Ratio	~	~	0.18

Total Project Costs			
Item	**Federal ($)**	**Non-Federal ($)**	**Total ($)**
Alternative 1	n/a	n/a	n/a
Alternative 2A	$124,306,650.00	$66,934,350	$191,241,000
Alternative 2B	$125,313,500.00	$67,476,500	$192,790,000
Alternative 5A	$60,165,950.00	$32,397,050	$92,563,000
Alternative 5B	$95,406,350.00	$51,372,650	$146,779,000
Alternative 5C	$121,117,100.00	$65,216,900	$186,334,000
Alternative 5D	$168,288,250.00	$90,616,750	$258,905,000
Alternative 6A	$167,087,700.00	$89,970,300	$257,058,000
Alternative 6B	$225,259,450.00	$121,293,550	$346,553,000
Alternative 6C	$285,267,450.00	$153,605,550	$438,873,000

Annual Project Costs			
Item	**Federal ($)**	**Non-Federal ($)**	**Total ($)**
Annual Maintenance and Operations Costs	$435,500	$324,500	$ 670,000

Community Resilience Units (CRUs)		
Alt	**CRUs**	**Average Annual CRUs**
1	0	0.00
2a	2,925	58.50
2b	2,925	58.50
5a	1,038	20.77
5b	1,588	31.77
5c	1,720	34.41
5d	2,862	57.24
6a	2,935	58.71
6b	2,862	57.24
6c	2,856	57.12

LIST OF ACRONYMS AND ABBREVIATIONS

ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
ADM	Agency Decision Milestone
AHRS	Alaska Heritage Resources Survey
AMM	Alternatives Milestone Meeting
APE	Area of Potential Effect
BCR	Benefit to Cost Ratio
BUECI	Barrow Utilities and Electric Cooperative, Inc.
CE/ICA	Cost Effective/Incremental Cost Analysis
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COL	Colonel
Corps or USACE	U.S. Army Corps of Engineers
CRA	Cultural Resource Acres OR Areas at Risk
CRU	Community Resilience Unit
CY	Cubic Yards
CYF	Cubic Yards Contaminated Fill
DDD	Direct Dollar Damage
EA	Environmental Assessment
EAD	Expected OR Estimated Annual Damage
EQ	Environmental Quality
ER	Engineer Regulation
FCSA	Feasibility Cost Sharing Agreement
FONSI	Finding of No Significant Impact
FR/EA	Feasibility Report and Environmental Assessment
ft	Feet/Foot
FTE	Full Time Equivalent Jobs Impact
FWOP	Future without-Project
FWP	Future with-Project
H&H	Hydraulics and Hydrology
HTRW	Hazardous, Toxic, and Radioactive Wastes
IDC	Interest During Construction
IWR	Institute for Water Resources
LERRD	Lands, Easements, Real Estate, and Rights-Of-Way
LiDAR	Light Detection and Ranging
M	Million
MLLW	Mean Lower Low Water
MSC	Major Subordinate Command
N/A	Not Applicable
NARL	Navy Arctic Research Lab

NED	National Economic Development
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NSB	North Slope Borough
NWS	National Weather Service
O&M	Operations and Maintenance
OMRR&R	Operation, Maintenance, Repair, Replacement, and Rehabilitation
OSE	Other Social Effects
PDH	Person-Days High Risk Job Activity
PDU	Person-Days without Critical Utilities
PED	Preconstruction Engineering and Design
PPA	Project Partnership Agreement
R	Republican
RED	Regional Economic Development
SHPO	State Historic Preservation Officer
TEK	Traditional Ecological Knowledge
TSP	Tentatively Selected Plan
U.S.	United States
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service

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1. INTRODUCTION

1.1 Project & Study Authority

This General Investigations study was conducted under authority granted by Section 116 of the Energy and Water Development and Related Agencies Appropriations Act of 2010 (P.L. 111-85), as amended (see Appendix A):

> *"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 implementation guidance for studies and projects under the Section 116 Authority notes that:

> *"Each decision document will present the National Economic Development (NED) analysis for all viable alternative and identify the NED Plan when alternatives exist with net positive NED benefits. If there is no NED Plan and/or the selection of a plan other than the NED Plan is based in part or whole on non-monetary units (Environmental Quality and/or Other Social Effects), then the selection will be supported by a cost effectiveness/incremental cost analysis consistent with established evaluation procedures" (Memorandum for Commander, Pacific Ocean Division, 10 May 2012).*

The guidance also notes that:
"the feasibility study will conform with the process for projects authorized without a report as discussed in ER 1105-2-100 (Appendix H) including the preparation of a Director's Report."

Upon signature of the Director's Report, the study is authorized to immediately move into Preconstruction, Engineering and Design (PED) and construction.

1.2 Problem Statement, Purpose & Need

The North Slope Borough (NSB) has been facing storm damage and erosion problems for decades. Traditionally, foundation materials for local infrastructure would be obtained from the beach or a gravel pit area, updrift (southwest) a mile from Barrow. The reduction of natural beach nourishment material, coupled with frequent storms and decreased ice cover has left the coastline vulnerable to flooding and erosion. The NSB currently engages in construction of temporary and sacrificial 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.

The problem statement is:
Barrow experiences frequent and severe coastal storms, resulting in flooding and erosion that threaten public health and safety, the economy of the community, over $1 billion of critical infrastructure, access to subsistence areas, and cultural and historical resources.

1.3 Scope of Study

Engineer Regulation (ER) 1105-2-100, "Planning Guidance Notebook" defines the contents of feasibility reports for coastal storm risk management. This Feasibility Report documents the studies and coordination conducted to determine whether the Federal Government should participate in coastal storm risk management at Barrow. Studies of potential coastal storm risk management considered a wide range of alternatives and the environmental consequences of those alternatives, but focused mainly on actions that would reduce erosion and flooding. Protecting Barrow from erosion and flooding caused by storm events is important for not only the community itself, but for surrounding communities as it is a regional hub for all communities on the North Slope of Alaska. Coastal storm risk management is a high priority mission for the United States (U.S.) Army Corps of Engineers (the Corps), and protecting the community of Barrow from erosion and flooding during storm events would generate sufficient benefits to allow the Corps to recommend a project under Section 116 of the Energy and Water Development and Related Agencies Appropriations Act of 2010 (P.L. 111-85), as amended.

The Alaska District, U.S. Army Corps of Engineers (the Corps) was primarily responsible for conducting studies for coastal storm risk management at Barrow. The studies that provide the basis for this report were conducted with the assistance of many individuals and agencies, including the NSB, the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), the U.S. Coast Guard (USCG), the State Department of Fish and Game (ADFG), the State of Alaska Department of Environmental Conservation (ADEC), and many members of the interested public who contributed information and constructive criticism to improve the quality of this report.

1.4 Study Location

The community of Barrow, currently recognized as the City of Utqiaġvik, is located on the Arctic Ocean (Figure 1), approximately 750 miles north of Anchorage, Alaska. The State of Alaska officially renamed the community Utqiaġvik on 01 December 2016. However, for the purpose of this study, the former name of Barrow will generally be used as a practical matter to keep the name consistent with the previous study and the current Feasibility Cost Sharing Agreement (FCSA). Barrow is the northernmost community in the U.S. and the administrative, economic, social, and cultural center for the NSB. Barrow's municipal limits include several "neighborhood" areas, namely Barrow and Browerville, as well as the Naval Arctic Research Laboratory (NARL), Nixeruk, and Nuvok (Figure 2). The study area (Figure 3) for this project, as defined during the charette on 12 September 2017, is approximately 5 miles of coastline heading North from the bluff area in front of the Wiley-Post Will Rogers Airport runway to Dewline Road, just past NARL.

Figure 1. North Slope Borough, Project Vicinity Map. (USACE 2010)

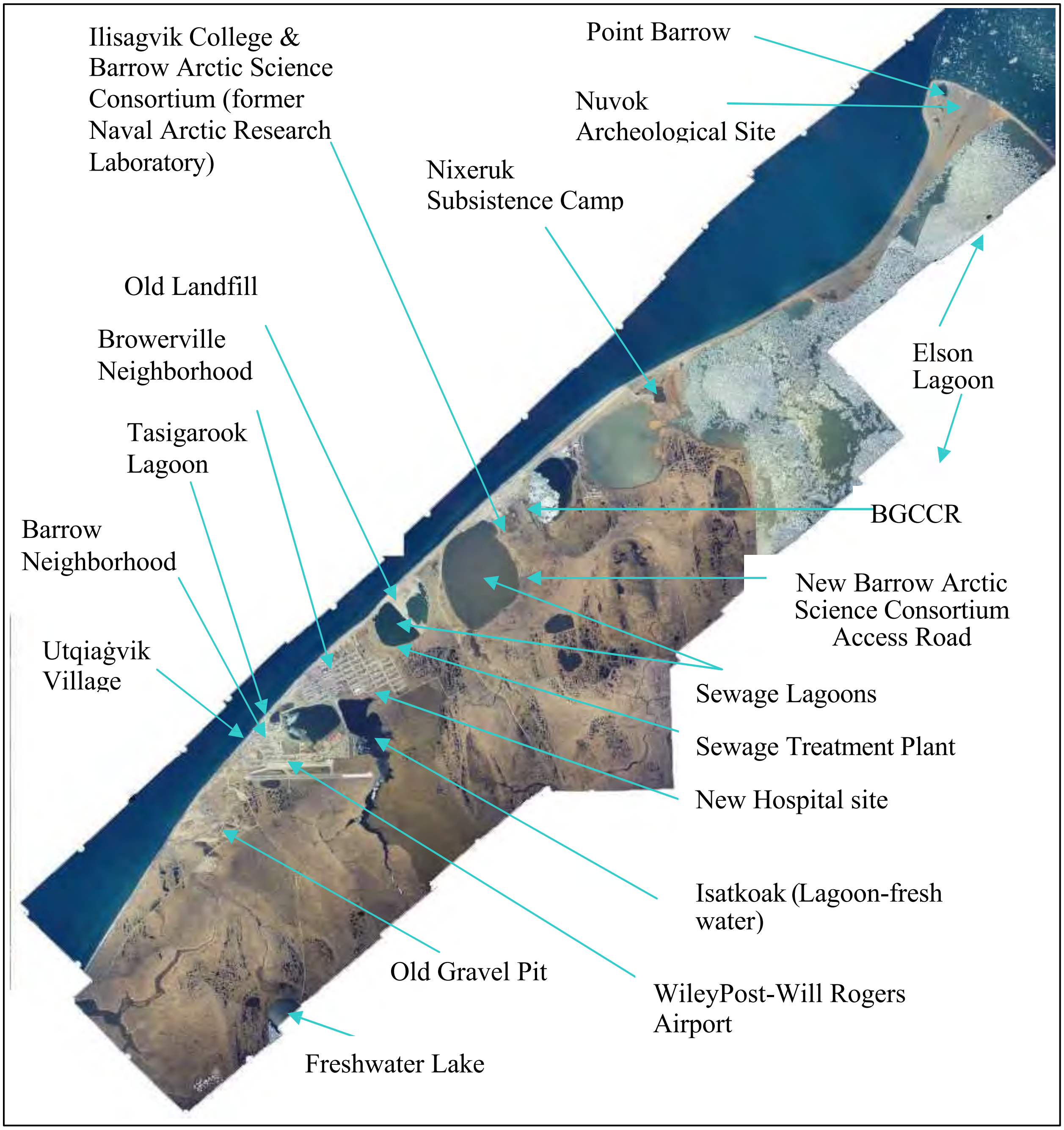

Figure 2. Local Features (approximate location, not drawn to scale). (USACE 2010)

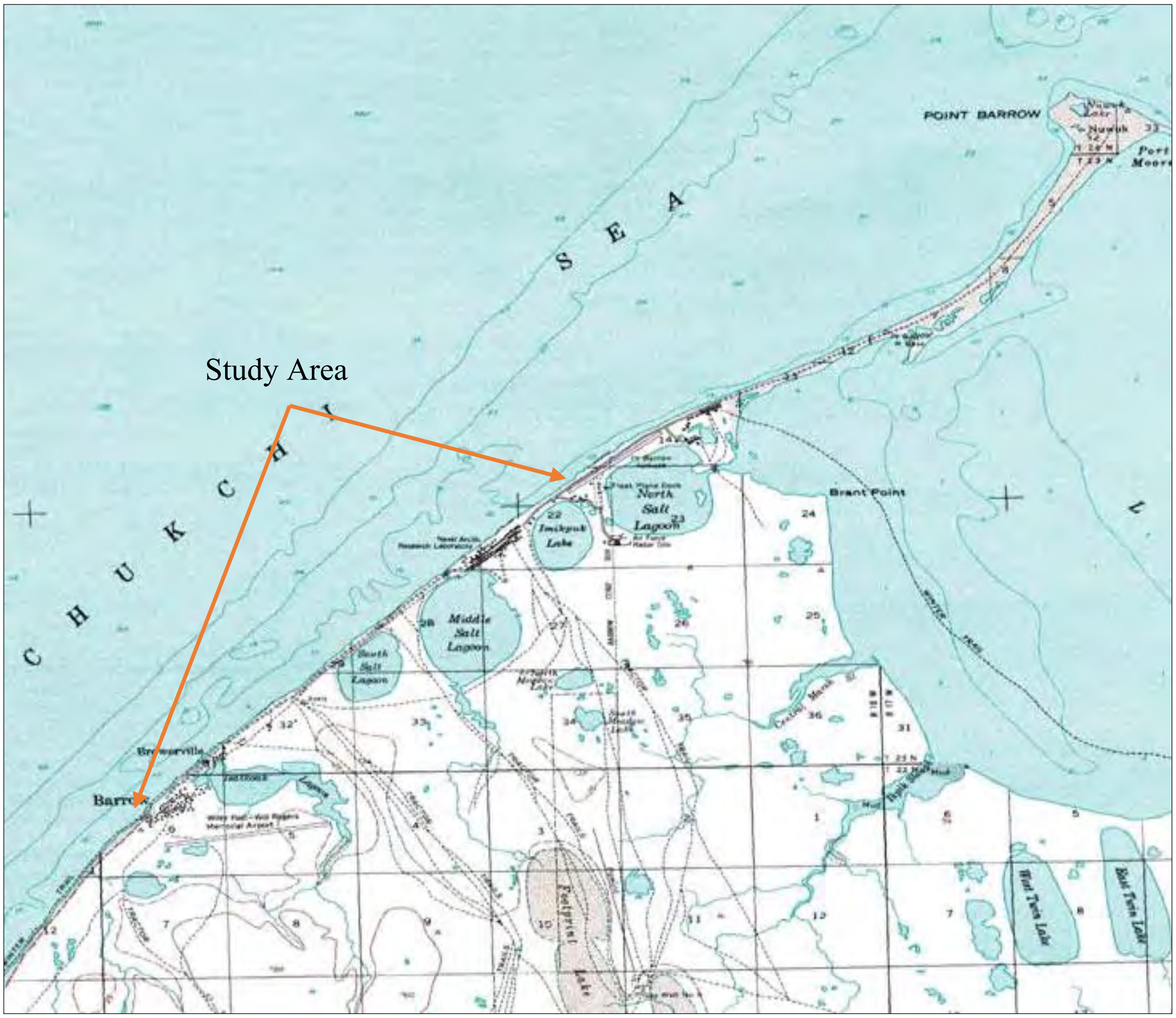

Figure 3. Study Area (approximate, not drawn to scale).

1.5 Historical Storms

Historical data from storm surges and flooding events in Barrow are limited. According to traditional ecological knowledge (TEK), the biggest storm on record occurred in 1963. There is limited data regarding economic and physical damages from this storm. More recently, there have been three large storm events (2010, 2015, and 2017), and two of these storms were declared as states of emergency. Other notable storms are as follows:

- September 1954: Surge depths reached between +9 MLLW and +10 feet (ft) MLLW, washing water over the beach and washing the community's helium tank nearly to Point Barrow.
- October 1954: Minor damage occurred with a maximum surge depth of +9.5 ft MLLW.
- October 1963: There is limited data available about this event, but local knowledge suggests storm surge depths reached up to +14 ft MLLW. Flooding was more extensive in NARL than Barrow, with NARL being isolated for several days. A total of 32 homes were affected, 17 damaged and 15 destroyed, along with 3 small airplanes (Barrow 2015).

- September 1968: A maximum wave height of +5 ft MLLW eroded an average of 14 ft of bluff 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.
- September 1970: Minor damage occurred with an unknown surge depth.
- December 1977: Barrow's gas well runway partially flooded when 6 to 18 inches of water rose 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 surge depth of +3.5 ft MLLW was reached.
- September 1978: A maximum surge depth of +5 ft MLLW occurred causing between $5,000 and $50,000 (not adjusted for inflation) in damages to the road between NARL and Barrow.
- September 1986: There is limited 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, with heightened effects from the lack of sea ice. The NSB Disaster Coordinator reported $7.7M in damages (not adjusted for inflation). Most of this damage occurred to a beach nourishment dredge that was ripped from its anchors and washed ashore. The barge was grounded on the shoreline, damaging the bottom of the vessel beyond salvageable repair. The dredging operation was suspended after the storm due to the damages sustained and the operation's inability to produce gravel of sufficient quality for use on the beach. Additionally, 36 private homes and 4 NSB housing units sustained roof and siding damages. About 6 miles of road between the gravel pits and Piqniq were damaged as well.
- 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 ft MLLW. 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.
- November 2010: High storm surge flooded portions of the town.
- August 2015: A maximum surge depth of +5 ft MLLW was reached and caused $7M in damages (according to local knowledge). This storm was declared as a state of emergency and FEMA helped with post emergency efforts.
- September 2017: Waves reached a peak of about +8 ft MLLW and caused $10M in damages (according to local knowledge). This storm eroded approximately 3 miles of beach, washed away approximately 60 ft of guardrail, and destroyed approximately 6,000 ft of street surfaces. This storm was declared as a state of emergency and FEMA helped with post emergency efforts. Flooding persisted into October 2017.

1.6 Congressional District

The study area is in the Alaska Congressional District, which has the following Congressional delegation:

Senator Lisa Murkowski (R);
Senator Dan Sullivan (R);
Representative Don Young (R).

1.7 Non-Federal Sponsor

The NSB is the non-Federal sponsor and has stated its intention to cost-share in Federally-constructed coastal storm risk management measures. This partnership of Federal and non-Federal interests in coastal storm risk management helps ensure that a constructed project would effectively serve both local and national needs. The FCSA for this Study was signed on 12 July 2017. This agreement creates a Federal and non-Federal partnership with the objective to effectively serve both local and national interests. The feasibility phase is conducted at a 50/50 cost share.

1.8 Related Reports and Studies

There are no current Corps Civil Works projects in the Barrow area. However, the Corps 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, 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) as well as studies of small boat harbors in 1979 and 1993 (under Section 107 of the 1960 River and Harbor Act) (USACE 2010). In June 2001, the Corps conducted a Section 905 (b) (Water Resources Development Act 86) Analysis entitled "Barrow, Alaska, Storm Damage Reduction, Flood Reduction, and Navigation Channel" (Corps 2001). The analysis recommended a further study to determine the feasibility of providing storm damage reduction, flood reduction, and navigation improvements.

A feasibility study with the NSB was initiated in 2003 and completed in 2010. The final deliverable was a Corps technical report entitled "Barrow, Alaska Coastal Storm Damage Reduction Technical Report," dated July 2010 (USACE 2010). This report considered five basic alternatives with variations based on scale: rock revetments, beach nourishment, joining the National Flood Insurance Program, elevating/relocating buildings, and lagoon filling. At that time, analyses indicated that there was no economically justified Federal interest.

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. In recent years, a number of Barrow stakeholders have been actively involved in planning, designing, and/or constructing new facilities. One characteristic common to the facilities being replaced or upgraded is their close proximity to the shoreline and their potential to suffer significant damages during future extreme storm events. Local entities have taken the erosion and flooding threat seriously 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 access road, and the dam renovation. These new projects are intended to 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 what they can out of harm's way, before damages could occur. Portions of existing commercial, residential, and public land and structures still remain susceptible to erosion and flooding from extreme storm events. The current study provides an opportunity to address the storm damage problems that threaten the long-term economic, social and environmental well-being of Barrow and the NSB.

2. TENTATIVELY SELECTED PLAN

2.1 Description of Tentatively Selected Plan (TSP)

Including the No-Action Alternative, seven alternatives were considered at the Alternatives Milestone Meeting (AMM). For a full description of each alternative, see Section 7.4. Alternatives three, four, and seven were eliminated from consideration after AMM due to the non-efficiency and non-effectiveness of the alternatives to meet the needs of the objectives. Alternatives two, five, and six were further optimized between AMM and TSP (See Section 7.4). Alternative 2 was selected as the TSP, with Options A and B (revetment vs. raise Stevenson Street). Options A and B were later combined into a hybrid labeled Alternative 2: Rock Revetment, Berm, and Raise Stevenson Street. Cost and Economic Analysis was completed for options A and B separately and the team has made the risk informed decision to choose the higher cost of $193M as the Alternative 2 project cost. The costs and figures associated with this alternative reflect the pre-revised alternative described below and will be revised for the final report.

2.2 Original Alternatives Carried Forward as the TSP

2A. Rock Revetment at Bluff and Berm in Front of Stevenson Street. This alternative would provide erosion protection for the bluffs starting in front of the airport until the bluffs transition to low lying areas in front of Tasigarook Lagoon, approximately 1 mile of bluff protection. This alternative would also include flood protection for the low lying areas starting in front of Tasigarook Lagoon with a smooth transition from a protected rock revetment in front of the bluffs to a revetted berm in front of Stevenson Street. The revetted berm would then continue in front of Stevenson Street until it intersects with Dewline Road on the far side of NARL. The revetted berm would extend approximately 4 miles. This alternative would have a height of +14.5 ft MLLW.

2B. Rock Revetment at Bluff and Raise Stevenson Street. This alternative would provide the same level of protection as Alternative 2A. The erosion protection for the bluff would still extend from in front of the airport to in front of Tasigarook Lagoon. Instead of constructing a revetted berm on the seaward side of Stevenson Street for the approximate 4-mile stretch, Stevenson Street would be raised. Stevenson Street would be raised to +14.5 ft MLLW and the seaward side of the street would be revetted. This would allow people driving on the road to still have a view of the ocean and could decrease the quantity of armor rock.

2.3 Alternative 2 Revised

Rock Revetment, Berm and Raise Stevenson Street. This alternative would provide erosion protection for the bluffs in front of Barrow starting in front of Wiley-Post Will Rogers airport and heading north until the bluffs start to decrease in height from +19 ft MLLW to +15 ft MLLW. A +14.5 ft MLLW berm would tie into the rock revetment and follow the shoreline north to where Tahak Street intersects Stevenson Street. Stevenson Street would be raised to a height of +14.5 ft MLLW with the seaward side revetted starting at this intersection and heading north to Dewline Road, just past NARL. Beach access points within the project area will be established during the PED phase and will account for spring break-up, drainage, and public access. Design of the beach access points will be based on community feedback and modeling. Reaches within this alternative will be further refined during PED.

2.4 Alternative 2 Design Descriptions

Revetment. The revetment along the bluff area will consist of two layers of 2.7 ton armor stone on the structure slope and two layers of B stone (Figure 4). The B rock, core, and gravel filter layers will be buried to match the existing beach elevation. The crest height is set at +19 ft MLLW, which is 0.5 ft higher than the 50-year run up estimate. The bluffs will not be excavated to provide a uniform slope on which to build, rather they will be dressed with local fill material to achieve a uniform slope. The bluffs are archaeologically rich, so no excavation will be permitted on the bluff face.

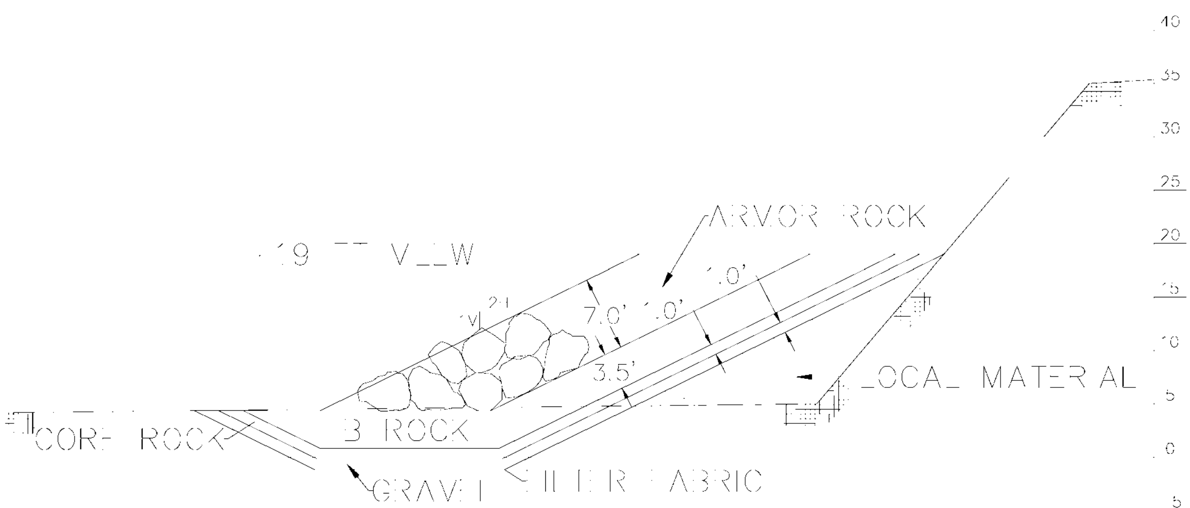

Figure 4. Bluff erosion protection with armor sized for wave protection

Revetted Berm Structure. 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 the 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 ft MLLW and the 100-year run up elevation is +14 ft MLLW but the crest height of the revetted berm is determined by the average stone diameter. Because the structure is set back from the beach, a two armor stone thickness would result in a +14.5 ft MLLW crest elevation (Figure 5). The filtering B rock layer, core, gravel, and fabric would be placed below the natural beach line for ice survivability. 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 reduced size of the structure would likely result in increased maintenance due to ice impact, but the reduced size would make the maintenance of the structure easier to perform. A stockpile of replacement stone will be kept at Barrow for maintenance activities. The B rock would be a double layer placed on a 1 ft layer of core, 1 ft 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.

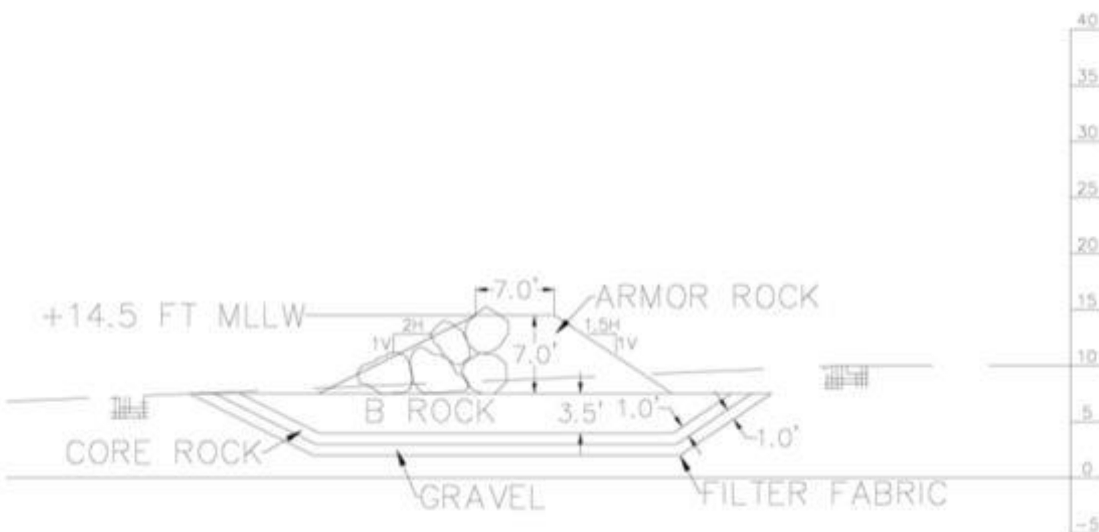

Figure 5. Revetted Berm Sized for Waves

Raise Stevenson Street. As an alternative to a revetted berm, Stevenson Street can be raised and revetted. Raising Stevenson Street, as opposed to a revetted berm, would decrease the quantity of armor rock required while maintaining a view of the ocean from the street. Stevenson Street would be raised to the elevation of the revetted berm with fill material to ensure a 100-year level of protection. The seaward slope of the street would be revetted with two layers of 2.7 ton armor stone and two layers of B stone (Figure 6). The B rock, core, and gravel filter layers would be buried to match the existing beach elevation.

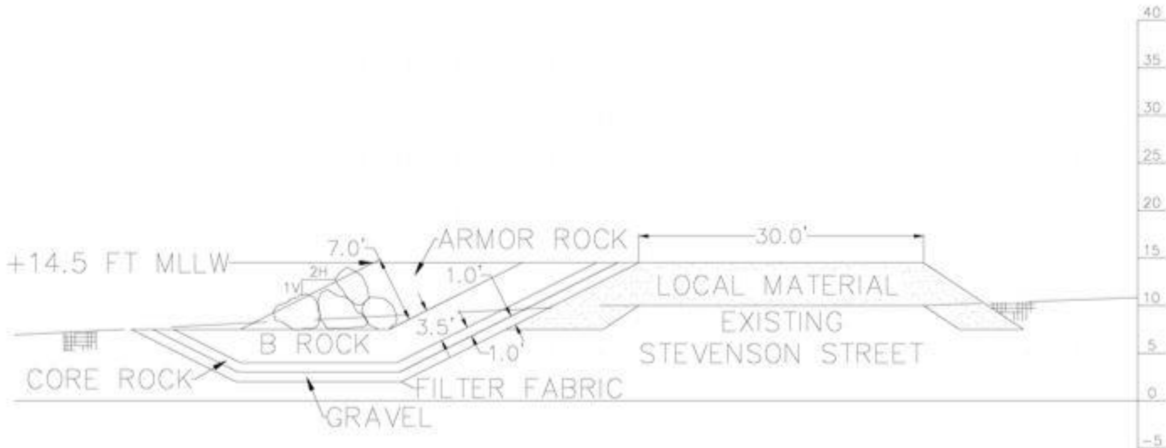

Figure 6. Stevenson Street Raised +4.5 ft with Revetted Seaward Slope Sized for Waves

2.5 Construction of TSP

Typical construction practices will be used to transport and place the plan components for the revetment, raising the road and placing a berm in front of the road. The rock and gravel for the project will likely come from Nome, Alaska by barge (see Appendix B). It is assumed that construction access will be by water, with the barge off-loading materials onto the beach. Construction will most likely occur during the summer months of June through September due to freezing temperatures and low light availability impacting the ability to construct during the other months of the year. Staging of equipment and materials could take place outside of the summer season. A Section 106 Coordination letter with the State Historic Preservation Officer (SHPO) will be completed along with National Environmental Policy Act (NEPA) coordination before construction starts. In addition, all necessary real estate coordination and acquisition of lands and property will be complete before construction can start.

2.6 Operations & Maintenance

Initial estimates of operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) for the recommended plan are as follows: $635,000 to $670,000 per year, based on a 50 year period of analysis. This estimate will be further refined for the final report.

2.7 Project Cost

The TSP yielded initial costs of $191M to $193M. Preliminary analyses indicate that the recommended plan will have an average annual equivalent cost of $8.5M. Maximum annual benefits for the recommended plan is estimated at $1.5M. This calculation includes the simplifying assumption that each alternative would eliminate all damages, resulting in zero residual damages. This estimate will be further refined for the final report.

2.7.1 Cost Apportionment

The TSP will be cost shared 65% Federal and 35% non-Federal ($125.5M Federal/$67.5M non-Federal, respectively)

2.7.2 Schedule

The study schedule for the feasibility phase is shown below in Table 1. This study has been accelerated to be completed within 24 months of signing the FCSA.

Table 1. Feasibility Study Schedule

Milestone	Date
Feasibility Cost Sharing Agreement Executed (FCSA)	12-Jul-17
Alternatives Milestone Meeting (AMM)	16-Nov-17
Tentatively Selected Plan Milestone (TSP)	28-Jun-18
Agency Decision Milestone (ADM)	31-Oct-18
Major Subordinate Command (MSC) Transmittal of Final	1-Apr-19
Director's Report Signed	30-Jul-19

2.7.3 Real Estate Considerations

The study area is located in Barrow along approximately 5 miles of shoreline extending from the bluff in front of the Wiley-Post Will Rogers Airport runway north to Dewline Road, just passed NARL. Land, Easements, Rights-of-way, Relocation, and Disposal Areas (LERRD) necessary to implement a project include private and commercially owned properties and structures. In order to construct the revetment along the bluff in front of Barrow, an estimated six structures and nine properties will need to be bought-out. Additional areas in front of Barrow and Browerville may need to be partially bought out or require an easement as property boundaries in some locations extend onto the beach or even into the water due to erosion and land loss. A full assessment of real estate located in the study area can be found in Appendix C.

3. RISKS AND UNCERTAINTIES

3.1 Risk & Uncertainty

A great deal of analysis has already been conducted and data obtained in relation to coastal erosion and flooding in Barrow. The bulk of the existing data is between 9 and 14 years old. As part of the study, the economic evaluation will take place to account for local and regional economic benefits, and the social and cultural value of a given project, in accordance with the Section 116 authority. Figure 7 shows a breakdown of high, medium, and low risks associated with this study, and some risk items are explained below.

Figure 6 depicts identified risks for the TSP. Some of the items listed will remain risks throughout the project lifespan, including all items within the low risk category and potential for cultural impacts.

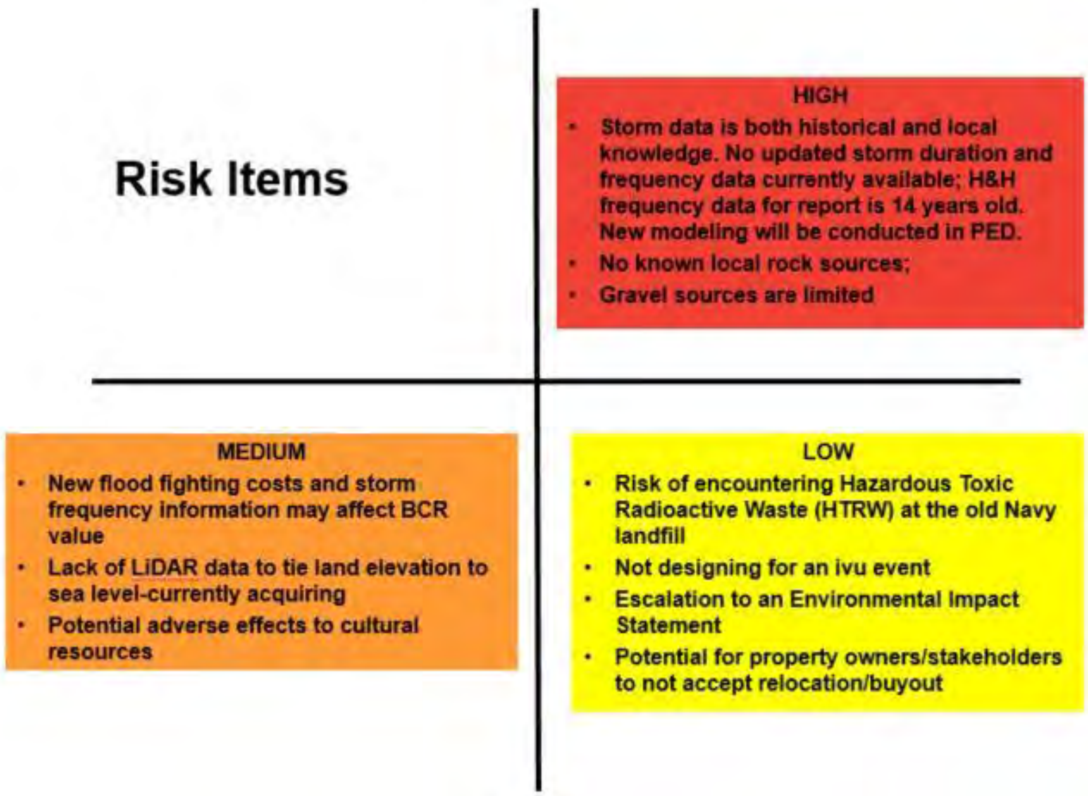

Figure 7. Risk Items

Due to the acceleration of the study timeline and available funding, risk informed decisions were made to move the updating or completion of some modelling, geophysical surveys, identifying of rock sources, and design optimization to the PED phase. Some analysis and data collection were necessary for determination of costs and quantities that were conducted during the study. Both the collection of light detection and ranging (LiDAR) data and updating storm reoccurrence intervals are being conducted, although this data would not be available prior to the release of this draft report.

Due to timeline acceleration and the need to reduce the cost of the study, Hydraulics and Hydrology (H&H) modeling was not updated from the 2010 study before determining the TSP. Coastal storms are increasing in frequency and duration due to the delay of shorefast ice development until November, December, or later (mid-January in 2018). The modeling will be updated during PED and will likely affect both H&H design and the cost for the project. Likewise, the tidal datum will not be determined until PED. While this does not affect the TSP, the current flood inundation modeling could be inaccurate, resulting in improper damage estimates and requiring redesign during PED.

Selection of a source of rock and gravel that is suitable, available, and cost-effective is still under evaluation. The current assumption is the rock would be sourced from Nome, Alaska (Appendix B). If a rock/gravel source is identified and then the volumes or costs of those materials change significantly, there is a risk of having to find another source that would satisfy the needs of the project.

4. EXISTING CONDITIONS

Existing conditions within the study area are described below. Some existing resources are likely to be impacted, although most of the physical environment will not be impacted, including affects to the sea ice, climate change, and hydrology. Those resources that will be impacted are summarized below as background information to help inform the decision. The full inventory and analysis is included in the Environmental Assessment (EA) Appendix D.

4.1 Physical Environment

Barrow is located, approximately 329 miles 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 approximately 9.9 miles to the northeast.

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 (USACE 2010). 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 driving nature of the concern for this study is that the changing nature of sea ice, which would normally buffer the coastline is now exposed to storm and wind driven waves during increasing ice-free periods.

Along with the delay of sea ice, warmer climates are affecting the spring runoff and permafrost melting within the bluff, further adding to the erosion problem. Although the Corps cannot change this natural process, this study does recognize these issues as influencing factors and considers alternatives to help mitigate their impacts.

4.2 Terrestrial and Nearshore Environment

All of the study alternatives consider a similar footprint along a portion or entirety of the 5 mile study area which includes beach and bluff environment. Barrow also has a seasonal abundance of marine and terrestrial fauna including marine mammals, shorebirds, and fish species.

<u>Bluffs</u>
The predominant land type in Barrow is tundra, which is formed over a permafrost layer that is as much as 1,300 ft (400 m) in depth. The top of the bluff, adjacent to the airport runway, is vegetated with tundra and topped with 6 houses. The bluff face terminates onto the beach and is within the wave-impact zone during storms and heavy wind events, causing active erosion during the summer and fall. Approximately 0.6 acres of tundra are within the study area.

Migrating waterfowl and seabirds nests on the tundra near Barrow typically from late May through June, when the ice is more present. These birds return again in late summer to early fall, however, aggregations are more noticeable in the spring time.

Beach and Nearshore

The entire study area is situated along beach and nearshore habitat. The beach environment is highly dynamic and heavily impacted by anthropogenic activities and the current erosion problem. To help prevent flooding, a sacrificial berm has been erected along the entire coastline from the bluffs to Dewline Road. Heavy equipment is used to push sand and gravel from the tidal zone up the beach, forming these sacrificial berms. Continual maintenance is necessary to maintain the sacrificial berms during the open water season since they can be easily washed away during larger storm events.

This nearshore marine habitat is also used occasionally by shorebirds, gulls, and arctic terns in the summer and early fall. None of the shoreline in the study area is used for nesting. The beach area is heavily trafficked by four-wheelers, heavy equipment during flood fighting, and receives wave action that makes it unsuitable for nesting. Although not a breeding area, seals and walrus will occasionally haul onto the beach to rest or hunt in the nearshore area. Polar bears are more frequent throughout the year, using the nearshore habitat as a transit corridor and to hunt.

The study area does not extend into the nearshore environment as it currently is, however if further erosion continues, this may not be the case. Based on previous Corps sampling efforts, it was determined that fish species in the area are highly variable in the nearshore habitat (USACE 2010).

Access points to the project would be via already existing roads and along the beach. Due to the instability of the berm top, most of the bluff work will be conducted from the beach. A staging area will be located at an old gravel pad approximately 0.8 miles south along the coastline. Additional staging areas will be created as necessary along the beach or within parking lots.

Inter-agency coordination for NEPA is on-going. The draft environmental assessment and Finding of No Significant Impact (FONSI) for NEPA compliance can be found in Appendix D.

4.3 Recreational

The City of Barrow utilizes the beach and associated access points for recreational purposes. These include boating, walking along the beach, viewing the ocean, and holding social events. Since the coast is one of the most prominent features and is directly tied to the cultures, access to the beach is very important to the community.

4.4 Historical & Archeological Resources

The largest community in the Alaskan Arctic is the City of Barrow. Cultural resources in the Barrow area range from prehistoric subsurface sites to historic structures, from approximately 5,000 years ago to the Cold War. Barrow has at least 42 historical and prehistoric sites which have been recorded to the Alaska Heritage Resources Survey (AHRS) which are near or within the Area of Potential Effect (APE) discussed in Appendix D. Five additional sites are located near the study area. Significant sea level and environmental changes over the span of a millennia have altered the shoreline and continue to alter the landscape, likely hiding or erasing sites.

4.5 NED Damages

NED benefits are effects which increase the economic value of the National output of goods and services. At Barrow, potential beneficial NED effects are possible by reduction of damages from flooding and erosion that would be expected to occur without a project.

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 Stevenson Street in the northeastern part of the neighborhood of Barrow and Browerville.

A detailed summary of analyses can be found in Appendix E.

4.6 Social Economic Resources

4.6.1 Life, Health, and Safety

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 (i.e. operating heavy equipment in increased wave conditions) in order to protect the community. The community faces risk of damage to personal property, including residential and non-residential structures and their contents. The high risk of flooding during storm events has negatively impacted the quality of life of local residents. Current erosion damage to Stevenson Street has resulted in hazardous road conditions during storms.

4.6.2 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 emergency infrastructure systems in Barrow that were identified as currently supporting operations in nearby villages included search and rescue, law enforcement, fire support, health care, communication, and cargo delivery. While the nearby 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 (Anchorage, Fairbanks, Kotzebue, and Nome) were identified and analyzed as alternatives for providing emergency support services to NSB communities should Barrow be unable to provide such support.

4.6.3 Population

The population of Barrow is approximately 4,438 (U.S Census Bureau 2017). Since the 2010 census, this population has increased by approximately 200 people. There are 234 registered companies operating as of 2012. The median household income is approximately $78,000 and the poverty level is at 14% (U.S. Census Bureau 2017). The coastal erosion is currently impacting businesses and housing located along the coast, bluffs, and in the nearby areas.

4.6.4 Subsistence Production

Subsistence is extremely important to the community of Barrow. Sixty-four percent of the population is Alaskan Native (primarily Inupiat Eskimo) and practice a subsistence lifestyle that includes traditional marine mammal hunts and other subsistence practices. The harvesting of whales (primarily Bowhead) in Barrow is intrinsic to its way of life.

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 to 22 ft that use this 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.

4.6.5 Infrastructure and Facilities

The Barrow Utilidor 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.

Loss of utility services in Barrow would result in substantial risk to human health and safety due to the inability of residents to heat and power their homes and businesses in a geographic region with extreme climactic conditions. Additionally, current flood fighting and erosion response approaches necessitate placement of temporary protective materials during storm conditions, including operation of heavy equipment in the surf. Impacts to infrastructure systems in Barrow extend the risk to human health and safety to other regional communities dependent upon Barrow for essential services and supplies. Barrow’s 2016 population was grouped into 1,370 households and the City included 1,662 total housing units. The average household size was 3.11 persons.

5. FUTURE WITHOUT-PROJECT CONDITIONS

The future without-project conditions (FWOP) mirror those conditions under the No-Action Alternative. Coastal erosion and flooding risk results in adverse effects to terrestrial and nearshore environments, recreational, historical/archeological, economic, and social/cultural resources in the community of Barrow. The FWOP is the basis of evaluation against with-project conditions, and is described below. The physical environment is a result of a changing climate and would not be significantly impacted in the FWOP conditions.

5.1 Terrestrial and Nearshore Environment

With the No-Action Alternative, the terrestrial and nearshore environment would continue to be impacted by erosion due to storms and heavy wave action. The tundra on the bluffs would erode potentially causing houses on the bluffs to collapse with the eroding soil or sustain damage due to the unstable terrain. If allowed to continue, the bluff erosion would eventually start to impact the airport runway. What little beach remains would be eroded away as well. It is likely the sand would accrue north at Point Barrow due to the longshore current transport. Stevenson Street would be the only direct barrier between the coast and the rest of Barrow. As the beach and coastal habitats continue to erode, the risk of flooding from wave run-up would also increase and threaten important infrastructure. Due to their migratory nature, most of the Barrow fauna would not be effected in the FWOP conditions.

Polar bears, which can be in the area year-round will likely continue to stay in the area, as long as they have a stable food source. Without a beach to use as a transit corridor, bears may be more frequent in the town, which could lead to higher human-bear interactions.

5.2 Recreation and Aesthetics

Recreational activities along the coast are very important to the community. In the FWOP, the use of the beach would remain the same in the short term, however, it would be limited or nonexistent due to increased erosion in the long-term. Housing, utilities, and roads would remain at risk along the coast as storms and erosion continue. Some activities would likely shift to other locations, including vessel access and social events. Aesthetics would not be affected by the No Action Alternative. There is currently a sacrificial berm blocking the view to the ocean at approximately +20 ft MLLW. This will likely remain as a flood control measure used by the NSB.

5.3 Historical & Archeological Resources

With the No-Action Alternative, cultural resources and opportunities would be exposed to further damage from erosion and flooding, including the Utqiaġvik Village archeological site in Barrow. Thawing permafrost in the Russian Arctic has led to the damage of several hundred buildings, many constructed after 1940 and designed for arctic conditions, as permafrost thawed and made the foundations unstable (Nelson *et al*. 2002).

5.4 NED Damages

The updated evaluation of economic damages associated with coastal storm damages and erosion in the study area identified total estimated annual damages (EAD) of $1,799,500. These include expected coastal storm/flooding damages to structures and their contents and erosion damages to the NSB's system of coastal storm protection beach berms, Stevenson Street, and lands and improvements located within the predicted erosion zone atop the bluff in Barrow. This amounts to a 27% increase in EAD as a result of the price level and discount rate update from the analysis completed and documented in the 2010 Technical Report. Table 2 provides a summary of the expected annual without-project damages from coastal flooding and erosion in the study area.

Table 2. NED Update, Summary of Expected Annual Damages

Damage Category	Estimated Present Value	Estimated Annual Damage	%
Coastal Storm Damages	$3,674,543	$136,108	9%
Coastal Erosion Damages	$36,808,062	$1,363,404	91%
TOTAL	**$40,482,605**	**$1,499,513**	**100%**

The PDT is working with the Sponsor to update the analysis and damages to include recent storm event damages and dollar charges. It has been recognized that the estimated annual damages reflected above do not include these recent storm events. Updated information and a revised analysis will be conducted before the final report.

5.1 Social Economic Resources

5.1.1 Life, Health, and Safety

The No-Action Alternative poses the same negative impacts to personal safety and mortality by not addressing the current risks of coastal storm damages and erosion in the study area. These impacts would be the same as the existing conditions in Section 4.6.1.

5.1.2 Regional Emergency Services

Because the No-Action Alternative would not reduce the risk or occurrence of coastal flooding and erosion in the study area regional emergency services of Barrow would still provide important services to other communities in a FWOP. If storm event frequency and duration increase, there would likely be more frequent inundation and flooding, which would require emergency services. There are additional communities that can aid if needed, however, more frequent need of services will cost these communities more money and valuable resources.

5.1.3 Population

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 results of the modeling in the 2010 Technical Report, 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 12% of Barrow's total of 1,722 jobs as reported in the 2016 U.S. Census.

A large potential risk to employment and income in the study area is the loss of utility services provided by the underground Utilidor. 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.

5.1.4 Subsistence Production

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 Point 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 this issue. The No-Action Alternative could lead to negative health effects on many subsistence resources if debris and contaminants enter the freshwater, marine and terrestrial environments due to damage from continued coastal erosion and flooding.

5.1.5 Infrastructure & Facilities

Coastal flooding in the Barrow neighborhoods of eastern Barrow and Browerville is expected to continue under FWOP conditions. The Barrow Utilities and Electric Cooperative, Inc. (BUECI) provides Barrow with water, sewer, and electric service. The City's water source is the upper portion of Isatkoak Lagoon. The 2010 Technical Report provided estimates that the spillway will undergo damage when water surfaces in the area exceed +8 ft MLLW (USACE 2010). Similarly, the Utilidor would undergo damage when water surfaces in the area exceed +10 ft MLLW.

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 $1.7 million and an average annual value of $65,000. 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.

6. STUDY OBJECTIVES AND PLANNING CRITERIA

6.1 Study Opportunities

Opportunities are statements about what will be realized or what will have the potential to be realized by meeting the main study objectives. The study opportunities that could be realized are as follows:

- Maintain social and cultural values
- Maintain food security (subsistence resources)
- Ensure health and safety of smaller communities that rely on Barrow
- Preserve existing views of the Chukchi Sea
- Long-term economic growth and stability in Barrow
- Increased tourism and revenue
- Maintain access to Distant Early Warning Line and environmental research facilities
- Reduce risk to critical and future infrastructure
- Improve real estate situation
- National Flood Insurance Program eligibility
- Improve navigation access to community
- Protect recreational sites
- Reduce economic threat to NSB budget that impacts other communities
- Increased investment in infrastructure

6.2 National Objectives

The Federal objective of water and land resources planning is to contribute to NED in a manner consistent with protecting the nation’s environment. NED benefits increase the net value of goods and services provided to the economy of the nation as a whole. In general, only benefits contributing to NED may be claimed for Federal economic justification of a project. However, Section 116 Implementation Guidance allows for selection of a plan based in part or whole on non-monetary units supported by a Cost Effectiveness/Incremental Cost Analysis (CE/ICA) if no NED plan is identified.

6.3 Study Objectives

The planning goal is to formulate an effective and achievable measure or set of measures that will result in selecting an alternative plan that will meet the following study objectives:

- Reduce risk to life, health, and safety

- Reduce damages caused by flooding and shoreline erosion to residential and commercial structures and critical public infrastructure
- Reduce or mitigate damage to tangible cultural heritage

6.4 Study Constraints

Constraints are statements about what should be avoided or what cannot be changed while meeting the study objectives. The study constraints are as follows:

- Minimize adverse impacts to threatened and endangered species
- Minimize adverse impacts to cultural resources
- Maintain access for subsistence activities
- Minimize impacts to permafrost

6.5 National Evaluation Criteria

Alternative plans should be formulated to address the study objectives and adhere to study criteria. Each alternative plan shall be formulated in consideration of four criteria: completeness, efficiency, effectiveness, and acceptability. In addition to these, other screening criteria were used to evaluate alternative measures to include constructability, avoidance of constraints, completeness, first costs, and maintenance costs. A list of measures can be found in Section 7.3.

7. FORMULATION & EVALUATION OF ALTERNATIVE PLANS

7.1 Plan Formulation Rationale

Plan formulation is the process of building alternative plans that meet planning objectives and avoid planning constraints. Alternatives are a set of one or more management measures functioning together to address the study objectives. A management measure is a feature or activity that can be implemented at a specific location to address one or more of the objectives. A feature is a "structural" element that requires construction or on-site assembly. An activity is defined as a "non-structural" action.

7.2 Plan Formulation Criteria

Measures were screened during the charette using the four national criteria and five study specific criteria, discussed in Section 6.5. Each measure was evaluated against the general metric of whether the design would address the major mechanisms causing the erosion and flooding (wave-run up, increased period during storm events, freeze thaw cycles of permafrost). Wave run-up has been identified as the major driver for flood inundation during storm events and increased wave action undercutting the bluff. This leading to erosion and calving, affecting the Utqiaġvik Historical Site. Specific engineering design criteria used to develop the measures are presented in the Appendix F.

7.3 Measures

A total of ten potential structural measures and nine non-structural measures were initially identified during the scoping meeting, or charette. After screening, eight structural and eight non-nonstructural measures were identified to be carried forward for consideration to be incorporated into alternatives. Table 3 lists measures identified during the planning charette on 12-13 September 2017 which includes a combination of structural and non-structural solutions. Measures were screened out using the above criteria explained in Section 6.5.

Table 3. Measures

Measures	Retained	Description	Screening Considerations
Revetment	Yes	Structural	
Seawall	Yes	Structural	
Breakwater	Yes	Structural	
Berm (permanent, not sacrificial)	Yes	Structural	
Beach nourishment	Yes	Structural	
Join NFIP	No	Non-Structural	Do not currently qualify for national flood insurance program. Added as an opportunity.
Raise Stevenson Street	Yes	Structural	
Ring wall (protective levee)	Yes	Structural	
Fill in front of freshwater lagoon (elevating it)	Yes	Structural	
Artificial Reef	No	Structural	Risk of impacting subsistence activities. Risk of ice damage.
Zoning	Yes	Non-Structural	
Buyout Acquisition	Yes	Non-Structural	
Recover cultural sites (excavate)	Yes	Non-Structural	
Groin Field	No	Structural	Little longshore sediment transport; risk of starving one area to supply another.
Remediate contaminated sites	Yes	Non-Structural	
Relocate at-risk structures	Yes	Non-Structural	
Elevate at-risk structures	Yes	Non-Structural	
Emergency warning system and signage	Yes	Non-Structural	

Structural measures are generally the measures that would reduce erosion and flooding. Non-structural measures would reduce consequences of erosion, flooding, relocations, and buyouts associated with the project. Underwater reef and groin field were removed during the charette due to ineffectiveness and inefficiency. Seawall was removed as a measure in April 2018 with buy-in from the non-Federal Sponsor.

7.4 Alternatives Considered

All structural and non-structural measures were combined into common themes and developed into realistic alternatives that would meet the objectives of this study. Seven alternatives were considered after the AMM and are described below:

Alternative 1: No-Action
The No-Action Alternative would not take action to reduce or halt erosion and flooding along the coastline of Barrow, Alaska. The study objective would not be met and no opportunities would be realized. Erosion would continue to take place and flooding would occur during storm events. Public and private infrastructure, historical buildings, and cultural resources would continue to be lost as the ground beneath them eroded away.

Alternative 2A: Rock Revetment at Bluff and Berm in Front of Stevenson Street
This alternative would provide erosion protection for the bluffs starting in front of the airport until the bluffs transition to low lying areas in front of Tasigarook Lagoon. This alternative would also include flood protection for the low lying areas starting in front of Tasigarook Lagoon with a smooth transition from a protected rock revetment in front of the bluffs to a revetted berm in front of Stevenson Street. The revetted berm would then continue in front of Stevenson Street until Stevenson Street intersects with Dewline Road on the far side of NARL. The revetted berm would run the remaining distance of the project area. This alternative would have a height of +14.5 feet.

Alternative 2B: Rock Revetment at Bluff and Raise Stevenson Street
This alternative would provide the same level of protection as Alternative 2A. The erosion protection for the bluff would still extend from in front of the airport to in front of Tasigarook Lagoon. Instead of constructing a revetted berm on the seaward side of Stevenson Street for the approximate four miles stretch, Stevenson Street would be raised to +14.5 feet and the seaward side of the street would be revetted. This would allow people driving on the road to still have a view of the ocean and could decrease the quantity of armor rock.

Revised description of Alternative 2 refined after TSP is described in Section 2.3.

Alternative 3: Flood-Proofing and Beach Nourishment
Residences located within the flood projections for the 50-year period of analysis would be elevated or bought out and relocated. Zoning would be enforced so no infrastructure is built in these high risk areas. Beach nourishment would take place and have to be maintained throughout the 50 year period of analysis.

Alternative 4: Ice Berm
A facility would be constructed to produce large enough blocks of ice that would persist through the warmer seasons. Thermal off gassing equipment would be installed along the whole stretch of the study area to assist with keeping the ice frozen and shoreline stabilized. The ice berm would in effect work as the decreasing sea ice works in cutting down on wave action and working as a barrier between waves and the bluff.

Alternative 5A: Protect Major Infrastructure
A revetted berm in front of the Tasigarook Lagoon would protect the community's fresh water source and it would be extended north-easterly to protect pump station #3 of the Utilidor. Infrastructure at greatest risk from flooding would be protected 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 would consider the social, local, and economic issues associated with any action and be based on the flood exceedance probabilities and stage frequency flood plots that can be found in detail in Appendix F.

This alternative also considered filling in a portion of Tasigarook Lagoon as an alternative to a berm revetment, which was considered in the 2010 Technical Report and resulted in the highest benefit to cost ratio (BCR) in that report. This measure is no longer being considered within this study and costs and figures will be updated for the final report.

Alternative 5B. Barrow and Browerville Neighborhoods
Expanding on Alternative 5A, the Barrow and Browerville Neighborhoods alternative would include a rock revetment for the bluffs starting at the airport and extend the revetted berm to the end of Browerville, near the intersect of Stevenson Street and Ahmoagak Avenue.

Alternative 5C: Barrow and Browerville Neighborhoods plus NARL
In addition to Alternative 5B, the Barrow neighborhood from erosion and Tasigarook Lagoon and the Browerville neighborhood from flooding, this alternative would protect NARL from flooding by raising Stevenson Street in front of NARL.

Alternative 5D: Barrow and Browerville Neighborhoods Plus NARL and Old Navy Landfill
In addition to Alternative 5C, the Barrow neighborhood from erosion and Tasigarook Lagoon, the Browerville neighborhood, and NARL from flooding, this alternative would protect the old Navy landfill from flooding by nourishing the beach.

Alternative 6A: Combination Rock Revetment, Raise Stevenson Street, and Revetted Berm with Limited Beach Nourishment
This alternative includes erosion and flood protection in front of the airport through the end of NARL with a secondary level of protection added as beach nourishment. Various protection measurements would be used for different stretches of the beach. The bluffs would be revetted, a revetted berm along with beach nourishment would be constructed in front of Tasigarook Lagoon and continue through the end of Browerville, and then Stevenson Street would be raised from the end of the berm through the end of NARL.

Alternative 6B: Combination Rock Revetment, Raise Stevenson Street, Revetted Berm, and Beach Nourishment:
Alternative 6B is similar to 6A in the type of protection measures and length of coast protected. Instead of raising Stevenson Street in front of the salt lagoon and old Navy landfill, these areas would utilize beach nourishment for coastal protection.

Alternative 6C: Beach Nourishment Only
This alternative only includes beach nourishment as a protection measure. Beach nourishment would be placed along approximately five miles of coastline, from the airport through the end of NARL where Stevenson Street intersects with Dewline Road. The beach nourishment could be gravel or coarse sand depending on the method of fill design. The interval of re-nourishment would depend on the size of material used for the initial nourishment.

Alternative 7: Series of Offshore Breakwaters and Beach Nourishment
A series of breakwaters would be constructed offshore to lessen wave action and protect the shoreline during storm events. Accompanied with beach nourishment, current residences and public infrastructure could be flood-proofed in place with ring walls (protective levees) placed around pump stations and the old Navy landfill. An advanced warning system would also be established to allow the public to prepare during severe storm events.

7.5 Alternatives Carried Forward

A description of each alternative that was carried forward to the TSP Milestone is depicted in Table 4. Alternatives 3, 4 and 7 were eliminated prior to the TSP Milestone. Alternative 3, flood proofing, was removed because it did not adequately address the study objectives. The measure of beach nourishment in Alternative 3 was incorporated into four of the final array of alternatives. Since the primary causes of erosion is related to the reduction in sea ice and permafrost melting, Alternative 4 was not guaranteed for a 50-year period and was thus screened out. Alternative 7 would decrease wave action, however it would not eliminate the risk of flooding.

Table 4. Alternatives Carried Forward

Alternative	Description
Alternative 1 (No-Action)	This alternative would be to take no action and leave the City susceptible to the effects storms.
Alternative 2A*	Rock Revetment at Bluff and Berm in Front of Stevenson Street
Alternative 2B*	Rock Revetment at Bluff and Raise Stevenson Street
Alternative 5A	Protect Major Infrastructure
Alternative 5B	Barrow and Browerville Neighborhoods
Alternative 5C	Barrow and Browerville Neighborhoods Plus NARL
Alternative 5D	Barrow and Browerville Neighborhoods Plus NARL and old Navy Landfill
Alternative 6A	Combination Rock Revetment, Raise Stevenson Street, and Revetted Berm with Limited Beach Nourishment
Alternative 6B	Combination Rock Revetment, Raise Stevenson Street, Revetted Berm, and Beach Nourishment

Alternative	Description
Alternative 6C	Beach Nourishment Only

*See Section 2.1 for revised description of the preferred alternative, Alternative 2 Rock Revetment, Berm, and Raise Stevenson Street.

8. ECONOMIC ANALYSIS

For this analysis, a set of preliminary alternatives were identified, and their NED effects were evaluated to support plan screening and identification of a set of final plans for further consideration. Detailed effects, and in-depth economic analysis can be found in the Economics Analysis Technical Report (Appendix E).

8.1 Alternative Costs

The NED benefits from the 2010 Technical Report were updated to current prices and the current Federal discount rate. Because no new engineering information was available there were no changes to underlying modeling assumptions and no new model runs were performed in Beach-Fx. Refinements to the 2010 engineering analyses are currently being conducted and will be used to refine design criteria in subsequent phases of the study. This update to the 2010 NED analysis includes price level and discount rate updates of the estimated FWOP damages from that previous study. These updated values were then compared to the cost of the alternative plans formulated for the current study. The summary of the alternative costs developed for use in the CE/ICA analysis is shown in Table 5 and further in Appendices E and G.

Table 5. Alternative Costs

Alt	First Cost	Contingency	Total Cost	PV O&M	Months	IDC PV	Tot PV	Total Annualized (2.75%)
Alt 2A*	**$130,862,000**	**46.10%**	**$191,241,000**	**$33,489,000**	**25.3**	**$5,420,865**	**$230,150,865**	**$8,525,000**
Alt 2B*	**$131,923,000**	**46.10%**	**$192,790,000**	**$31,728,000**	**25.1**	**$5,418,960**	**$229,936,960**	**$8,517,076**
Alt 5A**	$62,958,000	47.00%	$92,563,000	$7,034,000	12.8	$1,261,912	$100,858,912	$3,735,907
Alt 5B**	$100,099,000	46.60%	$146,779,000	$16,305,000	14.6	$2,309,468	$165,393,468	$6,126,326
Alt 5C**	$127,153,000	46.50%	$186,334,000	$22,887,000	23.9	$4,972,109	$214,193,109	$7,933,910
Alt 5D**	$176,338,000	46.80%	$258,905,000	$42,689,000	25.7	$7,461,953	$309,055,953	$11,447,717
Alt 6A	$175,471,000	46.50%	$257,058,000	$52,579,000	26.5	$7,653,395	$317,290,395	$11,752,728
Alt 6B	$235,747,000	47.00%	$346,553,000	$89,199,000	25.2	$9,782,117	$445,534,117	$16,502,993
Alt 6C	$297,431,000	47.60%	$438,873,000	$140,363,000	15.5	$7,367,429	$586,603,429	$21,728,330

*Alternatives 2A and 2B have been combined. Due to consistency, Alternative 2B cost is used throughout.
** These costs include the 2010 measure of filling in Tasigarook Lagoon. This was eliminated by the PDT before TSP. Some information used in the 2010 Technical Report includes this measure in costs and quantities and will be modified by the final report.

8.2 With-Project Benefits

Table 6 presents updated benefit calculations for the final array of alternatives. Because no new modeling has been performed for the alternatives, detailed quantitative modeling of with-project benefits is not yet available. Storm reoccurrence intervals are being modeled and will be used along with updated flood fighting and storm damage costs to refine the BCR. These dates will be included in the final report. The No-Action Alternative description is located in Section 5.4.

Table 6. Benefits Analysis with Updated NED and New Alternatives

Alternative	Annual Costs (2.75%)	Max Annual Benefits ($, 2.75%)	Benefit Cost Ratio[1]
2A	$8,525,000	$1,499,513	0.18
2B	$8,517,076		0.18
5A	$3,735,907		0.40
5B	$6,126,326		0.24
5C	$7,933,910		0.19
5D	$11,447,717		0.13
6A	$11,752,728		0.13
6B	$16,502,993		0.09
6C	$21,728,330		0.07

[1] This BCR calculation includes the simplifying assumption that every alternative would eliminate all damages, resulting in zero residual damages. Analysis will be refined in subsequent phases.

The simplifying assumption used in Table 6 overstates the protection provided by the alternatives, especially for alternatives that do not include protection throughout the entire study area such as 5A, 5B, and 5C. However, given the resultant benefit cost ratios, the table serves to illustrate the low likelihood of achieving positive net benefits based only upon the NED account and existing data. Based on the findings of the economic analysis documented in Appendix E, none of the plans provided net positive NED economic benefits. Therefore, no alternative was designated as the NED Plan Qualitative discussion of the effectiveness of each alternative and residual risk is provided in the following section on the CE/ICA.

8.3 Cost Effective/Incremental Cost Analysis (CE/ICA)

The Section 116 Authority is intended to support development of Corps projects in rural Alaska which improve communities' resilience to flooding and erosion hazards. While current information suggests that positive net NED benefits may not justify the project alone, there are significant other risks to the Barrow community which can be quantified in terms of local and regional economic impacts, risk to life and public health and safety, and risk of environmental contamination. As directed by Section 116 Implementation Guidance, when there is no NED Plan and/or the selection of a plan other than the NED Plan is based in part or whole on non-monetary units, the selection must be supported by a CE/ICA consistent with established evaluation procedures in ER 1105-2-100, Appendix E.

The PDT developed a framework for evaluating the effects of alternatives based upon the concept of community resilience. The proposed community resilience evaluation framework provides the data required for a CE/ICA to compare alternatives in terms of their contribution to improving community resilience at Barrow. In Barrow, a resilient coastal storm risk management project would not only be independently resilient, but would also improve the resilience of existing transportation and utility systems in the community. Development of the framework was based upon Corps approaches to consideration of resilience, applied to the project context at Barrow

Community resilience emphasizes the cooperation of a broad base of stakeholders and supporting partners. A resilience planning process helps a community define its greatest risks and supports decisions that decrease those risks and increase resilience. To facilitate characterization of community resilience across projects and systems, a triple bottom line framework considered **economic**, **social/cultural**, and **environmental** components. This approach identified variables within each resilience component and identified key consequences that describe community resilience. The proposed framework evaluated the alternatives in terms of their reduction of adverse effects compared to the without-project condition. The complete CE/ICA discussion can be found in Appendix E.

Table 7 provides a cross-walk between the ten identified consequence categories and the three resilience areas. As shown in the table, consequence categories may have more than one relevant unit of measure and may apply to more than one resilience area.

Table 7. Resilience Consequence Categories and the Triple Bottom Line

<table>
<tr><th rowspan="2">Consequence Category</th><th colspan="3">Community Resilience</th></tr>
<tr><th>Economic</th><th>Social / Cultural</th><th>Environmental</th></tr>
<tr><td>1) Structures & Contents, Flood</td><td rowspan="5">Direct Damage/Cost</td><td>N/A</td><td>N/A</td></tr>
<tr><td>2) Structures & Contents, Erosion</td><td>N/A</td><td>N/A</td></tr>
<tr><td>3) Land loss, Erosion</td><td>N/A</td><td>N/A</td></tr>
<tr><td>4) Bluff (historic village)</td><td>Cultural resource areas at risk</td><td>N/A</td></tr>
<tr><td>5) South and Middle Salt Lagoons, Flood (sewage system & old Navy landfill)</td><td>N/A</td><td>Volume of contaminants</td></tr>
<tr><td>6) Tasigarook Dam & Lagoon (water supply and utilities)</td><td rowspan="2">Direct Damage/Cost & Job Loss</td><td rowspan="2">Public safety risk from loss of critical utilities</td><td>N/A</td></tr>
<tr><td>7) Utilidor, Flood (critical utilities)</td><td>N/A</td></tr>
</table>

Consequence Category	Community Resilience		
	Economic	Social / Cultural	Environmental
8) Utilidor, Erosion (critical utilities)			N/A
9) Stevenson Street	Direct Damage/Cost	N/A	N/A
10) Berm/Emergency Maintenance		Public safety risk from high-risk emergency maintenance	N/A

This resilience-based framework for evaluating without-project conditions and the effects of alternatives is translated into a CE/ICA analysis by identifying a set of output variables which may serve as measurement tools for the types of consequences shown in Table 6. Six such variables were identified for this framework, including:

Economic Resilience

- Direct Dollar Damage (DDD): dollar damages and costs, such as structure and content losses, or storm response costs.
- Full Time Equivalent Job Impacts (FTE): based upon estimated downtime for critical utility services, temporary employment impacts.

Social/Cultural Resilience

- Cultural resource acres at risk (CRA): Significant cultural resource areas will be quantified in terms of the total area at risk of loss.
- Person-days without critical utilities (PDU): Breach or damage to the Tasigarook Dam or Utilidor could result in critical utility systems going offline during the event and for some period following for recovery. Lack of fresh water, energy, or sanitation utilities would be equated to person-days of increased risk to human health and safety.
- Person-days high-risk job activity (PDH): During coastal storms, the NSB frequently must perform emergency berm repair and shore protection, necessitating machinery operator's work during dangerous conditions. This risk to human health and safety will be quantified in person-days of this high-risk emergency maintenance activity.

Environmental Resilience

- Cubic yards contaminated fill (CYF): Estimated volume of potentially contaminated materials at risk of spill from flooding or erosion.

Full description of CE/ICA methodology and analysis can be found in Appendix E. Four main steps were conducted for the CE/ICA. This section describes each step and the CE/ICA outputs. The four steps include:

1) Quantify without-project adverse effects by consequence category and output variable
2) Quantify each alternative's potential contribution to community resilience by estimating how much each alternative would reduce the adverse effects for each output variable

3) Compute Community Resilience Units (CRUs) for each alternative based on the percent reduction in adverse effects (increase in resilience) estimated for each alternative
4) Perform CE/ICA in Institute for Water Resources (IWR) Planning Suite

Figure 8 shows the resulting estimate of resilience output by alternative for each of the three resilience areas.

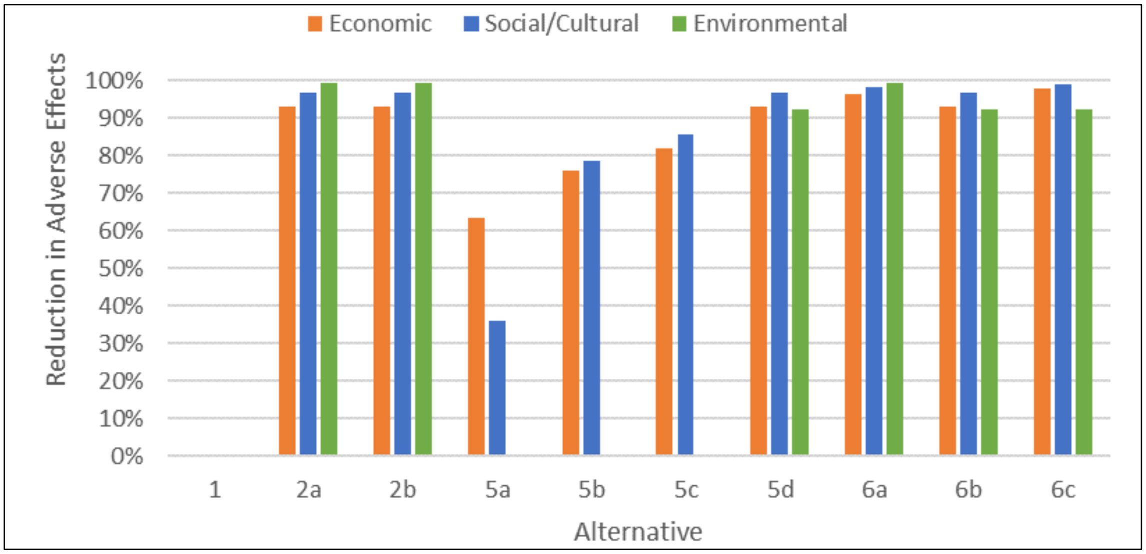

Figure 8. Triple Bottom Line Alternative Performance

Because the percent reductions used in previous steps were relative to the No-Action Alternative, the estimated total CRUs are inherently net of the No-Action Alternative. The total CRUs may also be averaged over the period of analysis to show average annual CRUs. Table 8 shows the estimated total CRUs and average annual CRUs for each alternative.

Table 8. CRUs by Alternative

Alt	CRUs	Average Annual CRUs
1	0	0.00
2a	2,925	58.50
2b	2,925	58.50
5a	1,038	20.77
5b	1,588	31.77
5c	1,720	34.41
5d	2,862	57.24
6a	2,935	58.71
6b	2,862	57.24
6c	2,856	57.12

The CE/ICA was performed using IWR Planning Suite for consistency with standard practices. Alternative cost (Table 6) and average annual CRUs (Table 7) were entered for each alternative and the CE/ICA was run. Based upon current costs and outputs, alternatives 1, 2, and 6A were identified as Best Buy plans, alternatives 5A, 5B, and 5C were identified as cost effective plans, and alternatives 5D, 6B, and 6C were not cost effective. Figure 9 presents a scatter plot of all the alternatives, differentiated. As shown in the figure, alternatives 2A and 2B have the same output, but a small difference in cost. Table 9 presents the incremental cost calculations for the best buy plans 1, 2 (A+B) and 6A.

Figure 9. All Plans Differentiated

*Alternative 2A and 2B have equal values and are represented as Alternative 2 in the Figure

Table 9. Incremental Cost Summary

Best Buy #	Alt	Average Annual Cost ($)	Annual CRUs	Incremental Cost	Incremental Output	Incremental Cost per Unit Output
1	1	$0	0	$0	0	$0
2	2A	$8,525,000	58.50	$8,525,000	58.50	$145,719
3	2B	$8,525,000	58.50	$8,525,000	58.51	$145,719
4	6A	$11,752,728	58.71	$327,728	0.20	$15,807,609

9. PROJECT CONSEQUENCES

In the future with-project (FWP) conditions, any action alternative would provide some level of protection from coastal erosion and flooding. All alternatives would be constructed along the coastline, which is a high energy environment. Therefore, there will be no significant impacts to the physical resources. Most impacts will be positive in reducing flooding and coastal erosion which will, in turn, create mostly positive benefits to social effects. Significant impacts for each resource are described below.

9.1 Terrestrial and Nearshore

All action alternatives, including the TSP, would provide some level of erosion protection to the bluffs, excluding Alternative 6C. Approximately 0.6 acres of tundra would be removed to place the revetment cap along the bluff. This is a minimal impact to the overall tundra loss since the primary vegetation in Barrow is tundra. Alternatives that include berm or raising and revetting Stevenson Street would be built along the coastline or on the existing road right-of-way. The beach would be less susceptible to wave erosion and flooding, and the City would be protected from larger storms.

Alternatives with limited reach, 5A, 5B, and 5C would not provide any protection to the landfill or the sewage outflow. In the event of a larger storm event or heavy winds from the west, these areas would be susceptible to breach, flushing their contaminants into the nearshore environment.

The beach nourishment alternatives (5D, 6A, 6B, and 6C) would cause a large impact on nearshore fish and invertebrates. These fish and invertebrates would be covered or displaced. The nearshore marine environment is a productive and dynamic area based on previous fish surveys and many of these fish would be harmed by placing large amounts of sediment near shore. The impacts would continue in future years, thought likely to a lesser extent, as more material is added to the beach nourishment areas for maintenance. These alternatives would also impact the nearshore environment by helping maintain or build up the beach and add more protection for wave run up along the low-lying areas over time. Beach nourishment would extend into the tidal zone, which is turbid due to the dynamic environment.

9.2 Recreation and Aesthetics

The coastline would be altered to some degree with each alternative. A sacrificial berm will no longer be needed. Alternatives with rock revetment or raising Stevenson Street would also change the area visually, limiting the view to the ocean by an additional +4 ft from street level. There will be boat ramps and access points along the revetments to allow for boating and beach access for social activities. Alternatives with beach nourishment would help maintain the beach in front of the City. This would allow activities to occur on the beach.

9.3 Historical/Archeological

All action alternatives incorporate some bluff revetment resulting in similar impacts. A section of the Utqiaġvik Village site would be directly under a section of the proposed revetment. This would cover the seaward section of the site and make it impossible for any future data recovery, as well as, place a significant amount of weight directly on top of the site. Normally, permafrost protects cultural resources in the Arctic, but this area has seen permafrost thaw. The amount of pressure that armor rocks would place on the cultural resources would increase under these conditions. The weight of the armor rocks, combined with the weakening permafrost, would likely cause the splash apron and cap to sink into the site. There may also be crushing from the revetment itself from the side as the soil loses its permafrost.

Alternative 5A is the only action alternative that would not protect the bluff at the Utqiaġvik Village Site from continued erosion, and effects would be similar to the No-Action Alternative. All other action alternatives would protect the archeological site in Barrow and the associated cultural resources and opportunities. SHPO coordination is on-going and would be finalized prior to construction. See Appendix H for all correspondence.

9.4 NED Damages

Alternatives 2A, 2B, 6A, and 6C

These alternatives are designed to provide protection throughout the study area resulting in similar effects for each. In the short term, positive, temporary benefits would occur in employment from construction of the project. Secondary benefits would be generated from the need to house, feed, and supply the workers fuel and materials. Over the longer term, these alternatives 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 alternatives 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.

Alternatives 5A, 5B, 5C, and 5D

These alternatives offer incrementally increasing levels of protection for the study area. In the short term, the study area is expected to experience positive income and employment effects from construction of any of these alternatives. However, implementation of successively larger alternatives would be expected to increase the magnitude of these positive effects as a result of increased construction cost, duration, and crew size, all of which could increase impacts.

Over the longer term, these alternatives 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. Alternative 5A, which protects critical infrastructure, would achieve the largest increment of beneficial regional effects. Successively larger plans would achieve additional benefits from protecting Browerville, NARL, and the South and Middle Salt Lagoons.

9.5 Social Effects of Alternatives

9.5.1 Life, Health, and Safety

Each alternative would reduce the identified risks to personal safety and mortality associated with coastal flooding, erosion, and flood fighting activities. The alternatives would also reduce coastal storm and erosion damages to property. There would also be an increase in the quality of life, a reduction in safety risk along the coastal roads, for residence resulting from the revetments, protection of life saving infrastructure, and a decreased risk of coastal flood emergencies.

Alternatives 2A, 2B, 6A, 6B, and 6C
Because these alternatives are designed to provide protection throughout the study area, effects would be similar. 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.

Alternatives 5A, 5B, 5C, and 5D
The magnitude of these positive effects increases with each alternative as additional areas are protected. All these alternatives offer protection of the Utilidor at Pump Station #4 from erosion damage and would reduce the potential damages to human health and safety risks that would be associated with an interruption in utility service. With alternatives 5A, 5C, and 5D, 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.

9.5.2 Regional Emergency

The action alternatives would result in a reduction of the flooding and erosion damage risk in Barrow. All the alternatives would reduce the risk of an emergency related to flooding or erosion. Regional emergency services would be able to spend more time, money, and attention on other needs within the community and region.

9.5.3 Population Effects

The action alternatives would result in a reduction of the flooding and erosion damage risk in Barrow. All the alternatives would reduce the risk of critical infrastructure failure and utility loss. The magnitude of other 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 as the level of protection increases.

9.5.4 Subsistence Production

All of the action plans would include access points along sections of the barriers to allow residents to have multiple entrances to the beach. These access points would also be used by the construction teams as the barrier is being constructed to safely move from either side for construction. The access points would be open to local subsistence hunters and whalers for use of these access points to deploy their boats. There would be no change to the subsistence lifestyle nor any known detriment to local wildlife.

9.5.5 Existing Infrastructure and Facilities

The action alternatives would result in a reduction of the flooding and erosion damage risk in Barrow. All alternatives would provide protection to existing infrastructure and facilities. The potential for a loss of infrastructure and facilities due to coastal erosion or flooding would be greatly reduced. Alternatives 2A, 2B, 5D, 6A, 6B, and 6C would reduce the identified risks to existing infrastructure along the entire proposed project length. Alternatives 5A, 5B, and 5C are more limited in scope and would protect critical infrastructure, but leave most of Stevenson Street exposed.

9.6 Unavoidable Adverse Impacts

The principle unavoidable adverse impact would be to cultural resources along the bluff face where a revetment is proposed. Mitigation would take place and local fill, where available, would be used to build out from the bluff in order to minimally impact the Utqiaġvik Historic Site. The placement of rock along the beach may alter the coastline over time, but is the best measure for ensuring preservation of the beach and access for subsistence activities. The completed project would have fewer access points than the current layout of the shoreline, but would protect life-sustaining infrastructure during storm events.

10. CONCLUSIONS & RECOMMENDATIONS

10.1 Conclusions

The Corps proposes that the coastal storm risk management recommended plan at Barrow, Alaska be Alternative 2 (a combination of Alternatives 2A and 2B) to include bluff revetment, a revetted berm, and raising and revetting Stevenson Street. Although there is no NED plan, the CE/ICA shows that Alternative 2 (combination of Alternative 2A and 2B) has the highest CRUs with the lowest project costs. Construction of the recommended plan would greatly improve the quality of life in the community for the long term as well as allow for future growth. The proposed plan would not constitute a significant impact to the quality of the human environment because the study area is already disturbed annually by coastal erosion and is constantly disturbed by human activity. There will be boat ramps, access points and interior drainage points along the revetments to allow for boating and beach access for subsistence, recreational and social activities. The U.S. Army Corps of Engineers (Corps) is working with the Sponsor and community to collect feedback on optimal locations for access points, boat ramps and interior drainage points. This design will be finalized in subsequent phases of this project. The non-Federal Sponsor (NSB) supports this recommended plan.

10.2 Recommendations

The Corps proposes that the coastal storm risk management measure at Barrow, Alaska be constructed generally in accordance with the recommended plan herein, and that any modifications that may be advisable thereof be at the discretion of the Chief of Engineers, at a certified estimated total project cost with contingency of $193,000,000, with no debt financing, annual Federal maintenance costs, or other obligations of future appropriations.

Recommendations for provisions of Federal participation in the recommended plan described in this report would require the project sponsor to enter into a written Project Partnership Agreement (PPA), as required by Section 221 of Public Law 91-611, as amended, to provide local cooperation satisfactory to the Secretary of the Army. Such local cooperation shall provide, in part, the following draft items of local cooperation:

a. Provide 35 percent of design costs allocated to hurricane and storm damage reduction in accordance with the terms of a design agreement entered into prior to commencement of design work for the project;
b. Provide, during construction, any additional amounts necessary to make its total contribution equal to 35 percent of initial Project costs;
c. Acquire the real property interests, and provide the Government with authorization for entry thereto in accordance with the Government's schedule for construction of the Project, and ensure that real property interests provided for the Project are retained in public ownership for uses compatible with the authorized purposes of the Project;
d. Operate, maintain, repair, rehabilitate, and replace the Project, or such functional portion thereof in a manner compatible with the authorized purpose of the Project and in accordance with applicable Federal and State laws and specific directions prescribed by the Government in the OMRR&R Manual and any subsequent amendments;
e. Perform surveillance of the Project, at least annually and after storm events, to determine losses of material;
f. Publicize information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations or taking other actions to prevent unwise future development, and to ensure compatibility with the Project;
g. Prevent obstructions or encroachments on the Project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) that might reduce the level of protection the Project affords, hinder operation and maintenance of the Project, or interfere with the Project's proper function;
h. Ensure the continued public use of Federal shores compatible with the authorized purpose of the Project;
i. Provide and maintain necessary access roads, parking areas, and other associated public use facilities, open and available to all on equal terms;
j. Not use Federal Program funds to meet any of its obligations under this Agreement unless the Federal agency providing the funds verifies in writing that the funds are authorized to be used for the Project;
k. Comply with all the requirements of applicable Federal laws and implementing regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964 (P.L. 88-352), as amended (42 U.S.C. 2000d);Department of Defense Directive 5500.11; the Age Discrimination Act of 1975 (42 U.S.C. 6102); the Rehabilitation Act of 1973, as amended (29 U.S.C. 794); and Army Regulation 600-7;

    1. Request in writing that the Government perform betterments on behalf of the Non-Federal Sponsor, and if the Government agrees to such request, the Non-Federal Sponsor must provide funds sufficient to cover the costs of such work in advance of the Government performing the work;
    2. Perform or ensure the performance of relocations in accordance with the Government's construction schedule for the Project or request in writing that the Government acquire all or specified portions of such real property interests, construct disposal area improvements, or perform the necessary relocations;
    3. Assure that fair and reasonable relocation payments and assistance shall be provided to or for displaced persons within a reasonable period of time prior to

displacement, comparable replacement dwellings will be available to displaced persons and property owners will be paid or reimbursed for necessary expenses;

4. If hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) are found to exist in, on, or under any required real property interests, the parties shall consider any liability that might arise under CERCLA and determine whether to initiate construction, or if already initiated, whether to continue construction, suspend construction, or terminate construction, and the non-Federal sponsor responsibilities will include:
    a. Undertaking any investigations to identify the existence and extent of any hazardous substances regulated under CERCLA that may exist in, on, or under real property interests required for construction, operation, and maintenance of the Project;
    b. Costs of cleanup and response, including the costs of any studies and investigations necessary to determine an appropriate response to contamination;
    c. Consult with the Government in an effort to ensure that responsible parties bear any necessary cleanup and response costs as defined in CERCLA;
5. Provide documents sufficient to determine the amount of credit to be provided for the real property interest;
6. Obtain, for each real property interest (except interests in lands subject to shore erosion that are publicly owned) an appraisal for fair market value;
7. Hold and save the Government free from all damages arising from design, construction, operation, maintenance, repair, rehabilitation, and replacement of the Project, except for damages due to the fault or negligence of the Government or its contractors.

The recommendations for implementation of coastal storm risk management measures at Barrow, Alaska reflect the policies governing formulation of individual projects and the information available at this time. They do not necessarily reflect the program and budgeting priorities inherent in the local and State programs or the formulation of a national civil works water resources program. Consequently, the recommendations may be changed at higher review levels of the executive branch outside Alaska before they are used to support funding.

____________________________ ____________________
PHILLIP J. BORDERS Date
COL, EN
Commanding

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Barrow Alaska Coastal Erosion Feasibility Study

Appendix A: Policy and Guidance

Barrow, Alaska

August 29, 2018

US Army Corps
of Engineers
Alaska District

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

CECW-PB/CEMP-POD

MAY 10 2012

MEMORANDUM FOR COMMANDER, PACIFIC OCEAN DIVISION

SUBJECT: Implementation of Studies and Projects under Section 116 of the Energy and Water Development and Related Agencies Appropriations Act, 2010, Public Law 111-85

1. Section 116 of the Energy and Water Development and Related Agencies Appropriations Act of 2010 (P.L. 111-85) provides authority for the Secretary of the 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 Act provides that the non-Federal cost share of any project carried out pursuant to Section 116 shall be no more than 35 percent 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). A copy of Section 116 is enclosed. Guidance for the implementation of Section 116 was previously issued by HQUSACE on 1 June 2010. This guidance replaces the previous version.

2. At such time that funds are appropriated, the District shall prepare a Project Management Plan (PMP) and negotiate a feasibility Cost Share Agreement (FCSA) with a non-Federal sponsor. The Feasibility Cost Sharing Agreement model for studies of proposed projects under the Continuing Authorities Program and for studies of proposed projects under other Program authorities that do not require additional authorization to implement a project should be used. Upon completion of the PMP and the execution of the FCSA the District will undertake a feasibility study in accordance with the polices and procedures of Engineer Regulation (ER) 1105-2-100 and CECW-CP Memorandum dated 8 February 2012, subject: U.S. Army Corps of Engineers Civil Works Feasibility Study Program Execution and Delivery, and will be cost shared with the non-Federal sponsor at 50 percent Federal and 50 percent non-Federal. The feasibility study will conform to the process for projects authorized without a report as discussed in ER 1105-2-100 Appendix H including the preparation of a Director's Report.

3. Each decision document will present the National Economic Development (NED) analysis for all viable alternatives and identify the NED Plan when alternatives exist with net positive NED benefits. If there is no NED Plan and/or the selection of a plan other than the NED Plan is based in part or whole on non-monetary units (Environmental Quality and/or Other Social Effects), then the selection will be supported by a cost effectiveness/incremental cost analysis consistent with established evaluation procedures (see ER 1105-2-100, Appendix E). The decision document will present the tradeoffs of impacts in the four accounts for the plans contained in the

final array and describe in detail the compelling justification for any plan that is not the NED Plan. Non-monetary benefits that may be considered include such things as public health and safety; local and regional economic opportunities; and, social and cultural value to the community. For each project, a decision document will be prepared that identifies a recommended plan and complies with all applicable environmental laws, regulations, and policies. In addition, an ability to pay analysis will be conducted in accordance with existing Ability to Pay Guidance in the Final Amended Rule, Federal Register, (60 FR 5133), 26 January 1995 and included in the feasibility report.

4. Subject to a determination by the Assistant Secretary of the Army (Civil Works) [ASA(CW)], and to the appropriation of funds for design of a project, a Design Agreement (DA) may be negotiated with an appropriate non-Federal interest in accordance with section 221 of the Flood Control Act of 1970, as amended (42 U.S.C. 1962-5b). Design costs will be shared 65 percent Federal and 35 percent non-Federal in accordance with the terms of the DA.

5. Subject to a determination by the ASA(CW), and to the appropriation of funds for construction of a project, a Project Partnership Agreement (PPA) may be negotiated with an appropriate non-Federal interest in accordance with section 221 of the Flood Control Act of 1970, as amended (42 U.S.C. 1962-5b). Construction costs will be shared 65 percent Federal and 35 percent non-Federal in accordance with the terms of the PPA. Operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) of the completed project are a 100% non-Federal responsibility.

6. On 11 March 2009, Section 117 of the Energy and Water Development Appropriations Act, 2005 (Division C of the Consolidated Appropriations Act, 2005, Public Law 108-447) (hereinafter "Section 117") was repealed. At the time of the repeal, a number of Alaska District projects were underway using Section 117 as the authority for full Federal funding of costs associated with those projects. With limited exceptions, Section 117's repeal barred further full Federal funding of these projects, requiring their prompt termination. In proposing the initiation of new work on these projects under Section 116, the Alaska District shall follow all requirements of this guidance, except for the four Alaska Coastal Erosion projects (Unalakleet Shoreline Erosion, Kivilina Shoreline Erosion, Shishmaref Shoreline Erosion, and Newtok Shoreline Erosion) that were under construction at the time of repeal of Section 117. Subject to the availability of funds and amendment of existing PPAs to reflect the cost sharing requirements for work pursuant to Section 116, the Alaska District may proceed under the Section 116 authority to enter into construction contracts or modification of the existing construction contract to complete the four named projects as defined by their respective Decision Documents. For each of these four named projects, the Pacific Ocean Division (POD) Commander shall forward to the POD Regional Integration Team for HQ-level review and submission to ASA(CW) for

approval, a PPA amendment package to incorporate the cost share and OMRR&R requirements set out in paragraph 5. The amendment package will include the previously executed Section 117 agreement with proposed changes indicated by redline/strikeout.

FOR THE COMMANDER:

Theodore A. Brown

Encl

THEODORE A. BROWN, P.E.
Chief, Planning and Policy Division
Directorate of Civil Works

Section 116 of the Energy and Water Development and Related Agencies Appropriations Act, 2010, Public Law 111-85, Title I 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)."*

Barrow Alaska Coastal Erosion Feasibility Study

Appendix B: Geotechnical

Barrow, Alaska

August 29, 2018

US Army Corps of Engineers
Alaska District

PRELIMINARY GEOTECHNICAL APPENDIX
BARROW ALASKA COASTAL EROSION FEASIBILITY STUDY
BARROW, ALASKA

1. INTRODUCTION

1.1 This preliminary geotechnical appendix is provided in support of the on-going coastal erosion feasibility study for Barrow, Alaska, being prepared by the Alaska District, U.S. Army Corps of Engineers. This appendix will be updated on conclusion of geotechnical field investigations and LIDAR/bathymetric surveys planned for summer 2018, along with additional research to be conducted on significant study issues (e.g. rock and gravel material sources) during the Planning, Engineering and Design (PED) Phase.

1.2 The specific problem being addressed by the feasibility study is the occurrence of frequent and severe coastal storms in Barrow, resulting in coastal erosion and flooding which threaten public health and safety and the economy of the community. The study's intent is to identify a safe and functional method of coastal storm damage protection, with objectives to: (1) reduce risk to public health, life, and safety; (2) reduce damages caused by flooding and shoreline erosion to residential and commercial structures and critical public infrastructure; and (3) reduce or mitigate damage to tangible cultural heritage. Details on the coastal erosion and flooding problem are covered in the main report summary and are not elaborated within this appendix. The geotechnical contribution to the feasibility study is to provide input on geotechnical site conditions that impact and influence the selection of measures to mitigate the coastal erosion and flooding problem.

1.3 Barrow is located approximately 750 miles north of Anchorage and 320 miles north of the Arctic Circle (Figure 1). The coastal city of Barrow has a population of approximately 5,000 and is positioned where the Chukchi Sea meets the Beaufort Sea. Some of the main geographic and cultural features of the immediate Barrow study area are shown in Figure 2. As noted, the extent of coastline currently being studied is approximately 25,300 feet in length.

Figure 1 - General Site Location.

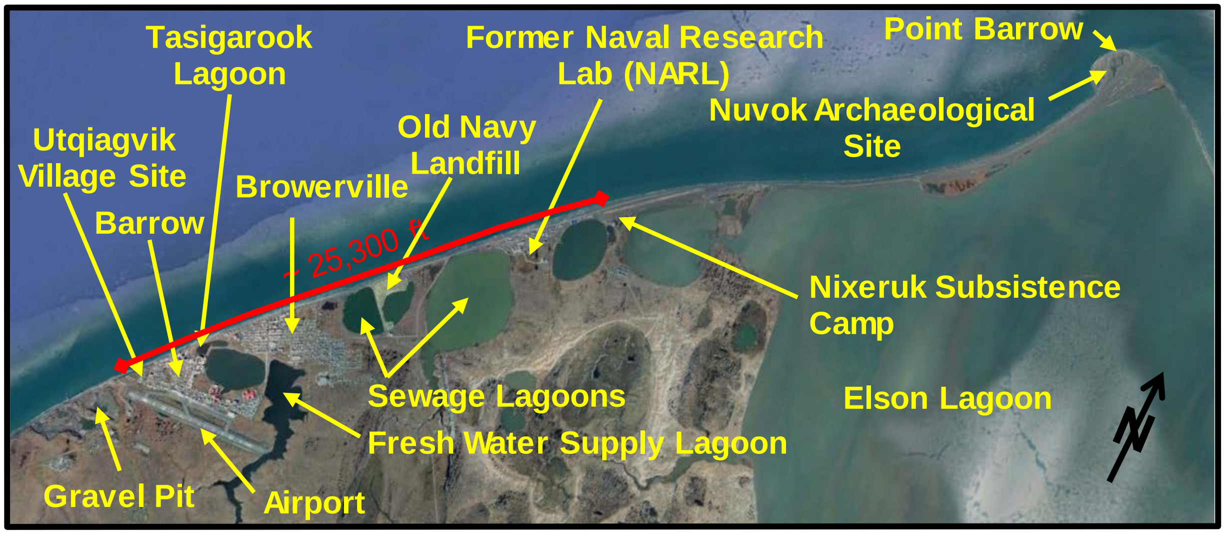

Figure 2 - Features within Study Area.

2. ALTERNATIVES AND TENTATIVELY SELECTED PLAN

2.1 The study team has narrowed the focus to the following mitigation alternatives for further evaluation in final determination of the Tentatively Selected Plan (TSP). The TSP Milestone was achieved on 28 June 2018 with Alternatives 2A and 2B chosen as the recommended plans. A description of each alternative is listed below.

- **Alternative 1:** No Action
- **Alternative 2A:** Rock Revetment and Berm-Protected Stevenson Street (rock revetment along bluff with revetted berm in front of Stevenson Street)
- **Alternative 2B:** Rock Revetment and Raised Stevenson Street (rock revetment along bluff with raised and revetted Stevenson Street)
- **Alternative 5A:** Protect Major Infrastructure (rock revetment, revetted berm, and fill Tasigarook lagoon limited to protect Utilidor and water supply)
- **Alternative 5B:** Barrow/Browerville Neighborhoods (extended rock revetment along bluff, revetted berm, and fill Tasigarook lagoon)
- **Alternative 5C:** Barrow/Browerville Neighborhoods plus NARL (extended rock revetment along bluff, revetted berm, fill Tasigarook lagoon, with raised and revetted Stevenson Street along NARL)
- **Alternative 5D:** Barrow/Browerville Neighborhoods plus NARL and Old Navy Landfill (extended rock revetment along bluff, revetted berm, fill Tasigarook lagoon, with raised and revetted Stevenson Street along NARL and beach nourishment along Old Navy Landfill)
- **Alternative 6A:** Combination Rock Revetment, Raised Stevenson Street, and Revetted Berm with Limited Beach Nourishment (rock revetment along bluff with raised and revetted Stevenson Street, except for a revetted berm with beach nourishment adjacent to Tasigarook lagoon and revetted berm without beach nourishment adjacent to Browerville)

- **Alternative 6B:** Combination Rock Revetment, Raised Stevenson Street, Revetted Berm, and Beach Nourishment (rock revetment along bluff, revetted berm with beach nourishment adjacent to Tasigarook lagoon, revetted berm without beach nourishment adjacent to Browerville, beach nourishment between Browerville and NARL, and raised and revetted Stevenson Street through NARL)
- **Alternative 6C:** Beach Nourishment Only (beach nourishment along entire study area)

2.2 Details of Alternative 6A are shown in Figure 3 as a detailed example of the alternatives being proposed. The individual reaches (i.e. discrete sections along the coastline with specific mitigation measures identified) were developed based on a combination of geomorphic conditions (e.g. bluff versus beach) and features to be protected (e.g. major infrastructure). Reach locations will be better defined following geotechnical, hydraulic/hydrology, and survey field investigations to be performed in PED (e.g. the transition from bluff to beach; bluff slope and height; exact location of critical infrastructure).

Figure 3 - Alternative 6A (Combination Rock Revetment, Raised Stevenson Street, Revetted Berm, and Beach Nourishment).

3. GEOTECHNICAL SITE CONDITIONS

3.1 Geomorphology. Coastline photos were taken by the USGS in August 2006 for the North Slope area, including Barrow. Photo locations within the Barrow study area are plotted on Figure 4, with the photos given in Figures 5 through 21. Geomorphology combined with the nature of the subsurface materials across the study area have had a significant influence on the area's susceptibility to erosion and flooding, which will be discussed further in this appendix. The southwest portion of the study area (Figures 5 through 11) is characterized by high bluffs which gradually reduce to relatively low relief beaches abutting a slightly elevated Stevenson Street for the remainder of the study area (Figures 12 through 22). The bluffs are highest between the SKW gravel pit (Figure 5) and the Utqiagvik Village Site (Figure 8), ranging up to approximately 30 feet in height. Through storm wave action, the bluffs have been eroding and receding, and the low relief beaches have also been susceptible to erosion while presenting avenues for flooding of low-lying inland property. Field work to be performed in PED will better define material characteristics of the bluffs and beach that have made them continuously susceptible to erosion.

Figure 4 - Photograph Locations.

Figure 5 - SKW (City) Gravel Pit.

Figure 6 - SKW and ADOT Gravel Pits.

Figure 7 - Airport Runway.

Figure 8 - Utqiagvik Village Site.

Figure 9 - Barrow Neighborhood.

Figure 10 - Barrow Neighborhood.

Figure 11 - Barrow Neighborhood.

Figure 12 - Tasigarook Lagoon.

Figure 13 - In Front of Tasigarook Lagoon.

Figure 14 - Browerville Neighborhood.

Figure 15 - Browerville Neighborhood.

Figure 16 - Browerville Neighborhood.

Figure 17 - Edge of Browerville Neighborhood.

Figure 18 - Old Navy Landfill.

Figure 19 - Stevenson Street before NARL.

Figure 20 – NARL.

Figure 21 - Barge Unloading at Edge of NARL.

Figure 22 - Emergency Runway at End of Study Area.

3.2 Geologic Setting

3.2.1 The geology of Alaska is quite complex in its tectonic history, lithology, seismicity, structural geology (e.g. faults and folds), and stratigraphic characteristics. Fortunately for this geotechnical appendix, geologic conditions relevant to the feasibility study are fairly straight forward and relate to shallow soil conditions and relatively recent geologic factors (e.g. glaciation and sea level changes) across the site. A geologic map of Alaska covering the North Slope area is provided in Figure 23. A map showing common geologic provinces within northern Alaska is given in Figure 24. Barrow and the study area fall within the Arctic Coastal Plain, bound on the north by the Beaufort Sea, on the south by foothills of the Brooks Range, and on the west by the Chukchi Sea. Referring to Figure 23, the entire North Slope area is underlain by unconsolidated to poorly consolidated surficial deposits (QTs) of Quaternary, Pleistocene and upper Tertiary age. The sediment characteristics vary with location, but in general range from silt to coarse gravel, originating as fluvial, glaciofluvial, colluvial, eolian, and shallow marine deposits. Bedrock mainly consists of Cretaceous sedimentary rock, occurring at varying depths in an unconformable contact (i.e. age gap due to erosion or geologic structure) with these surficial deposits.

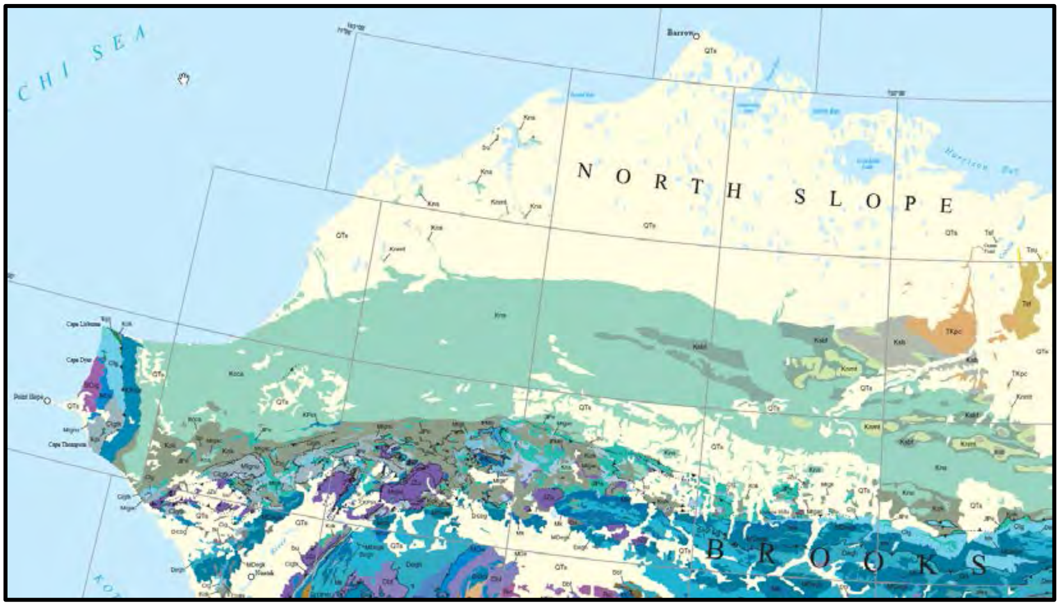

Figure 23 - Geologic Map of Alaska.

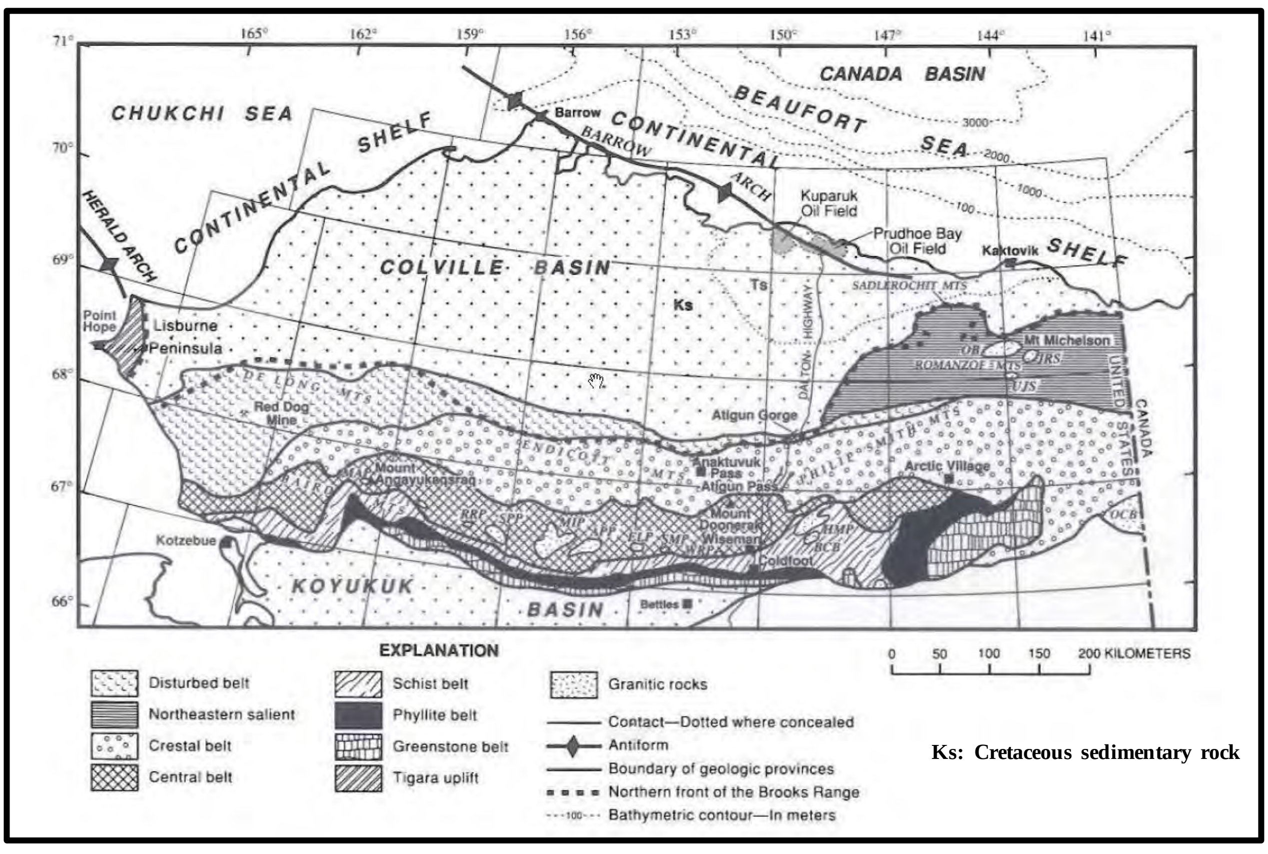

Figure 24 - Geologic Provinces within Northern Alaska.

3.2.2 Unconsolidated surficial deposits underlying the northern part of the Arctic Coastal Plain belong to the Quaternary Gubik Formation, generally consisting of marine and fluvial deposits characterizing a shallow near-shore shelf environment with periods of uplift and erosion and frequent shifting of the shoreline. The Gubik Formation is composed of three units, given in order of oldest to youngest: Skull Cliff Unit; Meade River Unit; and Barrow Unit. Figure 25 shows the distribution of these units, with the Barrow Unit most represented within the study area. The Barrow Unit consists of poorly-sorted to well-sorted mixtures of clay, silt, sand, and gravel, generally of marine origin near its base and lacustrine and fluvial in origin within its uppermost layers. Part of the Barrow Unit may be glacially derived, ice locally constitutes more than half its volume, and organic matter is abundant in its upper part. Previous investigations indicate that the Barrow Unit is generally 25 to 50 feet thick and is underlain by the Skull Cliff Unit which is mainly composed of silt and clay. The Gubik Formation within the immediate Barrow area is underlain by Cretaceous sedimentary rock (sandstone, conglomerate, shale, and coal) at depths below ground surface ranging from approximately 50 to 100 feet, based on a number of deep core borings conducted in the 1940s and 1950s.

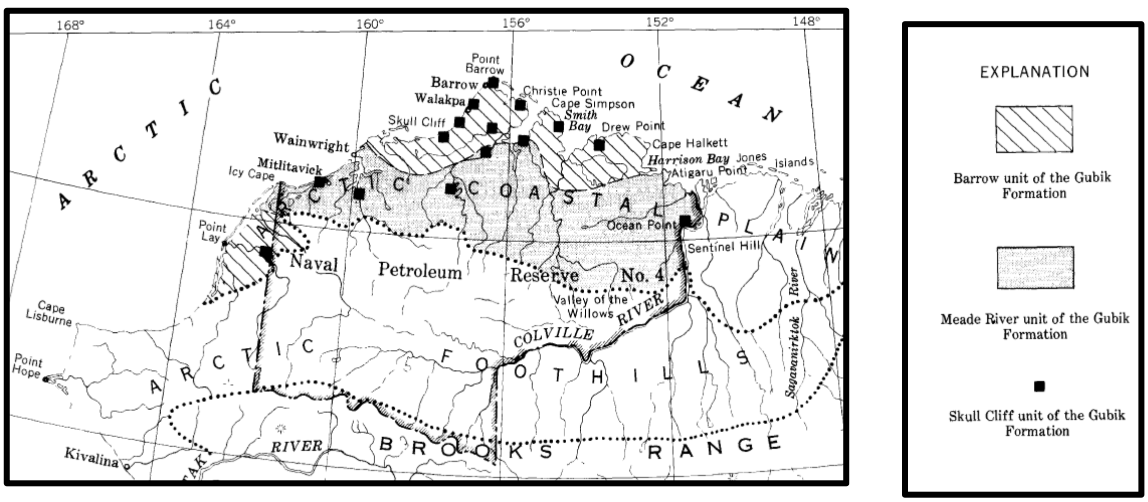

Figure 25 - Distribution of Gubik Formation within Arctic Coastal Plain.

3.3 Permafrost

3.3.1 The study area is underlain by continuous permafrost, defined as ground that maintains a temperature at or below 32° F for at least two consecutive years. Available information indicates that permafrost in the Barrow area may extend as much as 1,300 feet below the surface. The depth of the active layer below the surface (i.e. the zone that is subject to seasonal freeze-thaw cycles) typically varies between 1.5 and 3.0 feet. The presence of permafrost has resulted in characteristic surface features exhibited in the general study area, as illustrated in Figures 26 (ice wedges), 27 (polygon pattern), and 28 (thermokarst lakes).

3.3.2 Ice wedges are produced by the formation of thermal contraction cracks in winter and subsequent filling of the cracks with hoar frost, snow, and meltwater. Repeated cracking and filling of the vertical to near-vertical cracks results in wedges that can be as large as several meters across at the top, tapering downwards to apices that can be as deep as 10 m. Wedges then intersect across the landscape to form a network of enclosed polygons 5 to 30 meters in diameter. Ice wedges can be exposed along coastal bluffs, such as shown in Figure 26, where exposure to wind and wave action can dramatically accelerate thawing and erosion of the bluff.

3.3.3 Thermokarst lakes are formed by water collecting within ice wedge polygons, forming a pool at the surface. These pools deepen and expand laterally by thawing near-surface ice-rich permafrost along the pool edges and beneath the water. As shown in Figure 28, these thermokarst lakes are oriented with their long axes normal to the prevailing east-northeast and west-southeast winds as a result of wind-induced waves and currents which build protective banks on the downwind shores and concentrate erosion on the north-northwest and south-southeast shores.

Figure 26 - Ice Wedges along Coastline Bluff (Cape Blossom, Alaska).

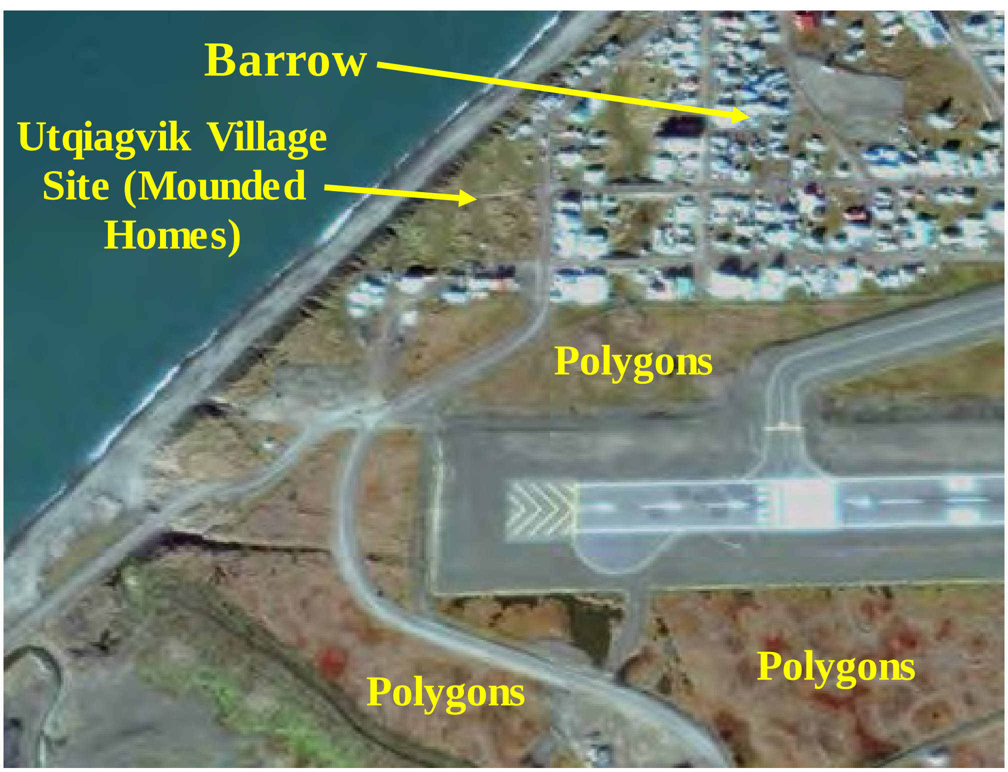

Figure 27 - Polygon Pattern (Barrow, Alaska).

Figure 28 - Thermokarst Lakes (Barrow, Alaska).

3.3.4 A unique aspect of coastal permafrost is that the permafrost contains dissolved salts in its pore water. Saline permafrost, also referred to as unbonded permafrost, freezes at lower sub-zero temperatures because of freezing-point depression of the dissolved salts, resulting in the permafrost only being partially frozen. The mechanical properties of saline permafrost have been well researched and documented in construction practice. Saline permafrost is mechanically weaker than non-saline permafrost, has reduced allowable strength and bearing capacity in foundation applications (e.g. spread footings and piles), has reduced stability in open trenches and excavations, and exhibits prolonged deformation under load (creep). In this relatively weak state, saline permafrost exposed along coastal bluffs such as in Barrow would be particularly susceptible to thaw and erosion.

3.4 Previous Geotechnical Site Investigations. There have been several geological and geotechnical site investigations conducted in the past within the Barrow area that provide information of value to this feasibility study - primarily regarding subsurface conditions and the search for local gravel materials to support potential coastal erosion mitigation measures. Relevant details of these investigations are summarized in Table 1, with approximate site investigation locations shown in Figures 29 through 31 (ID numbers in Table 1 are linked to site location). There have also been material source investigations conducted outside of the general Barrow area, with findings applicable to this study. Relevant details of these broader material source investigations are summarized in Table 2, with approximate source locations given in Figure 32 and photos of some of the sources shown in Figure 33. More complete documentation for these material source investigations will be provided in the final version of this geotechnical appendix.

Table 1 - Summary of Site Investigations within Barrow Area.

ID No.	Title/Author	Date	Comment
1	Fill Materials and Aggregate Near Barrow Naval Petroleum Reserve No. 4, Arctic Institute of North America	Jan 1973	Regional Exploration. Investigated possible gravel and coarse sand deposits within 25 mile radius of Barrow. Reported about 25 million yd^3 of gravel and sand, about 4 million yd^3 readily exploitable-without severe environmental damage. Identified these potential borrow sources: Barrier Islands (e.g. Cooper Island); western coast line and bluffs southwest of Barrow; southwest side of Point Barrow spit; uplifted beach ridges (e.g. Central Marsh Ridge); and isolated deposits south of Nunavak Bay.
2	Geotech Investigations for Barrow Utilities, Harding-Lawson Associates	Feb 1979	Barrow Neighborhood. 80 borings drilled to a maximum depth of 20.0 ft. Below a surficial layer of peat (average thickness 1.5 ft), soil generally consists of sandy silt and silty sand. Upper 5 ft has an organic content. Silt is more common in 5 to 10 ft range; silt decreases and sand becomes more predominant below 10 ft. Occasional stratum of gray to black silty clayey soil. Massive ice is greatest in 5 to 10 ft depth range, thickness up to 13 ft. Active layer in undisturbed areas 8 to 12 inches below surface. Unbonded permafrost in some borings due to saline content, with salinity increasing significantly below 10 ft. Fill material is locally present.
3	Same as above	Feb 1979	Browerville Neighborhood. 25 borings drilled to a maximum depth of 20.0 ft. Below a surficial layer of peat (average thickness 1.0 ft), soil generally consists of sandy silt and silty sand. Upper 5 ft has an organic content. Silt is more common in 5 to 10 ft range; silt decreases and sand becomes more predominant below 10 ft. Occasional stratum of gray to black silty clayey soil. Massive ice is greatest in 5 to 10 ft depth range, thickness up to 13 ft. Active layer in undisturbed areas 8 to 12 inches below surface. Unbonded permafrost in some borings due to saline content, with salinity increasing significantly below 10 ft. Fill material is locally present.
4	Same as above	Feb 1979	Sewer Outfall Alignment (Stevenson Street). 11 borings drilled to a maximum depth of 20.5 ft. Upper zone of peat or organic sandy silt to maximum 4-ft depth, typically underlain by ice-rich silty sand or sandy silt to bottom of borings. Some borings encountered 9 to 10 ft of massive ice directly below the peat. Zones of unbonded permafrost were encountered in five borings. Silty sand, gravelly sand, and sandy gravel found in four borings near South Salt Lagoon.
5	Same as above	Feb 1979	Block A. Six borings drilled to a maximum depth of 20 ft. Upper zone of sandy silty organic material (peat) to a maximum 3.5-ft depth, underlain by massive ice and ice-rich sandy silt to a depth of 15 to 18 ft, underlain by sandy silt and silty sand to the depth explored.
6	Preliminary Report - Barrow Winter Granular Borrow Source Study, RZA Inc. Geotech Consultants	Jun 1982	Elson Lagoon. Forty-six borings drilled within lagoon near Point Barrow spit. Identified two areas immediately against the spit with fine to coarse gravelly sand (25% gravel and 3% silt) with no significant overburden. Searching for final report with borehole details.
7	Same as above	Jun 1982	Emaiksoun Lake. Forty-nine borings drilled to maximum depth of 40.0 ft. Soil consists of clayey silt to silty fine sand.

ID No.	Title/Author	Date	Comment
8	Same as above	Jun 1982	Middle Salt Lagoon. Thirty-eight borings drilled to maximum depth of 35.0 ft. Northern shoreline consists of medium to coarse gravelly sand (12% gravel and 10% silt) with no significant overburden. Fine-grained soil elsewhere in the lagoon.
9	Same as above	Jun 1982	North Salt Lagoon. Three borings drilled along northern shoreline of lagoon. Soil consists of icy, silty fine sand.
10	Same as above	Jun 1982	Nunavak Bay. One hundred fifteen borings drilled in the northern and southern portion of the bay and upland area. Sandy gravel to gravelly sand (15% gravel and 5% silt) found along upper 9 feet of a barrier bar at mouth of Nunavak Bay. Elsewhere in the bay, material consists of silt to silty fine sand with occasional minor lenses of gravelly sand. Within upland area, a 6-ft thick deposit of silty gravel interlayered with gravelly silt is overlain by at least 20 ft of overburden consisting of icy silty soil.
11	Same as above	Jun 1982	Footprint Lake. Six borings were drilled across the lake, with the soil consisting of sandy silt and clayey silt.
12	Upland Barrow Borrow Source Reconnaissance, RZA Inc. Geotech Consultants	Oct 1982	Fresh Water Lake Road Beach Strand. Thirteen borings drilled along a 3-mile long relic beach strand to a maximum depth of 30.0 ft. A tundra mat covers the area to a maximum depth of 1.5 ft. Below the tundra, silty ice and icy silt with random pockets of icy silty sand and sandy silt to depths of 2 to 18 ft, underlain by icy gravelly sand and sandy gravel in strata 6 to 10 feet thick, underlain by icy silty sand and sandy silt to the depth explored.
13	Same as above	Oct 1982	Upper Isatkoak Lagoon Beach Strand. Five borings drilled along a 2.7-mile long relic beach strand to a maximum depth of 30 ft. A tundra mat covers the area to a maximum depth of 1.5 ft. Below the tundra, the soil primarily consists of icy silty sand, sandy silt, and silt to the depth explored. There are some intervening horizons of icy gravelly sand, sandy gravel, and sand.
14	Same as above	Oct 1982	Gas Well Road Beach Strand. Six borings drilled along and adjacent to a 4.5-mile long relic beach strand to depths of 15 to 30 ft. Below a 1.5-ft thick tundra mat, three borings within the beach ridge found icy silty sand and sandy silt with no significant gravel component. Below a 1.5-ft thick tundra mat, three borings drilled within a dry lake bed found icy sandy silt in upper 5 to 7 ft, underlain by icy gravelly sand and sandy gravel to depths of 6 to 16 ft, underlain by icy sandy silt and silty sand to the depth explored.
15	Barrow Borrow Source Study, RZA Inc. Geotech Consultants	Jul 1983	Upper Isatkoak Lagoon Area. Forty-four borings drilled to a maximum depth of 35.0 ft. Top 5 to 25 ft consist of non-usable overburden materials (sod mat; silt; ice; icy silty sand; icy silty, fine gravelly sand), underlain by fine gravelly sand and sand (non-continuous gravel content) with a thickness ranging from 1 to 30.5 ft.

ID No.	Title/Author	Date	Comment
16	Same as above	Jul 1983	Fresh Water Lake Road Area. Sixty-three borings drilled to a maximum depth of 35.0 ft. Top 5 to 15 ft consist of non-usable overburden materials (sod mat; silt; ice; icy silty sand; icy silty, fine gravelly sand), locally as thick as 20 ft, underlain by fine gravelly sand and sand (discontinuous horizons) with thicknesses ranging from 5 to 10 ft for the fine gravelly sand and 5 to 15 ft for the sand.
17	Same as above	Jul 1983	Gas Well Road Area. Twenty borings drilled to a maximum depth of 34.0 ft. Upper tundra mat and icy, organic silt and sandy silt layer from 3 to 17 ft, underlain by fine-grained icy materials (silt, silty sand, sand) with only sparsely scattered lobes of granular material. Not a viable gravel source.
18	Same as above	Jul 1983	Elson Lagoon. Six borings drilled to a maximum depth of 42.0 ft. Relatively uniform subsurface conditions consisting primarily of interbedded fine sandy silt and silty fine sand below lagoon water and ice. Not a viable gravel source.
19	Barrow Offshore Exploration, BTS/LCMF Limited	Sep 1988	Offshore Exploration. Fifty-four vibracores taken offshore from City gravel pit area up to Browerville. Vibracores up to 20 ft in length, taken in water depths from 7 to 40 ft. Sediment mainly silt and sand with little gravel content. Subsequent dredging in 1999 produced material high in silt with very little gravel content.
20	Foundation Investigation - Staff Housing, IHS Hospital, Duane Miller & Associates	Feb 1991	Foundation Investigation. Eleven borings drilled to maximum depth of 25.0 ft. Subsurface consists of upper sand layer underlain by silt, sandy silt, silty clay and silty sand. Site is underlain by permafrost, some being ice-rich. Pore fluid has high salinity, with much of the soil marginally bonded to unbonded. Poorly bonded soil typically found between depths of approximately 8 to 23 ft. Salinity ranges from 2 to 73 ppt, increasing with depth.
21	Geotech Investigation - Sanitation Facility, Duane Miller & Associates	Nov 1993	Foundation Investigation. Four borings drilled to maximum depth of 20.0 ft in a coastal beach environment. Stratigraphy from top to bottom consists of: sandy gravel and gravelly sand fill material to a depth of about 2 ft; then poorly-graded sand with occasional coarse gravel component to the depth explored. Continuous bonded permafrost below active layer, with salinity values less than 7 ppt.
22	Geotech Exploration, Naval Arctic Research Laboratory, Duane Miller & Associates	Aug 1994	Environmental-Related Investigation. Eight borings drilled to depths of 8 to 20 ft along alignment of proposed berm and contaminant recovery trench on NARL facility. Stratigraphy from top to bottom consists of: poorly-graded sand, silty sand and gravelly sand fill material, with occasional peat layer below the fill; then sandy silt, silty sand, and sand to the depth explored (beach deposits). Continuous bonded permafrost below active layer, with salinity values generally less than 8 ppt except for two borings with salinities up to 46 ppt.

ID No.	Title/Author	Date	Comment
23	UIC Gravel Investigation, Harding Lawson Associates	May 1998	Borrow Source Investigation. Thirteen borings drilled within an expansion area of the UIC borrow pit in Barrow. Borings were a maximum 14 ft deep (incomplete boring information). Also includes logs for nine borings drilled in Dec 1987 within the existing pit. Overburden material to a maximum depth of 6 ft is described in some borings as peat with segregated ice throughout, and ice and silty sand. Below the overburden, soil consists of these materials: sandy silt and silty sand (predominant soil type); silt; and sand with fine gravel within some borings. Continuous permafrost with both bonded and unbonded zones.
24	Geotech Investigation - Samuel Simmons Hospital Site, Duane Miller & Associates	Jun 2004	Foundation Investigation. Twelve borings drilled to maximum depth of 25.0 ft. Stratigraphy from top to bottom consists of: tundra mat followed by organic silt and peat to depth of about 2 ft; silt and ice to depths as great as 13 ft; then beach and marine deposits (silt and sandy silt) underlie the icy soils and contain high salt levels. Continuous permafrost, with unfrozen soil found in lower levels of three borings due to high salt content. Salinity ranges from near zero to more than 120 ppt, increasing with depth.
25	Coastal Storm Damage Reduction Gravel Exploration, USACE Alaska District	Mar 2005	Offshore Exploration. Four borings drilled 100 to 400 ft offshore of Barrow to maximum sampled depth of 25.5 ft. Fine sand with variable silt content, with only about 10% gravel content. Silt increases with distance from surf zone.
26	Same as above	Mar 2005	Cooper Island. Ten borings drilled Cooper Island over distance of 4 miles to a maximum sampled depth of 41.5 ft. Eleven feet of relatively clean sand overlies silt and clay than composes the seafloor. Average 10-20% gravel and 5% silt within sand.
27	Same as above	Mar 2005	BIA Tract. Thirty-one borings drilled within Bureau of Indian Affairs (BIA) tract to a maximum sampled depth of 41.0 ft. Upper 10 to 20 ft consists of frozen silt and silty sand. Sand with variable gravel content underlies upper silt/silty sand layer.
28	Same as above	Mar 2005	Offshore Exploration. Six borings drilled 2 to 6 miles offshore from Point Barrow spit to a maximum sampled depth of 33.0 ft. Sediment consists of fine silty sand and sand silt, with insignificant gravel content.
29	Geotech Exploration, Global Climate Change Research Facility, Duane Miller & Associates	Apr 2005	Foundation Investigation. Seven borings drilled to a depth of 23.0 ft in a coastal beach environment. Stratigraphy from top to bottom consists of: tundra mat with underlying peat and organic silt to depths of 3 to 12 ft; silt; sand, silty sand, and sandy silt to the depth explored. Massive ground ice found in several borings as thick as 6 ft and as deep as 9 ft. Continuous ice-rich permafrost below active layer, with salinity values generally less than 8 ppt.
30	Geotech Exploration, Naval Arctic Research Laboratory, Duane Miller & Associates	Jul 2005	Foundation Investigation. Five borings drilled for a Transfer Station Addition to the Thermal Operating System facility. Borings were a maximum 24.5 ft deep. Stratigraphy from top to bottom consists of: silty gravelly sand and sand fill with some debris to maximum 11-ft depth; then poorly-graded sand and silty sand with minor gravel component to the depth explored. Continuous well-bonded permafrost.

ID No.	Title/Author	Date	Comment
31	Geotechnical Report - Barrow Roads, HDL Consultants	Jun 2009	Laura Madison Road Extension. Four borings drilled to a maximum depth of 21.5 ft. Stratigraphy from top to bottom consists of: thin vegetative mat of a few inches; frozen organic silt to 2-ft depth; ice with silt to 3.5-ft depth; sandy silt, silt, and silty clay to 15-ft depth, with 2.5 to 5-ft thick massive ice sections in some two of the borings; then silty sand, sand, and gravelly sand to the depth explored. Pore water salinity varied from 0 to 19.3 ppt.
32	Same as above	Jun 2009	Proposed Uivaqsaagiaq Road. Nine borings drilled to a maximum depth of 21.0 ft. Stratigraphy from top to bottom consists of: thin vegetative mat of a few inches; frozen organic silt to 2-ft depth; ice with silt to 3.5-ft depth; sandy silt, silt, and silty clay to 15-ft depth, with 2.5 to 5-ft thick massive ice sections in some two of the borings; then silty sand, sand, and gravelly sand to the depth explored. Pore water salinity varied from 0 to 19.3 ppt.
33	Ahgeak Street Water and Sewer Extension, Geotech Report, Golder Associates	Oct 2010	Geotechnical Report. Nine borings drilled to a maximum depth of 30.5 ft. Stratigraphy from top to bottom consists of: fill to a depth of 2 to 5 ft, poorly-graded sand with gravel and trace fines; 2-ft layer of peat and organic silt; 2 to 5.5-ft layer of massive ice or silty massive ice; then various layers of silt, sandy silt, sand and silty sand to the depth explored. Unbonded permafrost zones encountered in three borings, generally below 22-ft depth. Pore water salinity varied from 0.4 to 44 ppt, increasing with depth.
34	Barrow Airport Apron Expansion Material Site Investigation, Alaska DOT	Mar 2014	West Material Source Area. Thirty-two borings drilled to a maximum depth of 47.0 ft. Top 4 to 19 ft consist of ice-rich and organic-rich silt and sandy silt, underlain by 2 to 10 ft of sand with silt to silty sand, underlain by sand and gravel with low silt content ranging in thickness from 5 to 36 ft. Contains layers of massive ice from 3 to 7-ft thick.
35	Same as above	Mar 2014	East Material Source Area. Sixty-three borings drilled to a maximum depth of 37.0 ft. Top 3 to 18 ft consist of ice-rich and organic-rich silt and sandy silt, underlain by 1 to 12 ft of sand with silt to silty sand, underlain by sand and gravel with low silt content ranging in thickness from 2 to 20 ft. Contains layers of massive ice from 4.5 to 7-ft thick. Most borings terminated in silt or clay-rich soil.
36	Barrow Airport Building Sites and Apron Expansion Project, Alaska DOT-PF	Sep 2014	Ahkovak Street. Thirteen borings drilled to depths ranging from 14 to 22 feet along and nearby Ahkovak Street. Stratigraphy from top to bottom consists of: 2.5 to 6.5 ft of embankment fill, composed of sand and gravel, with scattered zones of silty soil; ice-rich and organic-rich silt to silty sand with layers of massive ice, from 2.5 to 6.5 ft below ground to depth explored. Massive ice ranged from 5.5 to 9 feet in thickness in some borings.
37	Same as above	Sep 2014	Proposed Building Sites and Apron Extension. Eight borings drilled to depths ranging from 21 to 42 feet at three alternative building sites and the apron extension. Stratigraphy from top to bottom consists of: 2.5 to 6.5 ft of embankment fill, composed of sand and gravel, with scattered zones of silty soil; ice-rich and organic-rich silt to silty sand with layers of massive ice, from 2.5 to 6.5 ft below ground to depth explored.

ID No.	Title/Author	Date	Comment
38	Barrow Comprehensive Plan 2015-2035	Mar 2015	SKW Borrow Pit. The ASRC (Arctic Slope Regional Corporation) SKW operates a borrow pit on land owned by the City of Barrow. Material produced is classified as sandy gravel and gravelly sand, with a considerable amount of overburden fines (sand and silt) required to be processed to generate granular material. Generally produces 30,000 to 50,000 yd^3 of granular material annually, with an estimated 10 years useful life remaining.
39	Same as above	Mar 2015	UIC Borrow Pit. The UIC (Ukpeagvik Iñupiat Corporation) operated pit has material which is generally finer grained (sand and silt) than the SKW pit, typically producing poorly- graded silty sand with gravel. UIC applying for large pit expansion through the Alaska District.
40	Same as above	Mar 2015	Alaska DOT Borrow Pit. The ADOT has a borrow pit on State property adjacent to the airport, and is operated by SKW on behalf of ADOT. Material generated is for exclusive State use (e.g. FAA projects). Expansion of the pit is limited within State property. Material produced is similar to the SKW borrow pit.
41	Barrow-Pt. Hope Coastal Erosion Mitigation Report - Geotech Investigation, PND Engineers	Apr 2015	Pump Station 3. One boring drilled to a depth of 45 ft. Stratigraphy from top down consists of: 5-ft fill layer of poorly graded sandy silt fill; 1-ft layer of peat; 11 ft of mass ice; then, poorly-graded sand with silt and silty (fine) sand to depth explored. Salinity ranged from 2 to 80 ppt (average salinity of seawater is 35 ppt).
42	Same as above	Apr 2015	Pump Station 4. Five borings drilled to a maximum depth of 46.0 ft. Stratigraphy from top down consists of: 15-ft layer of unbonded poorly-graded sand with silt; from depth of 15 to 24 ft, bonded to unbonded lean clay; then, poorly- graded sand with silt to depth explored. Salinity ranged from 8 to 143 ppt.
43	Same as above	Apr 2015	Shoreline Borings. Three borings drilled along seaside edge of Egasak Street, by Pump Station 4, to a depth of 46.0 ft. Material consisted of sandy soils to 46.0 ft (poorly-graded sand with silt and gravel, silty sand, well-graded sand with gravel) with an interbedded 5 to 10-ft thick silt layer starting at about 15 ft in depth. Contained bonded and unbonded permafrost sections, with salinity ranging from 8 to 113 ppt (generally increasing with depth).

Figure 29 - Previous Geotechnical Site Investigation Locations.

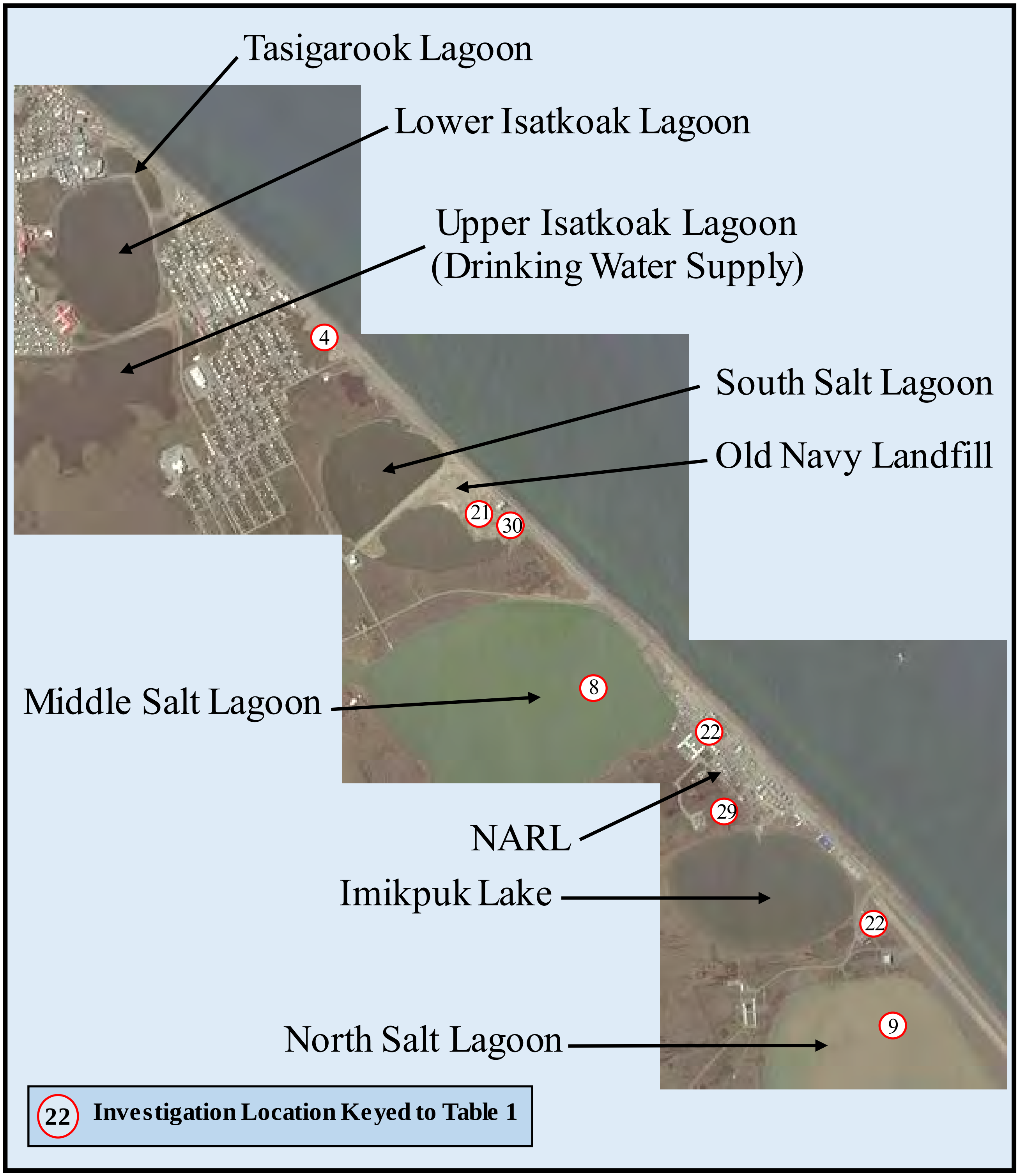

Figure 30 - Previous Geotechnical Site Investigation Locations.

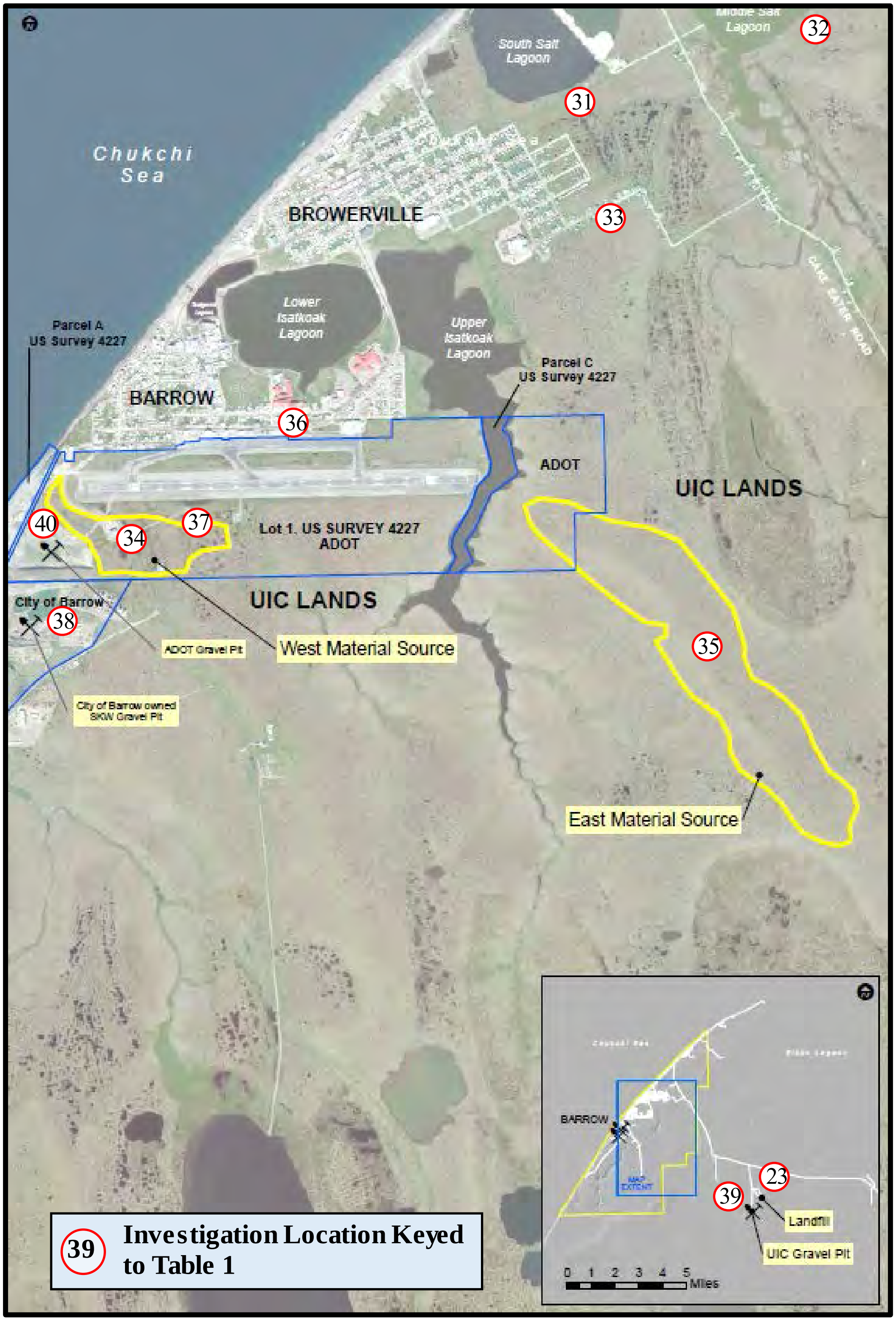

Figure 31 - Previous Geotechnical Site Investigation Locations.

Table 2 - Summary of Regional Borrow Sources.

ID No.	Source Location	Type of Borrow Material - Comments
1	Nome Quarry, AK	**Aggregate and Rock (granite).** Well established quarry supplying high quality rock, including riprap and armor stone, for civil works projects in Alaska. Stone has been barged to Barrow for upcoming road construction project by UIC. Reference: May 18 discussion with UIC.
2	Atigun Quarry, AK	**Aggregate and Rock (conglomerate).** Established quarry 150 miles south of Prudhoe Bay, Mile Post 261 on Dalton Highway, supplies aggregate and quality rock, including riprap and armor stone, for AK DOT and Prudhoe Bay oil industry. BLM property. Reference: Jan 18 discussion with AK DOT with accompanying documents.
3	Cape Lisburne Quarry, AK	**Aggregate and Rock (dolomite and limestone).** Established quarry for restricted, permitted use by the U.S. Air Force through the U.S. Fish and Wildlife Service in maintaining facilities at the Cape Lisburne USAF facility, including the construction of a coastal revetment by Corps of Engineers. Access to rock and aggregate from this location is doubtful due to federal military and wildlife refuge jurisdictions.
4	Point Hope, AK	**Aggregate and Rock (arkose and limestone).** Two potential material sources inland from Point Hope have been investigated for aggregate and rock. Further investigation and material testing is needed to determine the viability of establishing quarry operations in this area. Reference: NSB Erosion Protection, PND Engineers, Jul 2015; Point Hope Materials Source Reconnaissance, HDL Engineering, Mar 2011; Point Hope Materials Source Evaluation, UMIAQ Project #10-038, Apr 2011.
5	Kivalina, AK	**Aggregate and Rock (dolomite and limestone).** Several potential material sites inland from Kivalina have been investigated with borings by Alaska DOT for possible sand and gravel aggregate and armor stone. Further investigation and material testing is needed to determine the viability of establishing quarry operations in this area. References: UAA Coastal Erosion Workshop, NANA Regional Corporation, Jan 2010; Jan 18 discussion with AK DOT; Kivalina Replacement School Geotechnical Data Report, Golder Associates, Dec 2015.
6	Buckland, AK	**Aggregate and Rock (monzonite).** Existing material sources at the Kanik Creek quarry, but appears to be a small operation for local material use. Reference: UAA Coastal Erosion Workshop, NANA Regional Corporation, Jan 2010.
7	Deering, AK	**Aggregate and Rock (dolomite and andesite).** Existing material sources at the Kugruk and Inmachuk quarries, but appears to be a small operation for local material use. Reference: UAA Coastal Erosion Workshop, NANA Regional Corporation, Jan 2010.
8	Dutch Harbor, AK and BC, Canada	**Rock Quarries External to Mainland Alaska.** Rock revetment seawall was constructed at Wainwright, Alaska, for coastal erosion protection, using 30,000 tons of rock barged from the Bering Shai quarry at Dutch Harbor (B rock and filter rock) and the Stebbings Road quarry in Shawnigan Lake, British Columbia (armor stone). Project completed in Nov 2013. According to the NSB client, this combination of borrow sources proved more economical at the time than Nome. Reference: May 18 discussion with NSB with accompanying project documents.

ID No.	Source Location	Type of Borrow Material - Comments
9	Colville River, AK	**Aggregate.** The ASRC Colville Consolidated Use Gravel Pit is a large out-of-bank sand and gravel mining operation in the Colville River, Nuiqsut area. The current Phase 3 mining area contains about 430 acres of mineable quantities of sand and gravel, estimated at about 15 million yd^3. Reference: Permit modification letter to CEPOA-RD-N, 23 Jan 17.
10	Prudhoe Bay Area	**Aggregate.** There are multiple developed sand and gravel borrow pits within alluvial deposits formed by rivers flowing into Prudhoe Bay, including the Sagavanirktok River. The NSB owns three material sites in the Prudhoe Bay and Kuparuk area, identified as Mine Site F (7.0 million yd^3), Mine Site 3 (10.5 million yd^3), and Deadhorse South (10.5 million yd^3), with estimated sand and gravel marketable-quantities indicated in parentheses. References: May 18 discussion with NSB; Feasibility Study for NSB - Development of Three Gravel Sources in the Prudhoe Bay Area, UMIAQ, Jun 2014.

Figure 32 - Location of Regional Material Sources.

Nome Quarry (Granite)

Atigun Quarry (Conglomerate)

Cape Lisburne (Dolomite/Limestone)

Kivalina (Dolomite)

Buckland (Monzonite)

Point Hope (Limestone)

Dutch Harbor (Diorite)

Vancouver Island (Diorite)

Figure 33 - Photos of Some Regional Material Sources.

3.5 Geotechnical Site Conditions of Significance to Feasibility Study

3.5.1 The prior geotechnical investigation reports and available information on local and regional borrow material sources as summarized in Tables 1 and 2 provide a reasonable understanding regarding geotechnical site conditions of significance to the ongoing feasibility study. A discussion of these significant geotechnical factors is provided below and will be updated once investigations are completed.

3.5.2 **Bluffs.** The bluffs and ground immediately inland from the bluffs and beach area are typically underlain by the following deposits:

- For ground in its undisturbed condition, there is a thin vegetative tundra mat at the surface, underlain by peat and silt, sandy silty or silty sand with organic content to depths ranging from about 1.5 to 5.0 feet. For areas that have been filled over original or excavated ground, the fill material likely consists of poorly-graded sand, silty sand, gravelly sand, and gravelly sand as provided by the local UIC or SKW borrow pits.

- Below the upper organic layer, the soil probably consists predominantly of silty sand to sandy silt to the depths of interest to this study, with a minor component of fine gravel within certain strata. The proportion of silt typically decreases and sand becomes more prevalent below approximately 10 feet in depth.

- There is continuous permafrost below an active layer that occurs to a depth of about 1.5 to 3.0 feet. There are both bonded and unbonded zones within the permafrost, with unbonded zones appearing to increase below a depth of about 10 feet along with an associated increase in pore water salinity. Massive zones of ice and ice-rich silt are common to a depth of about 18 feet, with recorded thicknesses of massive ice ranging from 2.5 to 13 feet in the Barrow area. Ice wedges associated with polygon formation may be present behind the bluffs, which adds to the potential instability of the bluffs as advanced thawing and erosion occurs along the exposed slopes.

3.5.3 **Beach.** The characteristics of sediments underling the beach along the study area, will be more thoroughly defined during PED. The following soil conditions along or immediately adjacent to the beach were found, based on available information:

- The beach deposits appear to be predominantly silty sand, poorly-graded sand with silt and gravel, well-graded sand with gravel, and gravelly sand. The gravel component appears to increase towards the northeast end of the study area, continuing along the Point Barrow spit to Point Barrow.

- For the three borings drilled near Pump Station #4 (ID #43 in Table 1), along the seaside edge of Egasak Street, the soil was unbonded and thawed to a maximum depth of 10.0 ft, with pore water salinity increasing with depth (maximum 113 ppt). It is expected that beach deposits along the study area will exhibit increased depths of thawing compared to ground beyond the beach and above the bluffs.

3.5.4 Past and On-Going Erosion Mitigation Measures. Various measures have been used in the past at Barrow to provide some degree of localized protection from coastal erosion and flooding. These measures are fully documented in other project-related reports, with photos provided in Figure 34. Current local practice is to build berms along the seaside edge of the beach roads from Barrow to NARL. Dozers operate in the surf zone, reforming the berms that storm waves are washing away. Both the UIC and SKW borrow operations provide material for the emergency berms. Photos of the emergency berm activities are shown in Figure 35.

Gabions

HESCO Concertainers

Utilidor Wall

Longard Tubes

Supersack Revetment

Angled Tar Barrels

Beach Nourishment w/Dredge Material

Figure 34 - Past Erosion Mitigation Measures.

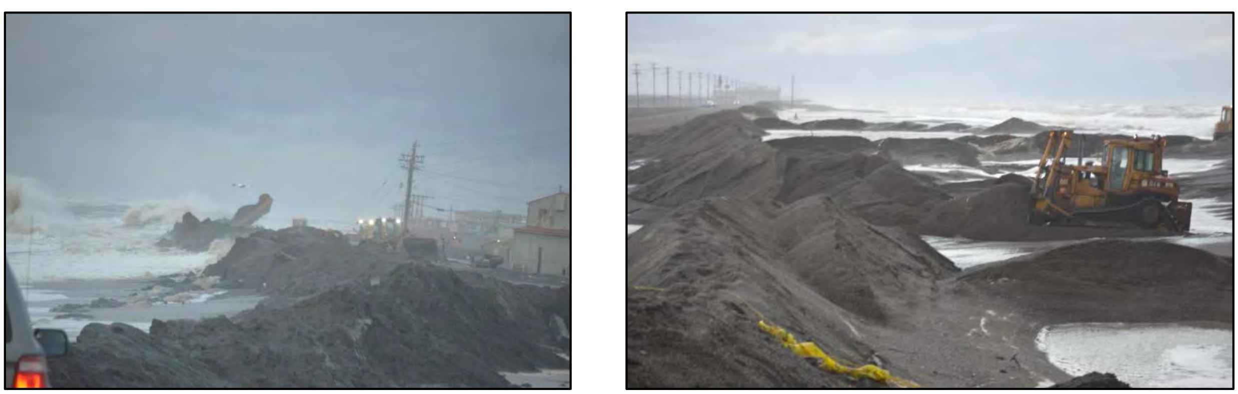

Figure 35 - Berm Protection during Storm Events.

3.5.5 Foundation and Earthwork Considerations. Geotechnical design input will be given during the Preconstruction Engineering and Design (PED) phase, specific to the adopted erosion mitigation design. Initial foundation and earthwork considerations are provided below, covering the multiple mitigation alternatives currently under evaluation.

- Coastal engineering design will account for the shore environment at Barrow (wind, waves, topography/bathymetry, subsurface condition, and seasonal ice), to be analyzed by the hydraulics/hydrology design team. With respect to aspects of bearing capacity, settlement, and slope stability, no major foundation impediments are foreseen to construct a rock revetment, revetted berm, or revetted and raised Stevenson Street at this location. Site-specific geotechnical information (borings and material testing) will be obtained during PED to ensure stable-embankment construction and the protection of adjacent ground and structures.

- There are unique challenges regarding the availability of gravel and rock borrow materials to support properly engineered embankment construction and beach nourishment. There are no local sources of rock within the Barrow area and are very few rock quarries in operation within the entire NSB region (see Tables 1 and 2). The largest rock quarry operations within the NSB region are the Nome quarry and Atigun quarry, approximately 700 miles and 350 miles from Barrow, respectively. There are a number of smaller rock quarries currently in operation (e.g. Buckland and Deering), and a number of locations that have been investigated as potential rock quarries (e.g. Kivalina and Point Hope). Cape Lisburne has a rock quarry that is currently active, but only for restricted use for local USAF projects. For planning purposes, it should be assumed that armor rock for revetment construction will be coming from the Nome quarry. As seen with the Wainwright seawall construction, it may be possible that rock quarries outside of mainland Alaska (e.g. Dutch Harbor) may turn out to be economically competitive at the time of construction bidding.

- With regard to gravel borrow materials, there are local borrow pits within the Barrow area, being the UIC and SKW (City of Barrow) operations, with the ADOT borrow pit operating exclusively for State of Alaska projects. Annual gravel production from each of the UIC and SKW pits is in the 30,000 to 50,000 yd^3 range. Quarry management indicate a potential for each providing up to 100,000 yd^3 of gravel a year. However, the SKW pit is limited in its ability to expand laterally due to property ownership boundaries, and their management indicate that gravel deposits will diminish in approximately 10 years. The UIC pit has room to expand laterally and was recently permitted for a phase of expansion.

- From review of gradation tests performed on material produced from the pits, a developed understanding of subsurface conditions in the area, as well as on-site discussions with the quarry operators, it is expected that what is being referred to as gravel is most often a fine gravelly sand or sandy fine gravel. This material is used, for example, for local road maintenance and construction, with the NSB reporting an average 1,000 yd^3 of material used for annual road maintenance. The local road construction practice is to place up to 5 feet of gravel with underlying insulation and geotextile fabric, over natural subgrade to protect the underlying permafrost from seasonal thawing. This road bed material is obtained from the local borrow pits, and while the road design calls for free-draining gravel, the material most likely consists of sandy fine gravel.

- Deposits within the UIC and SKW borrow pits consist predominantly of some combination of sand and silt, with less frequent layers of gravelly sand and sandy gravel being the most valued material being produced. Very similar stratigraphic conditions exist for the undeveloped West and East Material Source Areas (ID #34 and #35 in Table 1). As was the case for initial development of the UIC and SKW borrow pits, development of the new borrow sources will require a considerable effort to first remove thick deposits of ice-rich and organic-rich silt and sandy silt, followed by layers of sand with silt and silty sand, before reaching deposits containing the desired gravel component.

- The UIC and SKW borrow pits may be able to provide non-frost-susceptible fill material (sand with low silt content) and to a lesser extent, sandy fine gravel and gravelly fine sand, to support construction of certain elements of the coastal erosion measures (e.g. raising Stevenson Street and general fill for the berms), depending on fill material specifications to be developed during project design. Granular fill involved in road, berm, or revetment construction would have specific gradation limits that would require processing with screens. It was noted in a May 2018 site visit that the SKW borrow pit has some screens for processing material. The UIC borrow pit did not have screens at their operation, but staff stated that screens could be obtained if the need arose. The question of local borrow material being able meet beach nourishment requirements cannot be resolved until the quantity and gradation limits for the material have been determined.

- The total quantity of locally available borrow material that could actually be dedicated to coastal erosion mitigation is uncertain at this time, requiring further discussions with the local controlling agencies, and knowing that the community has other continuing needs for high quality gravel material as expressed in their Barrow Comprehensive Plan 2015-2035 report. Operation of the gravel pits is based on the specific amount of material that has been contracted for. One or more annual quarry blasts are performed to begin the process for providing the planned quantity of material to be delivered to customers. There is no mass stockpiling of gravel material at the quarries for possible advance use. Therefore, use of local borrow sources requires considerable advance planning and coordination, particularly if borrow site expansion is required or a new borrow source is considered for development.

- Granular material with very specific gradation requirements and with critical performance requirements may have to be provided by a quarry operation external to the Barrow area. This may include free-draining coarse gravel, the filter course used in rock revetment construction, and material for beach nourishment, to be clarified during project design. Large quarry operations at Coleville, Prudhoe Bay, and Nome would be able to provide select gravel material, but at very high transport costs.

- During the drilling of four borings at Pump Station #3 (ID #42 in Table 1), soil was found to be contaminated with diesel range organics that exceed ADEC cleanup levels. The potential for encountering fuel-contaminated soil during excavation for implemented erosion mitigation actions (e.g. rock revetment) needs to be taken into consideration for the work. In addition, there are archaeological artifacts including human remains within the study area, at known locations such as the Utqiagvik Village Site (Figure 8) and probably at locations not as yet uncovered. In recognition of one of the study's objectives (reduce or mitigate damage to tangible cultural heritage), the presence of archaeological artifacts within the study area will need to be considered in designing and executing the erosion mitigation work.

4. GEOTECHNICAL FIELD INVESTIGATIONS

4.1 Geotechnical field work will consist of test pit excavations to characterize beach sediments along the length of the study area. The test pits will be excavated along the length of the study area, positioned approximately midway between the waterline and toe of bluff or seaside edge of the beach perimeter road. These test pits will be spaced roughly 1500 feet apart, from Stations 210+00 to 620+00 as identified on Figure 36, and will be approximately 5 feet deep.

4.2 The purpose of performing test pits along the beach is to classify the sediment for ongoing hydraulic/hydrology analyses of beach erosion and beach nourishment, and to characterize any changes in sediment type along the study area alignment. A maximum of three sediment samples will be retrieved from each of these test pits for laboratory soil classification

4.3 In addition to the test pits, twenty shallow grab samples will be taken from the bluff face and twenty grab samples will be obtained from temporary berm materials in place along the seaward flank of Stevenson Road. The sediment samples will be analyzed for laboratory soil classification. Photos and a description of site conditions will be recorded for the sample locations.

4.4 All test pits will be logged by an Alaska District geotechnical engineer, with photos taken of the excavation, including photos (seaward and landward) and a description of the site conditions. The backhoe used for the excavations will be provided by the North Slope Borough in a project cost sharing agreement. An Alaska District archaeologist will be present during the test pit work to monitor for the presence of archaeological artifacts. The test pit work is expected to take approximately 2 weeks. Rights of Entry and digging permits will be coordinated and obtained by the Alaska District through the appropriate agencies at Barrow.

Figure 36 - Survey Stationing Established along Barrow Coastline.

Barrow Alaska Coastal Erosion Feasibility Study

Appendix C: Real Estate

Barrow, Alaska

August 29, 2018

US Army Corps of Engineers
Alaska District

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

BARROW ALASKA COASTAL EROSION FEASIBILITY STUDY
BARROW, ALASKA
REAL ESTATE PLAN

I. PURPOSE:

The purpose of the feasibility study is to evaluate potential alternatives. The Real Estate Plan (REP) identifies and describes the real estate requirements for the lands, easements, rights-of-way, relocations and disposal areas (LERRD) that will be required. The REP is tentative in nature; it is for planning purposes only and both the final real property acquisition lines and the real estate cost estimates provided are subject to change even after approval of the feasibility study.

II. PROJECT TYPE AND APPLICABILITY:

This feasibility study is being conducted under the authority provided by Section 116 of the Energy and Water Development and Related Agencies Appropriations Act of 2010 (P.L. 111-85) as amended:

> 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 non-Federal Sponsor for the study is the North Slope Borough (NSB).

III. PROJECT SCOPE AND CONTENT:

The community of Barrow, Alaska, now known as Utqiaġvik, is located on the Arctic Ocean (Figure 1), approximately 750 miles north of Anchorage, AK. The State of Alaska issued an order and officially changed the name of Barrow to Utqiaġvik on 1 December 2016. However, for the purpose of this study, the former name of Barrow will generally be used as a practical matter to keep the name consistent with the previous study and the current Federal Cost Sharing Agreement. This is a feasibility study to assess coastal erosion and flooding damages in the vicinity of Barrow, AK and determine whether Federal interest exists to construct a project to reduce these damages.

The coastal storm risk management study objectives are:

- Reduce risk to life, health, and safety.
- Reduce damages caused by flooding and shoreline erosion to residential and commercial structures and critical public infrastructure.
- Reduce or mitigate damage to tangible cultural heritage.

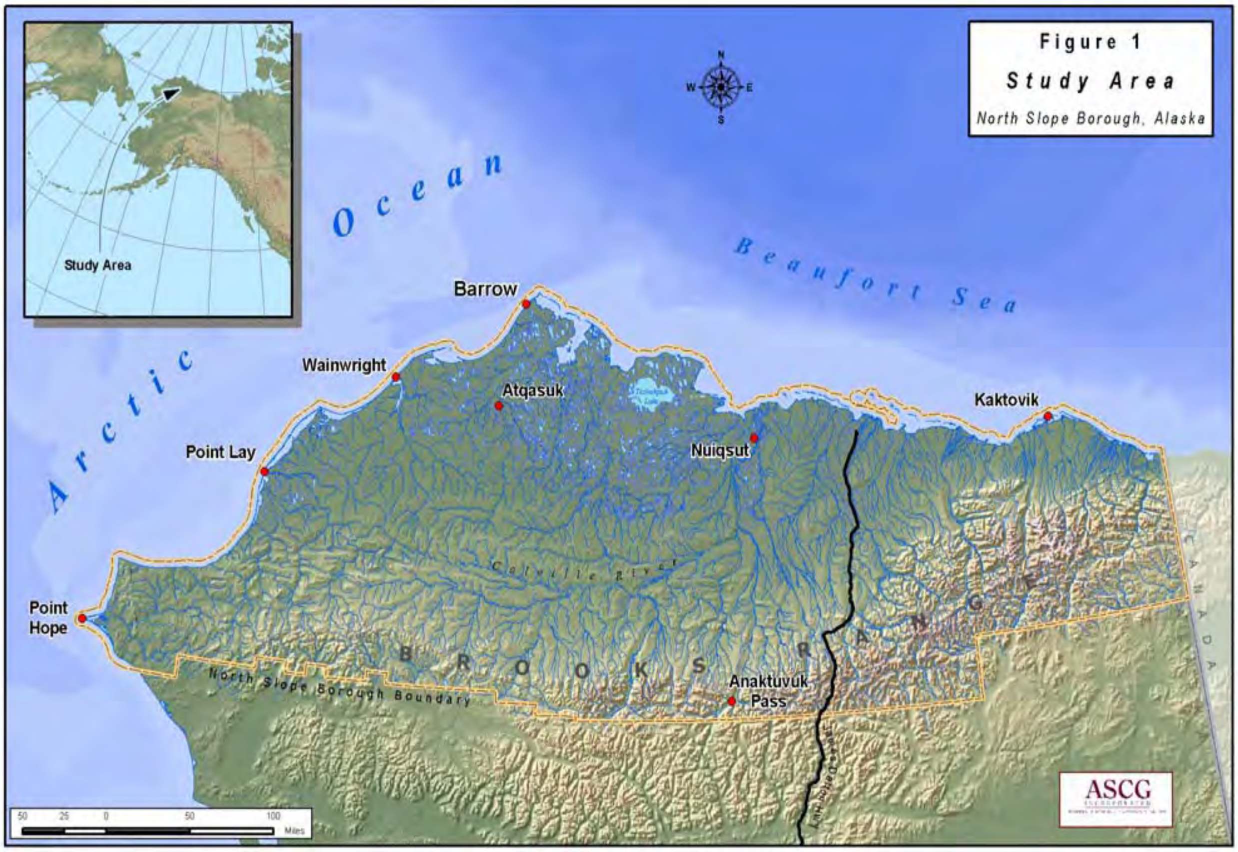

Figure 1: North Slope Borough, Alaska, Vicinity Map

IV. Alternatives as identified in Figure 2.

Alternative 1: No Action

Tentatively Selected Plan (TSP) Alternative 2, which is a combination of both Alternatives 2A and 2B.

Alternative 2A: Rock revetment and berm-protected Stevenson Street (rock revetment along bluff with revetted berm in front of Stevenson Street)

Alternative 2B: Rock revetment and raised Stevenson Street (rock revetment along bluff with raised and revetted Stevenson Street)

Alternative 5A: Protect major infrastructure (rock revetment, revetted berm, and fill Tasigarook lagoon limited to protect Utilidor and water supply)

Alternative 5B: Barrow/Browerville neighborhoods (extended rock revetment along bluff, revetted berm, and fill Tasigarook lagoon)

Alternative 5C: Barrow/Browerville neighborhoods plus Naval Arctic Research Laboratory (NARL) (extended rock revetment along bluff, revetted berm, fill Tasigarook lagoon, with raised and revetted Stevenson Street along NARL)

Alternative 5D: Barrow/Browerville neighborhoods plus NARL and Old Navy Landfill (extended rock revetment along bluff, revetted berm, fill Tasigarook lagoon, raised and revetted Stevenson Street along NARL, and beach nourishment along Old Navy Landfill)

Alternative 6A: Combination rock revetment, raised Stevenson Street, and revetted berm with limited beach nourishment (rock revetment along bluff with raised and revetted Stevenson Street, except for a revetted berm with beach nourishment adjacent to Tasigarook lagoon and revetted berm without beach nourishment adjacent to Browerville)

Alternative 6B: Combination rock revetment, raised Stevenson Street, revetted berm, and beach nourishment (rock revetment along bluff, revetted berm with beach nourishment adjacent to Tasigarook lagoon, revetted berm without beach nourishment adjacent to Browerville, beach nourishment between Browerville and NARL, and raised and revetted Stevenson Street through NARL)

Alternative 6C: Beach nourishment only (beach nourishment along entire study coastline)

Figure 2: Alternatives

V. DESCRIPTION OF LANDS, EASEMENTS, RIGHTS-OF-WAY, RELOCATION and DISPOSAL (LERR):

The extent of coastline currently being studied is approximately 25,300 feet in length.

LERRD necessary to implement this project include the non-Federal Sponsor (NFS), the tides and submerged lands lying within this section, the City of Barrow, uplands owned by City of Barrow, Arctic Slope Regional Corporation (ASRC), Ukpeagvik Inupiat Corporation (UIC), NSB, Tagiugmiullu Nunamiullu Housing Authority (TNHA), corporate owners, private owners, and native allottees.

LERRD necessary to implement this project are to be determined during the Preconstruction Engineering and Design (PED) phase. Current property values are based on a Fair Market Value Appraisal provided by Maria Moore, 13 September 2017.

Table 1: Properties and Owners Affected – TSP

PARCEL ID	FIRST NAME	LAST NAME	TYPE PROPERTY	ACRES	LAND VALUE ($)	IMPROVEMENTS VALUE ($)	TOTAL VALUE ($)
R-001-021-02	HEIRS OF GUY	OKAKOK	Native Restricted Property	0.132	24700	0	24700
R-001-021-03	ANDREW EARL	KROLL	Private	0.168	30000	88100	118100
R-001-021-05		NORTH SLOPE BOROUGH	North Slope Borough	0.269	43700		
R-001-021-32	HERMAN	KIGNAK	Native Restricted Property	0.036	6800	0	6800
R-001-021-33	NORA	SNOWBALL	Native Restricted Property	0.095	17700	0	17700
R-001-021-37		ASRC PROPERTIES, LLC	Corporation	0.930	77500	341700	419200
R-001-021-38		ESKIMOS, INC	Private	1.090	205100	116100	321200
R-001-021-39		ESKIMOS, INC	Private	2.561	481700	514900	1021400
R-001-031-25		CITY OF BARROW	City	5.464	0	0	0
R-001-031-30		CITY OF BARROW	City	0.148	27200	0	27200
R-001-031-31	MARY	NUKAPIGAK	Native Restricted Property	0.170	30300	63500	95900
R-001-031-32	EMMA SUSIE	KIGNAK	Native Restricted Property	0.180	15900	0	15900
R-001-031-57		NORTH SLOPE BOROUGH	North Slope Borough	4.102	275900	0	275900
R-001-041-10	OLIVER	LEAVITT	Private		31900	203100	241600
R-001-041-11	MORGAN JR	SAKEAGAK	Native Restricted Property	0.171	30600	0	30600
R-001-041-12	HEIRS OF LEE	SUVLU	Native Restricted Property	0.179	31700	7700	39400

PARCEL ID	FIRST NAME	LAST NAME	TYPE PROPERTY	ACRES	LAND VALUE ($)	IMPROVEMENTS VALUE ($)	TOTAL VALUE ($)
R-001-041-13	DAISY	TALEAK	Native Restricted Property	0.179	31700	3200	34900
R-001-041-14	HEIRS OF GEORGE	LEAVITT	Private	0.179	31700	49300	85600
R-001-041-15	MARILYN	KALAYAUK	Private	0.179	31700	84600	118300
R-001-041-19	MARTHA	LANGMADE	Private	0.137	0	0	0
R-001-041-20		CITY OF BARROW	City	0.105	0	0	0
R-001-051-08		TNHA	Housing Authority	0.172	30700	66100	98900
R-001-051-08		TNHA	Housing Authority	0.000	0	112200	112200
R-001-081-32		CITY OF BARROW	City		145800	0	159900
R-001-081-33		CITY OF BARROW	City		212500	0	212500
R-001-091-01		NORTH SLOPE BOROUGH	North Slope Borough		0	182100	182100
R-001-091-02		NORTH SLOPE BOROUGH	North Slope Borough		55700	1400200	1645600
R-001-191-01		UKPEAGVIK INUPIAT CORP	Ukpeagvik Inupiat Corporation	1.601	89700	0	89700
R-001-191-02		UKPEAGVIK INUPIAT CORP	Ukpeagvik Inupiat Corporation	2.501	0	0	0
ATS 283		CITY OF BARROW	City/TIDE LAND	420			
Steveson St		CITY OF BARROW	City	36			
Bluff		SOA DOT	State of Alaska	4.5			
Brower St		CITY OF BARROW	City	.06			

VI. PROJECT COMPONENTS:
See Baseline Cost Estimate Section.

VII. STANDARD ESTATES:
Fee
Temporary Work Area Easement
Perpetual Beach Storm Damage Reduction Easement

VIII. NON-STANDARD ESTATES:
None

IX. FEDERAL LANDS:
None

X. NEAREST OTHER EXISTING FEDERAL PROJECT:
There are no other existing Federal projects that will be affected by the project footprint.

XI. NAVIGATION SERVITUDE:
The navigation servitude may only be exercised by the Federal Government for Congressionally authorized projects or measures that are related to navigation or pursuant to regulatory authorities to protect navigation. Navigation servitude is not being applied to this project.

XII. INDUCED FLOODING:
Flooding is not expected as a result of this project.

XIII. BASELINE COST ESTIMATE FOR REAL ESTATE:
The NFS will acquire all necessary real estate interest in the lands necessary for the project. Baseline cost estimate for real estate necessary to implement this project will be determined during the PED phase.

XIV. UTILITIES & FACILITIES RELOCATIONS:
There are known utilities or facilities requiring relocation. The extent of the utilities or facilities relocation will be determine during the PED phase.

XV. RELOCATION ASSISTANCE BENEFITS:
There are P.L. 91-646 businesses or residential relocation assistance benefits required for this project. The extent of the businesses or residential relocation assistance benefits required will be determine during the PED phase.

XVI. HAZARDOUS, TOXIC, AND RADIOACTIVE WASTE IMPACTS:
There is no known information pertaining to hazardous, toxic, and radioactive wastes (HTRW) or materials within the project footprint.

XVII. MINERAL/TIMBER ACTIVITY:
There are no current or anticipated mineral or timber activities within the vicinity of the proposed project that will affect construction, operation, or maintenance of the proposed project, nor will any subsurface minerals or timber harvesting take place within the project.

XVIII. REAL ESTATE MAP:
The Real Estate Map will be produced by the U.S. Army Corps of Engineers, Alaska District (The Corps).

XIX. SPONSORSHIP CAPABILITY:
The NSB has been provided the Sponsor Real Estate Acquisition Capability Assessment form. A

determination will be made after the assessment form is returned from the NSB.

Robert (Bob) Shears
Deputy Director North Slope Borough's Capital
Improvement Program Management (CIPM) Department
Email: Robert.Shears@north-slope.org

XX. NOTIFICATION OF SPONSOR AS TO PRE- PROJECT PARTNERSHIP AGREEMENT (PPA) LAND ACQUISITION:
The NFS has been notified in writing about the risks associated with acquiring land before the execution of the PPA and the Government's formal notice to proceed with acquisition of the lands needed for the project.

XXI. ZONING ORDINANCES ENACTED:
No zoning ordinances will be enacted to facilitate the proposed coastal storm risk management activities. Therefore, no takings are anticipated as a result of zoning ordinance changes. No zoning ordinances are proposed in lieu of or to facilitate acquisition in connection with the project.

XXII. SCHEDULE:
The anticipated project schedule, unless revised after coordination with the NFS, is shown in Table 2.

Table 2: Project Schedule

Task	Start
NFS – Receipt of the final real estate drawing from the Alaska District, Engineers.	2-4 weeks after PPA execution.
The Corps – Formal transmission of right of way drawing and instructions to acquire LERRD.	4-6 weeks after PPA execution.
NFS – Certify all necessary LERRD available for construction.	6-24 months after PPA execution.
The Corps – Certifies/verifies the NFS has acquired the real interest required and sufficiency for contract advertisement, etc.	Prior to contracting.
NFS – Prepare and submit credit requests.	6-8 months upon completion of project.
The Corps – Review/approve or deny credit requests.	6 months of NFS submission

XXIV. VIEWS OF FEDERAL, STATE, AND REGIONAL AGENCIES:
This project is supported by Federal, State, and Regional agencies. The Corps has met with representatives of the NFS and other pertinent parties to discuss aspects of the proposed action. Further coordination will be ongoing. In compliance with NEPA rules/regulations, letters will be sent to resource agencies and residents in the area; public notices will transpire within the project vicinity.

XXV. VIEWS OF LOCAL RESIDENTS:
A public meeting has been conducted and local residents are in favor of the project. Further coordination will be ongoing between the NSB and the Corps, State and Federal resource agencies, and residents in the area.

XXVI. ANY OTHER RELEVANT REAL ESTATE ISSUES:
None.

PREPARED BY:	**REVIEWED AND APPROVED BY:**
________________________	______________________________
RONALD J. GREEN	MICHAEL D COY
Realty Specialist	Chief, Real Estate

Barrow Alaska Coastal Erosion Feasibility Study

Appendix D: Draft Environmental Assessment and Draft FONSI

Barrow, Alaska

August 29, 2018

US Army Corps of Engineers
Alaska District

FINDING OF NO SIGNIFICANT IMPACT

In accordance with the National Environmental Policy Act of 1969, as amended, the U.S. Army Corps of Engineers, Alaska District (Corps) has assessed the environmental effects of the following action:

Barrow Alaska Coastal Erosion
Barrow, Alaska

The Alaska District would protect approximately 5 miles of coastline along the Chukchi Sea near Barrow, Alaska to protect vital community infrastructure. The existing condition exposes Barrow to frequent coastal erosion and flooding from late summer and fall storms. The proposed erosion protection involves a rock revetment along approximately 5 miles of coastline between the airport and the old Navy Arctic Research Lab (NARL). Stevenson Street, the major coastal road in the community, would be located behind the revetment for part of its length and would be raised to run on top of the revetment for the balance of the distance.

This project would involve placement of approximately 370,000 cubic yards of material along approximately 5 continuous linear miles of coastline above the mean higher high water (MHHW) elevation to protect Barrow from coastal erosion and flooding. This material would come from an existing commercial quarry.

This action has been evaluated for its effects on several significant resources, including fish and wildlife, vegetation, wetlands, threatened or endangered species, marine resources, and cultural resources. No significant short-term or long-term adverse effects were identified.

This Corps action complies with the National Historic Preservation Act, the Endangered Species Act, the Clean Water Act, the Magnuson-Stevens Fishery Conservation and Management Act, and the National Environmental Policy Act. The completed environmental assessment supports the conclusion that the action does not constitute a major Federal action significantly affecting the quality of the human and natural environment. An environmental impact statement is therefore not necessary for the Alaska District's construction of coastal erosion and flooding protection structures in Barrow, Alaska.

________________________________ ________________________________

Phillip J. Borders Date
Colonel, U.S. Army
Commanding

Environmental Assessment for Barrow Alaska Coastal Erosion in Barrow, Alaska

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ABBREVIATIONS AND ACRONYMS

ADEC – Department of Environmental Conservation, State of Alaska
ADFG – Alaska Department of Fish and Game
AHRS – Alaska Heritage Resources Survey
APE – Area of Potential Effect
BMP – Best management practice(s)
BP – Before Present
CO – Carbon Monoxide
Corps – U.S. Army Corps of Engineers
CWA – Clean Water Act
cy – cubic yard(s)
DMMP-Dredged Material Management Plan
EA – Environmental Assessment
EFH – Essential Fish Habitat
EJ – Environmental Justice
EPA – U.S. Environmental Protection Agency
ESA – Endangered Species Act
FONSI – Finding of No Significant Impact
FR – Federal Register
Ft – Feet/Foot
MHHW – Mean Higher High Water
MLLW – Mean Lower Low Water
MSFCMA – Magnuson-Stevens Fisheries Conservation and Management Act
NARL - Naval Arctic Research Lab
NMFS – National Marine Fisheries Service
NOAA – National Ocean and Atmospheric Administration
NOx – Nitric Oxide and Nitrogen Oxide
PAH – Polycyclic aromatic hydrocarbon(s)
PM – Particulate Matter
PED –Pre-construction Engineering and Design
SHPO – State Historic Preservation Office
USFS – U.S. Forest Service
USFWS – U.S. Fish and Wildlife Service
VOC – Volatile Organic Carbon

Environmental Assessment for Barrow Alaska Coastal Erosion in Barrow, Alaska

1.0 PURPOSE AND NEED

1.1 Introduction

This environmental assessment (EA) has been prepared to evaluate the effects of material placement above the Mean Higher High-Water line (MHHW) for coastal erosion protection along an approximately 5-mile length of Chukchi Sea coastline in Barrow, Alaska.

1.2 Study Description

The community of Barrow, currently recognized as the City of Utqiaġvik, is located on the Arctic Ocean (Figure 1). The State of Alaska officially renamed the community Utqiaġvik on 01 December 2016. However, for the purpose of this study, the former name of Barrow would be used as a practical matter to keep the name consistent with a previous Corps study and the current Feasibility Cost Sharing Agreement (FCSA).

The North Slope Borough (NSB) has been facing storm damage and erosion problems for decades. Traditionally, foundation materials for local infrastructure would be obtained from the beach or a gravel pit area, updrift (southwest) a mile from Barrow. The reduction of natural beach nourishment material, coupled with frequent storms and decreased ice cover has left the coastline vulnerable to flooding and erosion. The NSB currently engages in construction of temporary and sacrificial 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.

The proposed coastal storm risk management study would involve providing both flooding and coastal erosion protection for the bluffs in front of Barrow heading north to Dewline Road, just past the Naval Arctic Research Lab (NARL). The study area would extend over a 5 mile stretch of coastline to help:

- Reduce risk to life, health, and safety
- Reduce damages caused by flooding and shoreline erosion to residential and commercial structures and critical public infrastructure
- Reduce or mitigate damage to tangible cultural heritage

1.3 Purpose and Need for the Action

The purpose of this study is to reduce coastal erosion and flooding damages in the vicinity of Barrow, Alaska (Figures 1 and 2). This study is needed because major flooding events took place in 1963, 1985, 1986, 2002, 2015 (USACE 2010), and most recently in September 2017. These events caused flooding and erosion damage shoreline roads, endangered private and public establishments, and unearthed and washed away Alaska Native cultural materials and human remains from the Utqiaġvik Village archaeological site and other cultural sites. Salt water inundation of the old Barrow landfill is a major concern, as it houses solid and hazardous wastes disposed of by the United States Navy and Air Force between 1950 and 1981 (USACE 2010). When a high-water event threatens the fresh water lagoon and Utilidor, public health and safety is at risk. Constructing coastal erosion protection structures to mitigate these issues could protect people's homes and public properties, safeguard important cultural sites lands that contain human remains, and defend the community's Utilidor and fresh water supply. The study area is depicted in Figure 3. Additional details on the existing conditions and problems faced in Barrow due to coastal erosion and flooding are located in Section 2 through 4 in the Feasibility Study.

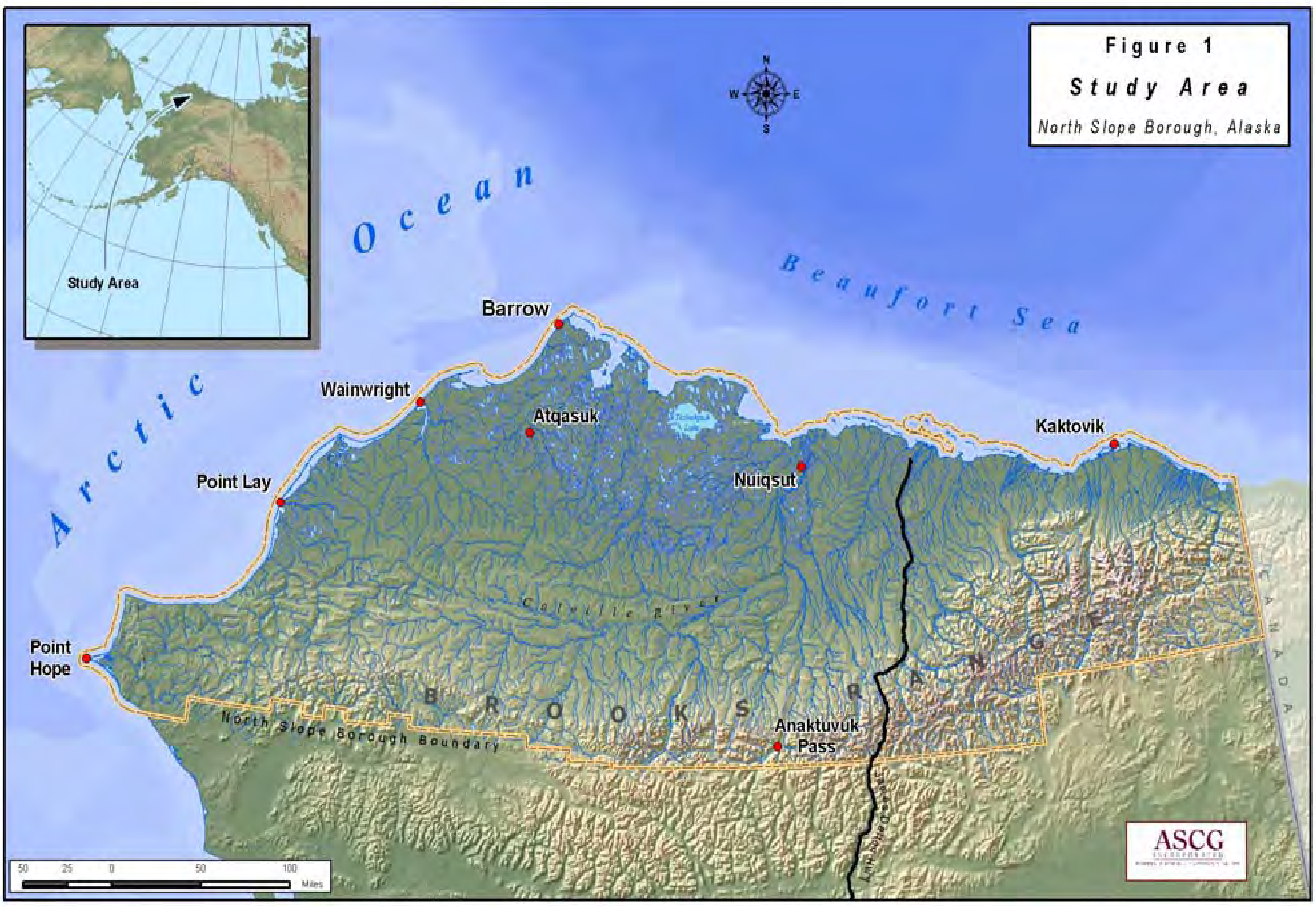

Figure 1. Proposed Project Vicinity Map

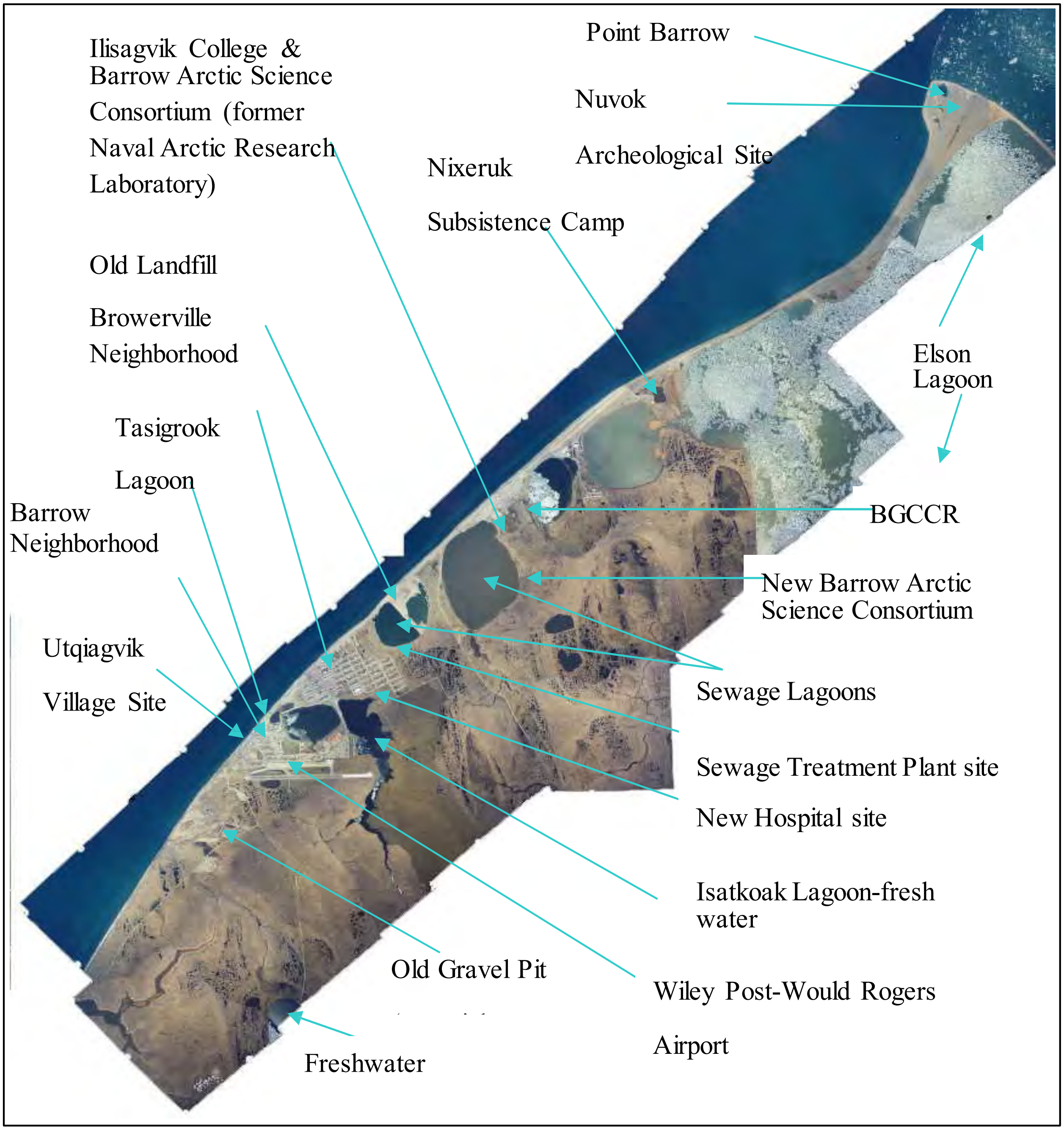

Figure 2. Local Features (Approximate location, not drawn to scale) (USACE 2010)

Figure 3. Proposed Project Area

2.0 ALTERNATIVES

A description of each alternative that was carried forward to the Tentatively Selected Plan (TSP) Milestone is depicted in Table 1. Alternatives 3, 4, and 7 were eliminated prior to the TSP Milestone. Alternative 3 consisted of flood proofing and beach nourishment. The City already utilized flood proofing and beach nourishment was carried into Alternatives 5D, 6A, 6B, and 6C. was eliminated due to the Since the primary causes of erosion is related to the reduction in sea ice and permafrost melting, Alternative 4 was not guaranteed for a 50-year period and was thus screened out. Alternative 7 would decrease wave action, however it would not eliminate the risk of flooding. See Section 2.1 in the Feasibility Report for revised description of the TSP, Alternative 2: Rock Revetment, Berm, and Raise Stevenson Street.

Table 1. Alternatives Carried Forward

Alternative	Description
Alternative 1 (No-Action)	This alternative would be to take No-Action and leave the city susceptible to the effects storms.
Alternative 2A (TSP)	Rock Revetment at Bluff and Berm in Front of Stevenson Street
Alternative 2B (TSP)	Rock Revetment at Bluff and Raise Stevenson Street
Alternative 5A	Protect Major Infrastructure
Alternative 5B	Barrow and Browerville Neighborhoods
Alternative 5C	Barrow and Browerville Neighborhoods Plus NARL
Alternative 5D	Barrow and Browerville Neighborhoods Plus NARL and old Navy Landfill
Alternative 6A	Combination Rock Revetment, Raise Stevenson Street, and Revetted Berm with Limited Beach Nourishment
Alternative 6B	Combination Rock Revetment, Raise Stevenson Street, Revetted Berm, and Beach Nourishment
Alternative 6C	Beach Nourishment Only

The alternatives presented in this EA include the No-Action alternative (Alternative 1), the Tentatively Selected Plan (TSP) (Alternatives 2A/2B), and two groups of alternatives that were carried forward in the study process that involve either different lengths of coastline protection (Alternatives 5A, 5B, and 5C) or alternatives that considered beach nourishment (5D, 6A, 6B, and 6C).

2.1 No-Action Alternative

Under the No-Action Alternative, there would be no Corps project to address coastal erosion and flooding in Barrow. Fall storms would likely continue to erode the Chukchi Sea coastline near Barrow with associated impacts to cultural resources and the City's infrastructure. Local efforts to counteract erosion and flooding, namely the maintenance of gravel berms along the coastline, would likely continue despite being only a short-term and only partially effective strategy.

2.2 Alternative 2 (Tentatively Selected Plan/TSP)

The TSP, a combination of Alternatives 2A and 2B, is to construct a rock revetment along the bluff area with a combination of a revetted berm and raising and revetting Stevenson Street the remainder of the 5-mile length of the proposed project area. The proportions of a revetted berm and raising and revetting Stevenson Street would be determined during the PED phase. The TSP is described in detail in the Feasibility Study in Section 2 and is summarized below. Conceptual design is shown in Table 4.

Work would start with the construction of a rock revetment along the bluff from the bluff area in front of the airport to the start of Tasigarook Lagoon (an approximate 1-mile stretch). The revetment would stabilize the bank and reduce undercutting from waves and localized melting of permafrost. Melting permafrost results in slumping of material and block (ice-wedge) failure. The revetment would consist of fill material to achieve the design slope, filter fabric, gravel, then core material overlaid by two layers of B rock then two layers of 2.7-ton armor rock. B rock, core, gravel, and filter fabric would be buried to match the existing beach elevation below the armor rock to prevent beach material from being washed through the armor layer. The impact to cultural resources would be reduced by using fill material to achieve the design slope rather than excavating into the bluffs to set the design slope. Beach access ramps, boat launches, and interior drainage points would be maintained along the length of proposed project, although the design and location may not be identified until the Pre-construction Engineering and Design phase (PED).

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. The B rock, core, and gravel filter layers would be buried to match the existing beach elevation. The crest height is set at +19 ft, which is 0.5 ft 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 local fill material to achieve a uniform slope. The bluffs are archaeologically rich, so no excavation would be permitted on the bluff face.

Revetted Berm Structure. Because the structure is set back from the beach, a two armor stone thickness would result in a +14.5 ft crest elevation. The filtering B rock layer, core, gravel, and fabric would be placed below the natural beach line for ice survivability. 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 reduced size of the structure would likely result in increased maintenance due to ice impact, 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 double layer placed on a 1 ft layer of core, 1 ft 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.

Raise Stevenson Street. As an alternative to a revetted berm, Stevenson Street can be raised. Raising Stevenson Street, as opposed to constructing a revetted berm, would decrease the quantity of armor rock required while maintaining a view of the ocean from the street. Stevenson Street would be raised to the elevation of the revetted berm with fill material to ensure a 100-year level of protection. The seaward slope of the street would be revetted with two layers of 2.7 ton armor stone and two layers of B stone. The B rock, core, and gravel filter layers would be buried to match the existing beach elevation.

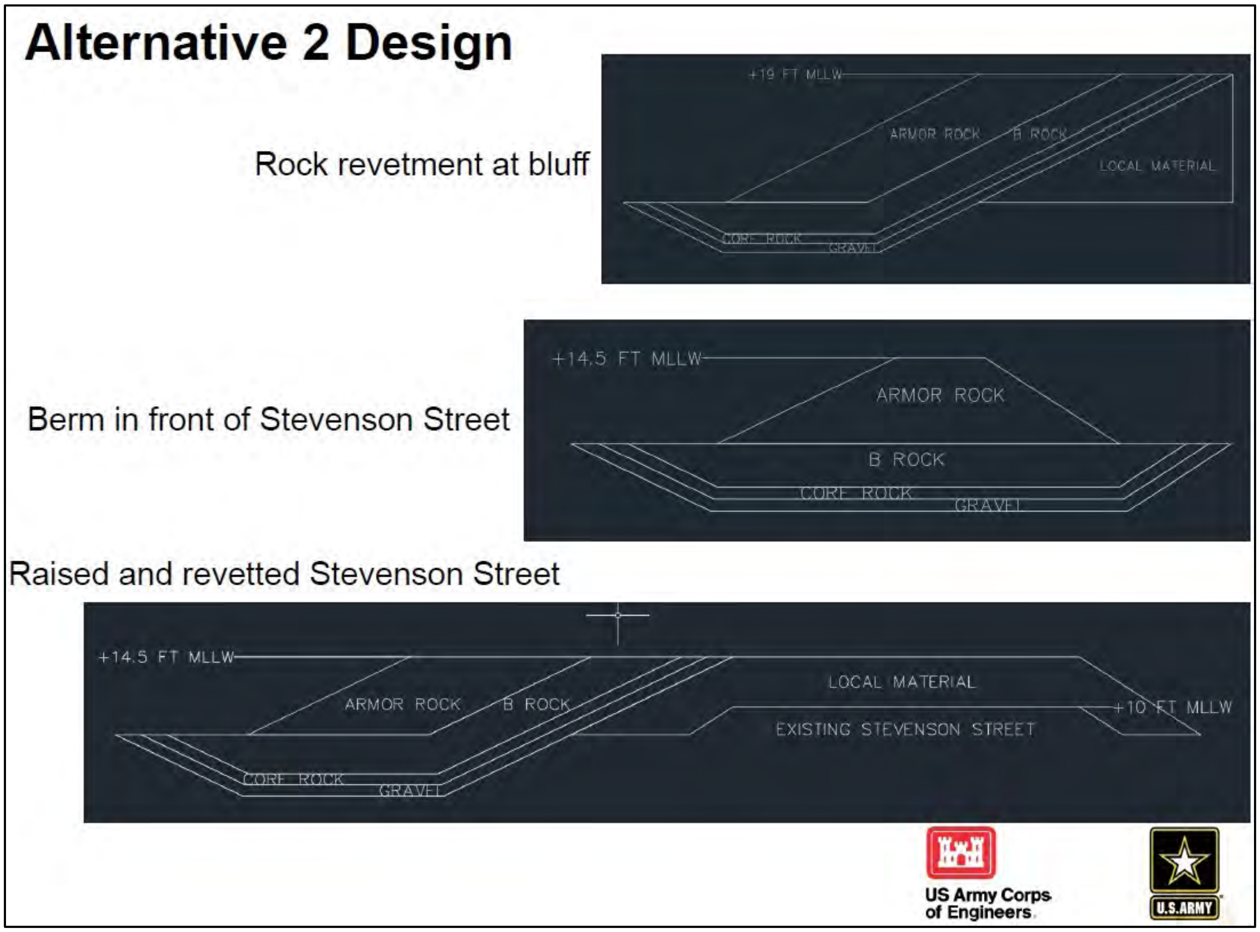

Figure 4. Conceptual design for the proposed revetment, berm, and raised and revetted Stevenson Street for the Barrow coastal storm damage reduction.

2.3 Alternatives Protecting Limited Reaches

These include alternatives 5A, 5B, and 5C and are described in detail in the Feasibility Study in Section 7, Formulation and Evaluation of Alternative Plans.

Alternative 5A would only protect major infrastructure such as the fresh water source (Isatkoak Lagoon, see Figure 2) and two Utilidors which are located closest to the coast.

Alternative 5B would include 5A plus involve a revetted berm to protect Barrow and Browerville.

Alternative 5C would include 5B plus include a revetted berm to protect NARL. The landfill area would not be protected under this alternative.

2.4 Alternatives Involving Beach Nourishment

Four alternatives were considered that involve beach nourishment, 5D, 6A, 6B and 6C. Beach nourishment is a construction measure that that places material, usually sand or gravel, on the coastline to build up the beach farther offshore. This typically requires maintenance with additional nourishment material over time; sometimes annually and perhaps only every several years.

Alternative 5D is nearly the same as the Alternative 5C, except beach nourishment would added in as a measure of protection between Browerville and NARL, which includes the sewage lagoon and the landfill.

Alternative 6A is nearly the same as the TSP (2A/2B) but uses beach nourishment in front of Tasigarook Lagoon instead of a revetted berm or raised road with revetment.

Alternative 6B is nearly the same as alternative 5D except the area in front of the landfill would have only beach nourishment in front of the landfill.

Alternative 6C would involve 5 miles of beach nourishment and none of the structural components included in the TSP.

3.0 AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

3.1 Cultural and Historic Resources

Cultural resources are any resource that may be considered of cultural character. These include any or a combination of: Native American graves and cultural items, shipwrecks, museum collections, historical documents, historic districts, sites, buildings, structures, religious sites, religious practices, cultural use of natural resources, folklife, tradition, other social institutions, theater groups, orchestras, and other community cultural amenities (King 1998:6; NPS 2012).

Cultural resources are limited, nonrenewable resources that have cultural value as traditional materials or locations, or potential for scientific research which may be easily diminished by actions impacting their integrity. Numerous laws and regulations require that possible effects on cultural resources be considered during the planning and execution of federal undertakings. These laws and regulations establish a process of compliance, define the responsibilities of the federal agency proposing the action, and prescribe the relationship among other involved agencies. This include the State Historic Preservation Officer (SHPO) as well as the Advisory Council on Historic Preservation. In addition to the National Environmental Protection Act (NEPA), the primary laws that pertain to the treatment of cultural resources affected by federal actions are the National Historic Preservation Act (NHPA) (especially Sections 106 and 110), the Archaeological Resources Protection Act, the Antiquities Act of 1906, the American Indian Religious Freedom Act, and the Native American Graves Protection and Repatriation Act (NAGPRA).

The area of potential effect (APE) under NHPA for this action includes those areas that could potentially be disturbed by the proposed construction activity. The APE for this undertaking follows the beach parallel to the City; with a barrier starting at the bluff at the southwestern extent of Barrow, to the NARL to the northeast (see Figure 3). The total area is 5 miles along the seaward side of Stevenson Street and the southern bluff.

3.1.1 Cultural History

The far northern shore of Alaska has had a number of cultural transitions, and, as with much of Alaska, has experienced significant change after contact with Euroamerican explorers and their following expansion. Significant sea level and environmental changes over the span of millennia have altered the shoreline and continue to alter the landscape, likely hiding or erasing sites. The largest community in the Alaskan Arctic is the city of Barrow. Cultural resources in the Barrow area range from prehistoric subsurface sites to historic structures, dating from approximately 5,000 years ago to the Cold War.

Precontact History

Several archaeological sites in the Brooks Range have been dated to the American Paleoarctic tradition, at around 11,500 years before present (BP) (Grover and Laughlin 2012). It is assumed that with no coastal sites documented, any coastal Paleoindian sites have been covered by rising sea levels after the Younger Dryas period began (Jensen 2014). This eustatic sea-level rise has likely covered and erased any occupied coastal areas prior to 4,000 years ago in Alaska north of Nome (Odess 2005). One of the earliest coastal archaeological sites in northwestern Alaska was identified in Norton Sound; this site, Iyatayet (NOB-002), was attributed to the Denbigh Flint Complex, an early regional variant of the Arctic Small Tool tradition dating to approximately 4,000 years ago (Dumond 1998a; Tremayne and Rasic 2016). Farther north, excavations from the lowest cultural levels at the Walakpa site (BAR-013)produced a radiocarbon (C14) date of 3,400±520 before present (BP), and the Central Creek Pingo site (XBP-008) produced a C14 date of 4060±130 BP (Lobdell 1992; Slaughter 2005; Stanford 1976).

The number of coastal settlements in northern Alaska began to increase around 2,500 BP (Anderson 1984; Dumond 1998b). Beginning around 1,550 BP, there was a second climatic warming period which decreased the amount of offshore ice, creating open waters during the summer season and making new resources accessible; the access to these new resources spurred the development of new hunting technology and techniques (Friesen and Mason 2016). During this time, whale hunting increased at some coastal sites (McClenahan 1993). These new cultural developments were associated with the Birnirk culture, and have been identified at the Utqiaġvik (BAR-002) and Birnirk (BAR-001) sites at Barrow, and the Kugusugaruk site (BAR-003), Coffin site (BAR-014), and Walakpa (BAR-013) sites to the southwest (Anderson 1998; Gerlach and Mason 1992; Stanford 1976).

By about 1,000 BP, cultural remains of the Western Thule people dominated the coast of northern Alaska. The Western Thule are easily recognizable as the direct ancestors of the Iñupiat people (McClenahan 1993). Material culture known from recent ethnographic records has been recovered at sites dating to this period. In addition, the Thule period was characterized by the development of technology for winter ice-hunting, as well as hunting by kayak and umiaq on the open sea. This people of this time period focused on whale hunting, supported by the continued hunting of caribou and other land mammals, as well as birds and freshwater fish. They also began settling in larger communities (Anderson 1984; McClenahan 1993; Morrison 1998). Sites occupied by the Western Thule culture at or near Barrow include Walakpa (BAR-013), Utqiaġvik (BAR-002), Nuvuk (BAR-011), and Birnirk (BAR-001) (Jensen 2016).

Russian Alaska

Northern Alaska was not noticeably affected during the Russian period; impacts from Western cultures were not discernable until approximately 1850 (Hall 1984). The Russian government did not consider the northern parts of Alaska a priority due to the lower quantity of fur-bearing animals in the vicinity. However, Russian trade goods such as tobacco, iron, copper, and glass beads did make it north via traditional trade fairs and routes (Jensen 2015; Kunz et al. 2005; Murdoch 1892).

The first two recorded Western visits to North Slope of Alaska both took place in 1826. Captain Frederick Beechey of the English Royal Navy, in command of the fifteen-gun sloop *HMS Blossom*, led an expedition into the Bering Strait and east to Icy Cape (Beechey 1832), while Sir John Franklin's expedition traveled west from the Mackenzie River until they reached Return Island just west of Prudhoe Bay (Franklin 1828). Although Beechey and *Blossom* did not make it much past Icy Cape and due to shallow waters, the Blossom's barge under the command of Thomas Elson and Wouldiam Smyth made it as far as Point Barrow and the settlement of Nuvuk (Beechey 1832).

In the 1840s, commercial whalers began hunting in the Bering Strait, followed by the Chukchi Sea in the 1850s and the Beaufort Sea soon after (Bockstoce 1986). Euroamericans established shore-based whaling stations, including one at Point Belcher slightly north of Wainwright, and many Iñupiat began participating in the commercial whaling industry (Allen 1978; Brower 1842; Cassell 2000, 2005). While the initial targeting of whales was primarily for the purpose of acquiring whale oil from the blubber, there was also a secondary market through the baleen trade which continued to support the industry even after the discovery of petroleum in the eastern United States. A combination of the collapse of the baleen market and the depletion of the whale stock essentially ended commercial whaling in about 1916 (Bockstoce 1986; Spencer 1959; Stefansson 1913, 1914).

American Period

There were limited changes in Barrow directly associated with World War II; however, the Seabee Arctic Oil Expedition set out in 1944 to construct a base in the Arctic and determine the amount of oil was in the reserves. A crew of 200 men and officers arrive in the waters of Barrow in August 1944 and began offloading and constructing a base of operations. The mission was deemed successful in the summer of 1945 when the Seabees discovered oil-bearing strata (Bingham 2011). In 1949, Barrow became the home of one of the Alaska Scout Battalions, when the C Company of the 1st Battalion of the Territorial Guard, also known as "Eskimo Scouts," was stationed there. The Alaska Scout Battalions were military groups of Alaska Natives who were trained to be the first line of defense against foreign invaders if Alaska was attacked. The C Company's primary duty was to protect and keep watch on Alaska's northern shores during the early Cold War period (Hendricks 1985; Hummel 2005).

The Cold War period had significant impacts on Barrow and its inhabitants. In 1948, the Office of Naval Research established NARL in Barrow with the purpose of conducting research in the arctic environment to improve the military's responses in the region. The development of NARL increased the population during the summer season as military and civilian researchers used the site. The Navy ended its involvement in NARL and associated facilities in 1980, and transferred the laboratory and camp area to Ukpeaġvik Iñupiat Corporation Science in 1984.

On a regional scale, one of the greatest impacts to northern Alaska came in the form of the Distant Early Warning radar system (DEW Line), whose stations stretched over 3,000 miles across Alaska and northern Canada to alert the military in the case of a circumpolar Soviet attack (Hummel 2005; OHA 2018). The Point Barrow station, POW-MAIN, was the main hub for the DEW Line in Alaska. The construction of POW-MAIN was completed in 1955. The system was upgraded in the 1980s, with the obsolete radar equipment replaced with the newer AN/FPS-117 MAR, and since has been part of the Alaska Radar Warning System (USAF 2006). Construction work and other associated jobs attracted people to the area, and the town of Barrow continued to grow throughout the Cold War.

3.1.2 Previous Archaeological Studies

Barrow has a number of historic and prehistoric sites near or within the APE which have been recorded in the Alaska Heritage Resources Survey (AHRS; Table 2). Several of these sites are eligible for or have been listed on the National Register of Historic Places (NRHP). The proposed project would have an impact on the integrity of the Utqiaġvik Village site (BAR-002) at the southwestern end of Barrow. The revetment would lay against it and partially on top of it; however, the site is also actively eroding out of the seaward bluff. There are also five other sites located near the APE, including Browerville (BAR-007), Esatkuat (BAR-009), the Refuge Station (Brower Café; BAR-012), the Elavgak House (BAR-016), and the Browerville Ice Cellar (BAR-060). The proximity of the proposed project to these sites makes the impact on these properties a possibility. The majority of known cultural resources, however, are not in proximity to the proposed project and would not be adversely affected by the construction.

Table 1: Sites within general vicinity of the APE (OHA 2018).

AHRS #	Site Name	Type	NRHP Status	In APE
BAR-001	Birnirk	Subsurface	National Historic Landmark	No
BAR-002	**Utqiaġvik Village Site**	**Subsurface**	**Eligible**	**Yes**
BAR-004	Utqiaġvik Presbyterian Church Manse	Structural	Listed	No
BAR-007	**Browerville**	**Structural**	**None**	**Near**
BAR-009	**Esatkuat**	**Subsurface**	**None**	**Near**
BAR-011	Nuwuk	Subsurface	Eligible	No
BAR-012	**Refuge Station (Brower Café)**	**Structural**	**Listed**	**Near**
BAR-015	Sod House	Structural	None	No
BAR-016	**Elavgak House**	**Structural**	**None**	**Near**
BAR-022	Kugok	Subsurface	None	No
BAR-041	POW-M (DEW Line)	Structural	Eligible	No
BAR-046	Building 100	Structural	Eligible	No
BAR-047	Building 101	Structural	Not Eligible	No
BAR-053	LRRS Road System (DEW Line)	Structural	Eligible	No
BAR-055	NWS House 1	Structural	Eligible	No
BAR-056	NWS House 2	Structural	Eligible	No
BAR-057	NW House 3	Structural	Eligible	No
BAR-058	NWS Recreation Hall	Structural	Eligible	No
BAR-059	Old government building	Structural	None	No
BAR-060	**Browerville Ice Cellar**	**Subsurface**	**None**	**Near**

BAR-061	NWS House Duplex B-4	Structural	Not Eligible	No
BAR-063	NWS Upper Atmosphere Facility	Structural	Not Eligible	No
BAR-065	NWS Office Building B-6	Structural	Not Eligible	No
BAR-066	Old Navy Bridge	Structural	Not Eligible	No
BAR-069	Cooper Is. Navy Station	Structural	Not Eligible	No
BAR-070	Cooper Is. 2	Subsurface	Eligible	No
BAR-073	Suvlu House	Structural	Not Eligible	No
BAR-074	Brower House	Structural	Not Eligible	No
BAR-075	NARL	Structural	Eligible	No
BAR-076	Building 250	Structural	None	No
BAR-079	NARL Airstrip	Structural	None	No
BAR-081	Building 133	Structural	None	No
BAR-082	Building 134	Structural	None	No
BAR-083	Building 130	Structural	None	No
BAR-087	Grave	Subsurface	None	No
BAR-101	Face-down burial (Uncle Foot)	Subsurface	None	No
BAR-102	Nungasak House	Structural	None	No
BAR-103	Yong House	Structural	None	No
BAR-121	Seabee Core Test Well #1	Structural	Eligible (assumed)	No
BAR-123	Barrow Big Rig Test Well #1	Structural	Eligible (assumed)	No
BAR-129	South Barrow Test Well #1	Structural	Eligible (assumed)	No
BAR-138	BUECI Water Treatment Plant Utilidor	Structural	None	No

BAR-002 is the Utqiaġvik Village site. This site was originally identified as having 61 house mounds, but with the continual growth of the City of Barrow the site has been reduced to approximately 35 (as recorded by Sheehan in 1982). The site also includes a number of historic ice cellars and other cultural features, as it covers approximately a 2-acre tract of tundra within Barrow (Figure 5). A number of excavations have been conducted at this site. The research gives evidence of the area slowly developing larger communities; increasing population sizes subsequently increased stresses on local resources. This led to the increasing importance of the whaling captains, *umialit*, as leaders in their communities, which still continues in the modern day (Sheehan 1997). Archaeological excavations have recovered bone, stone, ivory, baleen, and wood artifacts. Human remains have also been recovered from a number of house features. Artifacts and human remains were identified *in situ* in a protocontact house that was crushed by an *ivu*. An *ivu* is a specific type of ice movement, formed when a combination of strong winds, temperature changes, tidal change, and current all work in tandem to push sections of sea ice onto itself or onto land. This can push other ice or objects, or in some cases the ice would calve after being pushed up and crush anything underneath it. Damages to at least one house mound in BAR-002 indicate that a broken ivu crushed a house while the inhabitants were sleeping inside it (Reynolds 1995). The Utqiaġvik Village site has been determined to be eligible for the National Register of Historic Places by the Keeper of the National Register (OHA 2018). It is actively eroding out of the bluff in southern Barrow as seasonal storms continue to impact the coastline (Figure 6).

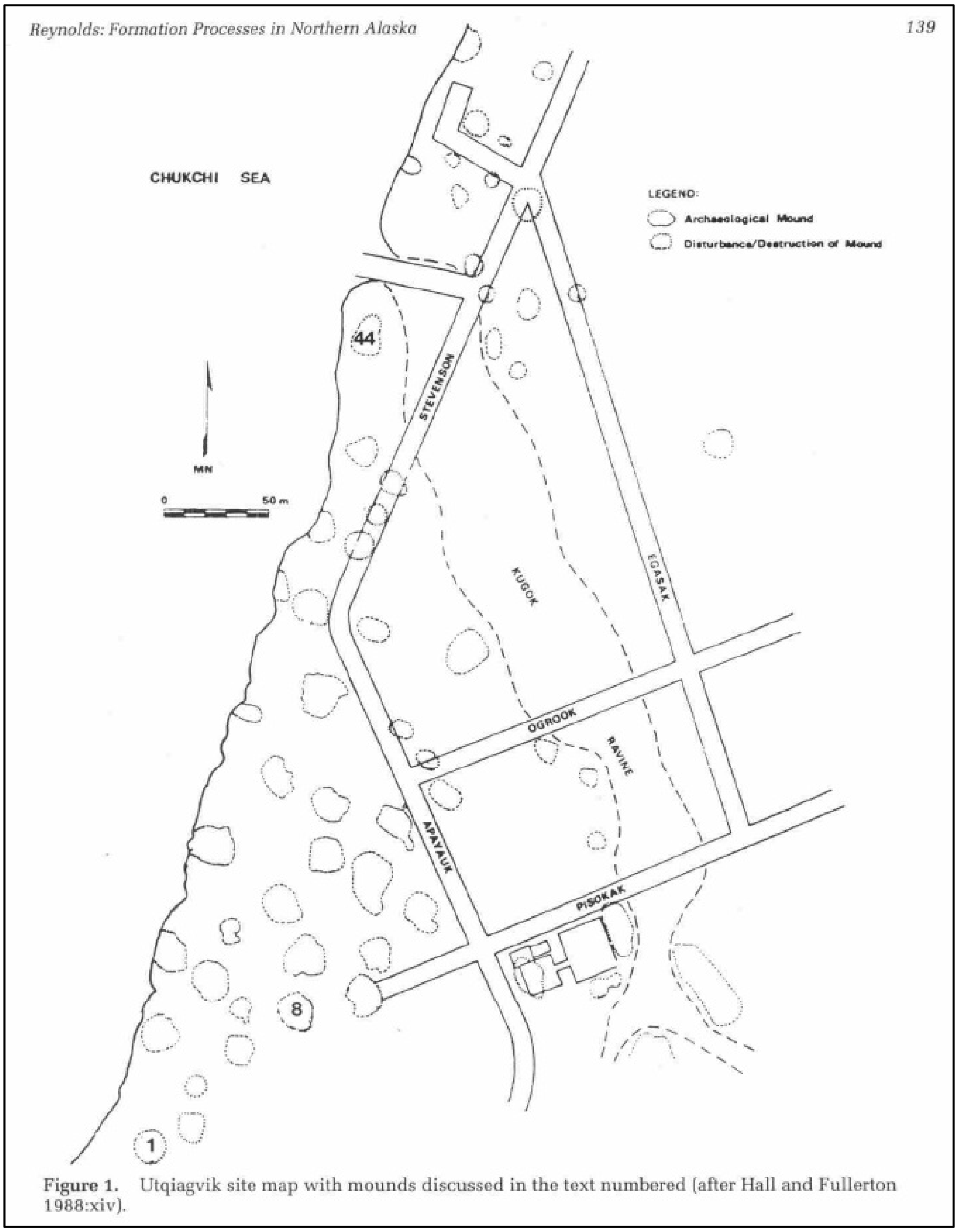

Figure 5. Sketch map of the Utqiaġvik Village site (BAR-002), with modern roads and some buildings drawn in relation to the mounds (*from* Reynolds 1995).

Figure 6. Section of BAR-002 eroding out of the bluff in 2017.

The Browerville site (BAR-007) was named after Charles D. Brower, who headed a whaling station in the Barrow area in 1886. Later he established a trading post near the site of the U.S. Polar Station (BAR-012). This site has not been evaluated to determine its eligibility, and would require a determination of eligibility (DOE) to be written if mitigation is required.

Esutkwa (BAR-009) was a former Iñupiat camp which was reported in 1892 by Sgt. John Murdoch. It was reportedly located at the northwestern end of Esatkuat Lagoon. Murdoch (1892:27) states that the site was already ancient by the time he wrote of it, but does not go into any further description. This site has not had a DOE completed (OHA 2018).

The Refuge Station (Brower Café) (BAR-012) is the oldest frame building in the Alaskan Arctic. It was constructed in 1893 by the government to be a whaler refuge station. It was acquired by Charlie Brower in 1897 as the base of his whaling and trading station known as Browerville (BAR-007). Later, it became a café in 1977, and is still in good condition. It has fulfilled a number of functions throughout its life, and is known for its association with most of the explorers, whalers, scientists, missionaries, politicians, entrepreneurs, and adventurers who visited the region. The site has been listed on the NRHP (OHA 2018).

BAR-016 is one of the oldest frame structures in Browerville. Known as the Dora Elavgak House, it was constructed in 1890 with lumber left over from the construction of the Charles Brower trading post; the approximate size of the house is 10 ft by 15 ft (Alaska Army National Guard 2009). The site has not had a DOE completed (OHA 2018).

BAR-060 is an ice cellar associated with the Browerville site (BAR-007). The AHRS card does not have any information regarding the site's description, and no DOE has been completed (OHA 2018). It is appears to be an unused, large communal ice cellar that is often visited by tourists (Figure 7).

Figure 7. Ice cellar (BAR-060) near the Brower café in 2017.

3.1.3 Consequences of Alternatives

Consequences of No-Action

The No-Action Alternative would leave the Utqiaġvik Village site (BAR-002) exposed to further damage from erosion and flooding. Portions of the site have already become exposed to the environment and have lost portions of its physical property. Furthermore, five other previously mentioned sites (BAR-009, BAR-060, BAR-007, BAR-016, BAR-012, and BAR-138) which are further north up the coast from BAR-002, would be threatened by the continual washout from the storms, and may eventually succumb along with the disappearing shoreline. Thawing permafrost in the Russian Arctic has led to the damage of several hundred buildings, many constructed after 1940 and were designed for arctic conditions, as permafrost thawed and made the foundations unstable (Nelson *et al.* 2002). They may also be damaged from the flooding that Barrow suffers after large storms as waves breach the temporary berms. The identified NHPA adverse effect anticipated with the No-Action Alternative includes:

1. Physical destruction of or damage to all or part of the property [36 CFR § 800.5(a)(2)(i)].
2. Neglect of a property which causes its deterioration [36 CFR § 800.5(a)(2)(vi)].

Consequences of Alternative 2 (Tentatively Selected Plan)

The proposed TSP includes the construction of a revetment barrier along the bluff at the southern end of Barrow, starting on the beach directly west of the airstrip and following the bluff up to the lagoon for approximately 1 mile. The revetment would consist of adding rock layers to the bluff face, using a filter layer or fabric over the exposed bluff, followed by layers of intermediate sizes of rocks and finally an armor layer with larger boulders (Figure 8). The revetment aims to reduce erosion and stabilize the bank.

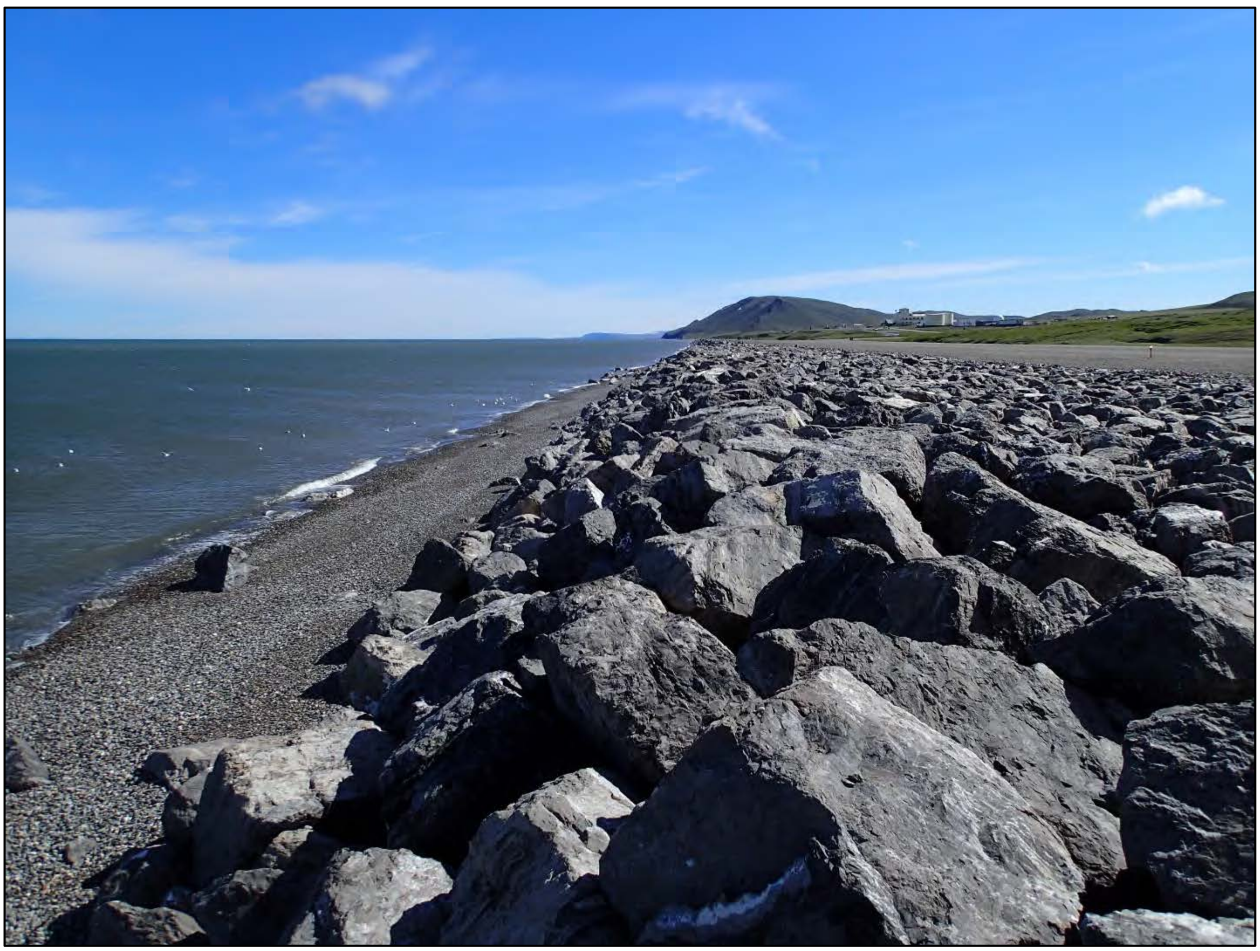

Figure 8. An example of a rock revetment from a Corps project on Cape Lisburne. Armor rocks shown are approximately 3.5 tons each. Note that there is no high natural bluff which is present in Barrow.

As part of the Utqiaġvik Village site (BAR-002) has become exposed by storms and erosion, a section of the site would be directly under part of the proposed revetment. This would cover the seaward section of the site and place a significant amount of weight directly against the site. The Barrow region, especially the coastline, has suffered from permafrost thaw. This is significant in that the subsurface cultural resources were formally protected by permafrost; without it the organic archaeological materials deteriorate and are vulnerable to surface pressure (Martens 2017; Matthiesen et al. 2014). Cultural resources and heritage sites have been found to be vulnerable to climate change, with increased variation of the freeze/thaw cycle and thawing of permafrost leading to destruction of site integrity, mold, rot, and other moisture-related destructive forces (Markham et al. 2016; Hollensen et al. 2016). The weight of the armor rocks, combined with the thawing permafrost, would likely cause the splash apron and cap to sink into the site. There may also be crushing from the revetment itself from the side as the soil thaws. Additionally, the existence of the revetment would preclude future archaeological recovery efforts.

The TSP is expected to alleviate the physical destruction at the Utqiaġvik Village site (BAR-002) caused by erosion and flooding; however, placement of the revetment itself is expected to have adverse effects. These include four specific types of adverse effects identified in the NHPA regulations:

1. Physical destruction of or damage to all or part of the property [36 CFR § 800.5(a)(2)(i)].
2. Alteration of a property, including… maintenance, stabilization [36 CFR § 800.5(a)(2)(ii)].
3. Change of the character of the property's use or of physical features [36 CFR § 800.5(a)(2)(iv)].
4. Introduction of visual, atmospheric or audible elements that diminish the integrity of the property's significant historic features [36 CFR § 800.5(a)(2)(v)].

While a portion of BAR-002 would be adversely effected by the construction of proposed alternative, the revetment would protect more inland portions of the site from future storm damage and erosion. The proposed revetment would continue up the coast for approximately one mile, and then transition into either a protective berm, or raising Stevenson Street and adding a revetment alongside; these two options, which would be identified in the engineering design, would continue for approximately four more miles towards the NARL site. On raising Stevenson Street, the Alternative 2 plan is to cover the existing area with local material, raising the height +10 ft MLLW to +14.5 ft MLLW. The proposed project would then add a revetment to protect it from future erosion and storm damage. The other five sites near the APE, the Esatkuat site (BAR-009), the Ice Cellar in Browerville (BAR-060), the Browerville structure (BAR-007), the Elavgak House (BAR-016), and the Refuge Station (Brower Café) (BAR-012) are along the shoreline near the APE where these two different barrier types are being considered. Neither of the barrier types would have any negative impact to the five sites. Either raising Stevenson Street with a revetment or building a berm would protect these sites from any future storm damages expected.

Consequences of the Alternatives Protecting Limited Reaches

The effects of the various alternatives that protect a limited reach of coastline would involve the effects described above for the TSP and the No-Action Alternative. The overall effects of any of the different alternatives (6A, 6B, 6C) that protect a limited reach would involve differing proportion of coastline with the effects of revetment and the consequences of No-Action. It is essentially subjective whether it is better to cover these resources under a rock revettment where they would remain in place but inaccessible or to leave them unprotected and subject to damage and loss.

Consequences of the Beach Nourishment Alternatives

This group of alternatives that involve varying degrees of the TSP and beach nourishment in front of the lagoon (6A) and the lagoon and landfill (6B) would lead to similar effects as the TSP. Cultural resources would be impacted where the revetted berm is placed (as described for the TSP). The areas in front of the lagoon (6A) or the lagoon and landfill (6B) would be protected from further coastal erosion be beach nourishment, but would not necessarily be protected from permafrost degradation.

Alternative 6C involves 5 miles of beach nourishment and not revetment. This would protect the cultural resources along the shoreline from coastal erosion by wave action, but the bluffs would continue to slough and cause damage to imbedded cultural resources due to permafrost degradation.

3.1.4 Mitigation Strategies

On 19 July 2018, the Corps found that the proposed revetment associated with the TSP would have an adverse effect on the Utqiaġvik Village site (BAR-002) (USACE 2018). On 21 August 2018, the SHPO requested that the Corps reengage in consultation once more specific construction details are identified (SHPO 2018). The Corps expects the TSP to require a Memorandum of Agreement (MOA) among all interested parties in order to determine the appropriate mitigation of adverse effects on BAR-002 [36 CFR § 800.6(c)]. The MOA process would begin with an invitation to participate mailed out to all interested parties. The Corps would work with the signatories, invited signatories, and concurring parties to the MOA to identify an appropriate mitigation strategy. Construction of the TSP would not begin prior to the execution of the MOA.

The other five known sites within the vicinity of the APE, which include Browerville (BAR-007), Esatkuat (BAR-009), the Refuge Station (Brower Café; BAR-012), the Elavgak House (BAR-016), and the Browerville Ice Cellar (BAR-060), would be not be significantly impacted by the TSP. Cultural uses of the beach in front of the City, including but not limited to subsistence hunting, would not be limited by the construction of the TSP.

3.2 Physical Environment

Barrow is at latitude 71°18'N, longitude 156°47'W, approximately 329 miles (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 approximately 10 miles (16 kilometers) to the northeast.

Attachment 1 describes the physical environment surrounding Barrow in great detail. Since Attachment 1 is a description of the affected environment, and not an EA, the primary resources that are likely to be impacted by the proposed action are described below.

3.2.1 Sea Ice, Climate, and Hydrology

Barrow is located in an arctic environment with an average annual precipitation (rain and melted snow water) of 5 inches and average annual snowfall of 29 inches. Temperature extremes are rarely below -36°Fahrenheit (F) or above 60°F, with average temperatures ranging -19°F to 47°F. The daily minimum temperature is below freezing 324 days of the year. The sun does not set between 10 May and 02 August every year, nor does it rise between 18 November and 24 January. The Chukchi Sea is typically ice-free from early July at Barrow. Freezing typically occurs in November, but the formation of stable shorefast ice may be delayed. During the winter of 2017-2018, shorefast ice had not formed until January (NWS 2018). Stability is achieved after one or more significant pack ice "shoves" deform and ground the ice.

Barrow is in an area of semi-diurnal tides with two high waters and two low waters each lunar day. Mean Sea Level (MSL) is +0.25 feet (ft) Mean Lower Low Water (MLLW) and Mean Higher High Water (MLLW) is +0.50 ft. Prevailing winds are easterly and average 12 miles per hour (mph) with maximum wind speeds recorded up to 48 mph. Barrow's wave climate is dictated by storms in the Arctic Ocean limited in extent by the pack ice. Tidal fluctuations at Barrow are minimal so the predominant source of currents is wind generation. Longshore sediment transport at the site was estimated at an average net transport rate of 7,300 cubic yards (CYs) per year to the northeast (USACE 2010).

The driving concern for this study is that the City of Barrow is centered within a dynamic coastal environment. Due to the changing nature of sea ice, which would normally buffer the coastline, the City is now exposed to storm and wind driven waves during increasing ice-free periods. The Chukchi Sea is typically ice-free from early July at Barrow. There has been a noticeable shift when sea ice forms along the coastline. Shore fast ice and freezing has historically been recorded in September, but now typically occurs in November, and has been delayed to as late as January (NWS 2018). 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 (USACE 2010). 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.

Along with the delay of sea ice, warmer climates are affecting permafrost melting. Permafrost is soil, rock, or sediment that is frozen more than two consecutive years. As the average temperature increases, precipitation has increased which in turn results in the weakening and eventual collapse of buildings in areas which lie upon the permafrost. In Barrow, reduction in permafrost is one factor adding to erosion, especially along the bluff.

A changing climate is leading to accelerated permafrost loss, decrease sea ice formation, and increase wet precipitation in the Arctic. Although the Corps cannot change this natural process, this study does recognize them as influencing factors and has developed an array of alternatives to help mitigate their impact.

3.2.1.1 Consequences of Alternatives

None of the alternatives, including the No-Action Alternative, would negatively affect the sea ice, climate or hydrology.

All action alternatives would positively address, to different extents, the impacts the community is experience from changing sea ice and storms

3.2.2 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.

Currently the City maintains a temporary berm along the coast to help protect the community from flooding and heavy wave action during storms. This is done using heavy machinery to push sand up from nearshore onto the beach. The use of heavy machinery adds to air pollution, which is quickly dissipated by the predominant winds. This would likely remain the same during the No-Action Alternative since this is the current means of shoreline protection implemented by the City.

3.2.2.1 Consequences of Alternatives

Under the No-Action Alternative, conditions would remain the same with consistent impacts to local air quality resulting from the maintenance of the temporary berm.

All of the action alternatives, including the TSP, would require the use of heavy machinery during construction. These would decrease air quality for the short term. However, since these alternatives are more permanent solutions to prevent coastal erosion and flooding, the long-term impacts to air quality would be less than during the No-Action Alternative. There would no longer be a need to maintain the temporary berm, reducing yearly impacts caused by this action. No significant impacts to air quality are anticipated.

3.3 Biological Resources

Biological resources near Barrow were described in the 2010 Coastal Storm Damage Technical Report. The environmental content provided in Attachment 1 was not part of an EA but was provided in a summary of the existing environment for a previous erosion control study that was not economically justified. The biological resources discussed were for a previous study that considered a much wider range of alternatives, including significant development in the nearshore marine environment and developing new gravel sources on the tundra in Barrow. The information in Attachment 1 goes into great detail regarding Arctic flora and fauna to include terrestrial wildlife, marine mammals, essential fish habit, nearshore fish species, vegetation, and protected species.

Because this study's reduced scope would predominantly impact the bluff, beach and nearshore environments, this section discusses those biological resources that are likely to be found within the proposed study footprint. An in depth description and inventory of resources can be found Attachment 1.The material source would be from an existing quarry, likely in Nome, Alaska. It is possible that some gravel would come from Barrow, but it would be from an existing commercial quarry.

3.3.1 Tundra

The predominant vegetation type in Barrow is tundra, which, in the study area is formed over a permafrost layer. 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 (USACE 2010). The top of the bluff, adjacent to the airport runway, is vegetated with tundra and topped with 6 houses. The bluff face terminates onto the beach and is within the wave-impact zone during storms and heavy wind events, causing active erosion during the summer and fall. Approximately 0.6 acres of tundra are within the study area.

3.3.1.1 Consequences of Alternatives

Consequences of No-Action

The No-Action Alternative would impact greater tundra habitat over the long-term due to bluff erosion and wave run-up action. This alternative would not protect the bluff, leaving them susceptible to the natural elements.

Consequences of the TSP

Alternative 2A/2B, the TSP, includes an element of bluff revetment. Construction of the revetment would consist of rocks abutting against the bluff face with a rock cap on the top of the bluff, which would impact the exposed surface of the bluffs and approximately 0.6 acres of tundra. Although construction would damage some existing habitat, over the long term, the revetment would protect the area from further erosion. No significant impacts are anticipated.

Consequences of the Alternatives Protecting Limited Reaches

Alternative 5A, includes a smaller area of bluff revetment in front of Barrow leaving the unprotected bluff area with similar impacts as the No-Action Alternative. No significant impacts are anticipated.

Alternatives 5B, 5C, 5D, would have similar impacts as the TSP because they each include the measure of armored bluff revetment extending along the same reach as Alternative 2A/2B. No significant impacts are anticipated.

Consequences of Beach Nourishment Alternatives

Alternatives 6A and 6B would have similar impacts as the TSP because they each include the measure of armored bluff revetment extending along the same reach as Alternative 2A/2B. No significant impacts are anticipated.

Alternative 6C would only place beach nourishment in front of the bluffs, adding some level of protection from smaller waves. Without an armored revetment, Alternative 6C would leave the bluff face exposed and unsupported during heavy storm events and when there is permafrost thaw. No significant impacts are anticipated.

3.3.2 Marine Fish and Invertebrates

Nearshore marine fish and invertebrates were sampled extensively near Barrow and along the Beaufort and Chukchi Sea coasts annually between 2004 and 2009. These surveys took place for the previous study when several alternatives involved placing large amounts of fill in the water. The results suggested that nearshore fish and invertebrate species are highly variable along the coast. Data from these surveys are discussed in Attachment 1, Thedinga et al. 2013, Johnson et al. 2010, and are available online in the Nearshore Fish Atlas of Alaska.

3.3.2.1 Consequences of Alternatives

Consequences of No-Action

Unlike many other studies, the No-Action Alternative could lead to several negative impacts for marine fish and invertebrates. While the no-alternative avoids all potential construction impacts associated with revetments, there are several potential implications of the No-Action Alternative. Coastal erosion and, to a greater extent, coastal flooding, typically leads to contamination and degradation of the marine environment. Erosion and flooding scatter everything from building materials to all types of personal property throughout the landscape leaving debris scattered across the tundra, in freshwater lakes including drinking water sources, and into the marine environment. This debris can impact everything from human health to marine mammals, birds, and fish.

In addition to the debris, a more persistent potential problem involves spills of fuel and oil from a major erosion event or a flood. This issue concerns everything from large scale releases, such as the gas station or large fuel tanks and the landfill, to numerous small spills from fuel cans, four-wheelers, snow machines, home heating oil tanks, etc. These sorts of items are moved, toppled, and displaced during major erosion and flood events and can lead to long term pollution of terrestrial, freshwater, and nearshore marine habitats and the humans and wildlife species that rely on them. Since a large portion of the subsistence resources are locally harvested, the effects of debris and spills can have long term effects on subsistence.

Consequences of the TSP

As the TSP (2A/2B) does not involve placing fill in the water, there are no consequences anticipated for nearshore fish and invertebrates from this study. Essential Fish Habitat would not be impacted by the proposed project and is not considered further in this document.

Consequences of the Alternatives Protecting Limited Reaches

Alternatives 5A, 5B and 5C would blend the effects of the TSP and the No-Action Alternative. While the effects of the preferred action pose no impacts to marine fish and invertebrates since the study footprint is out of the water, the section of coastline left unprotected under 5A, 5B, and 5C would leave open the possibilities described under the No-Action Alternative in terms of impacts to marine fish and invertebrates from debris and contamination from future coastal erosion and flooding.

Consequences of Beach Nourishment Alternatives

The beach nourishment alternatives (5D, 6A, 6B, and 6C) would cause a large impact on nearshore fish and invertebrates. These fish and invertebrates would be covered or displaced. The nearshore marine environment is a productive and dynamic area based on previous fish surveys and many of these fish would be harmed by placing large amounts of sediment near shore. The impacts would continue in future years, thought likely to a lesser extent, as more material is added to the beach nourishment areas for maintenance.

3.3.3 Protected Species

The protected species that may occur in the study area are listed in Table 3. The study area includes both the study footprint and the surrounding marine and terrestrial habitat. Additional information on species is discussed in Attachment 1. Protected species of concern for this study include both eider species, bowhead whales, and gray whales.

Table 3. Protected species that may be present in the study area.

Common name	Species name	Regulatory protection
Steller's eider	*Polysticta stelleri*	ESA - USFWS
Spectacled eider	*Somateria fischeri*	ESA - USFWS
Humpback whale	*Megaptera novaeangliae*	ESA - NMFS
Bowhead whale	*Balaena mysticetus*	ESA - NMFS
Harbor porpoise	*Phocoena phocoena*	MMPA - NMFS
Killer whale	*Orcinus orca*	MMPA - NMFS
Gray whale	*Eschrichtius robustus*	MMPA - NMFS
Narwhal	*Monodon monoceros*	MMPA - NMFS
Ribbon seal	*Histriophoca fasciata*	MMPA - NMFS
Spotted seal	*Phoca largha*	MMPA - NMFS
Beluga whale	*Delphinapterus leucas*	MMPA - NMFS

Eiders

Both Steller's and spectacled eiders can be found at nearshore leads in the sea ice in late May and early June. From June through early fall both species can be found on the tundra near Barrow during pre-nesting (adult males and females), nesting, and rearing of their broods. Males and unsuccessful females may briefly be found in marine waters near Barrow after nesting is initiated (males) and if the nesting is unsuccessful. Males and females may be found in nearshore marine waters for a brief period early in the nesting season if they choose not to initiate a nest that season. In the early fall, both species may briefly be present in nearshore marine waters as they leave the tundra from either the Barrow area or pass through the area from more distant breeding grounds to the east.

Whales

Humpback whales are very uncommon in in the Chukchi Sea, especially as far north as Barrow, although their range may be increasing. If they were to occur, they would most likely be from the endangered Western North Pacific Distinct Population Segment (DPS) or the threatened Mexican DPS.

Bowhead whales are very unlikely in the study area during the summer as they are found far the east and well into Canadian waters. Bowhead whales move back into the Barrow area in the fall where they are present for subsistence harvest by Barrow hunters, typically in October. Rock deliveries would likely be complete before this time of year to avoid bad weather in the Chukchi Sea and difficult conditions for offloading material at the beach.

3.3.3.1 Consequences of Alternatives

Consequences of No-Action

Unlike many other studies, the No-Action Alternative could lead to several negative impacts for marine mammals and birds. While this avoids all potential construction impacts associated with revetments, there are several potential implications of the No-Action Alternative. Coastal erosion and, to a greater extent, coastal flooding, typically leads to contamination and degradation of the marine environment. Erosion and flooding scatter everything from building materials to all types of personal property throughout the landscape leaving debris in the marine environment. This debris can impact birds and marine mammals but entanglement and ingestion. In addition to the debris, a more persistent potential problem involves spills of fuel and oil from a major erosion event or a flood. This issue concerns everything from large scale releases such as the gas station or large fuel tanks and the landfill, but also includes the potential for numerous small spills from fuel cans, four-wheelers, snow machines, home heating oil tanks, etc. These sorts of items are moved, toppled, and displaced during major erosion and flood events and can lead to long term pollution of nearshore marine habitats and the marine mammals and birds that rely on them. Since a large portion of the subsistence resources are locally harvested, the effects of debris and spills can have long term effects on subsistence, especially for protected species like seals and bowhead whales.

Consequences of the TSP

The TSP (Alternative 2A/2B) would have no effect on either species of eider. There are no plans to extract gravel from new sites on the tundra where impacts to nesting eiders could occur. There would be no impacts to eiders staging in the nearshore marine waters in springtime since any materials arriving by barge would not arrive until the region is free of sea ice. In the late summer and early fall it is possible that there would be some project related barge traffic in the area to bring in material for the revetment, but the additional traffic would occur in an area where there is already frequent barge traffic for both supplies (north of Barrow near NARL) and for routine fuel deliveries (immediately south of Barrow). It is common for exiting barge traffic to circle or stand offshore for several days awaiting their turn to unload or awaiting calm weather to ground on the shoreline and the addition of extra traffic to the area would not pose a risk to these species that might be in the area for a very brief period at low density.

The TSP would also have no effect on humpback whales as there is no marine construction taking place and the barge traffic would occur in an area where there is existing disturbance. Humpback whales might only be present at very low densities on rare occasions and likely would not be present at all. These alternatives would also have no effect on bowhead whales due to the very unlikely overlap between their distribution and the timing of material transport. There is also no marine construction occurring as the project footprint is above the MHHW line.

Consequences of the Alternatives Protecting Limited Reaches

Alternatives 5A, 5B, and 5C would have the same effects as the TSP. These would have no effect on either species of eider, bowhead or humpback whales.

Consequences of Beach Nourishment Alternatives

The beach nourishment alternatives (5D, 6A, 6B, and 6C), would have no effect on either species of eider, similar to the TSP.

Beach nourishment would involve placement of gravel in a wide section of nearshore marine habitat where humpback whales could be disturbed by underwater noise or physical disturbance. The beach nourishment alternatives, are unlikely to affect bowhead whales due to the close proximity of the work to shore and the construction timing relative to bowhead whale presence.

3.3.4 Marine Mammals

All marine mammals are protected under the Marine Mammal Protection Act (MMPA) and some have additional protection under the ESA. Therefore, all of the species are discussed, and the consequences have been considered in the Protected Species section (3.3.3) or in Attachment 1.

3.3.4.1 Consequences of Alternatives

The No-Action Alternative would have similar impacts described for Section 3.3.3.1 in the Protected Species Section.

This proposed alternatives would have no effect on the MMPA species listed in Table 3. The MMPA provides protection to all marine mammals, whereas the ESA provides additional protection for certain of these MMPA species. The rationale is the same as for humpback whales above; namely these species tend to be present at very low densities and the activity they might possible be exposed to is common to the area. No marine construction would occur to potentially impact these animals for either the TSP or alternatives that protect a limited reach. The beach nourishment alternatives could affect MMPA species, to a small degree due to the close proximity of the work to shore and the construction timing relative to their seasonal presence.

3.3.5 Birds

Many non-breeding seabirds occupy marine waters of the Chukchi and Beaufort seas offshore of Point Barrow during summer. 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.

Habitat on and near point Barrow 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.

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 National Petroleum Reserve, including Point Barrow, and non-breeders of many species might be present near the project area.

Birds in the Barrow are discussed in detail in Attachment 1 and protected species (Steller's and spectacled eiders) are discussed in section 3.3.3 above.

3.3.5.1 Consequences of Alternatives

Consequences of the No-Action Alternative

The No-Action Alternative is similar to that described in Section 3.3.3.1, Consequences of the Alternatives and has the potential to negatively impact a variety of bird species in both terrestrial, fresh water, and marine environments. While this alternative avoids all potential construction impacts associated with revetments, there are several potential implications of the No-Action Alternative. Coastal erosion and, to a greater extent, coastal flooding, typically leads to contamination and degradation of the marine environment leaving debris scattered across the tundra, in freshwater lakes including drinking water sources, and into the marine environment. This debris can impact birds on land, freshwater, and marine waters. In addition to the debris, a more persistent potential problem involves spills of fuel and oil from a major erosion event or a flood. These sorts of items can lead to long term pollution of terrestrial, freshwater, and nearshore marine habitats and the bird species that rely on them.

Consequences of the Action Alternatives, including the TSP

The proposed project area for the TSP (2A/2B), as well as all action alternatives, would not be used for nesting by any bird species. The area is eroded and filled annually and received a large amount of disturbance from vehicle and foot traffic. Several species of waterfowl and gulls would rest offshore, but this typically occurs farther north along the spit, especially near Point Barrow. The area of the spit adjacent to Elson Lagoon is heavily used as a crossing point for waterfowl migration to the west along the Beaufort Sea before turning south along the Chukchi Sea, and is well north of the project footprint. Other birds common in the project area include glaucous gulls and arctic terns, but these species already appear to tolerate the large amount of activity in the area and do not nest anywhere in the project footprint.

3.4 Land Use and Aesthetics

The project area is used year around for recreation and subsistence access. In the winter and spring, the beach is important for accessing seal and bowhead whale hunting sites. The beach is used in the summer for recreation to include hiking, and all-terrain vehicle riding for both pleasure and to access subsistence and cultural sites, and group gatherings. Having a view of the Chukchi Sea is important for residents to determine sea ice condition, wave conditions, and approaching weather fronts.

3.4.1 Consequences of Alternatives

Consequences of the No-Action Alternative

Under the No-Action Alternative, land use would likely remain the same in the short term, but housing, utilities and roads would remain at risk along the coast as storms and erosion continue. Aesthetics would be affected by continued flooding and erosion in the long term. The City would likely still maintain a temporary berm, similar to the existing conditions, limiting beach access and coastal views.

Consequences of the TSP

Construction of the TSP (2A/2B) would likely cause temporary displacement of people using the beach while the area is under active construction, but access would be available on either side of the construction area. When completed, points along the revetment would be included to allow for boat launching, all-terrain vehicles, snow machines, pedestrian pull-outs, areas to view the water, escape routes from polar bears, and flood control point. The revetted bluff would not disrupt the view of the Chukchi Sea, but the locations nearest the beach would no longer provide a clear view of the water. Residents would have to travel to either a raised section of the road or to the beach via an access point in the revetted berm.

Consequences of the Limited Reach Alternatives

For Alternatives 5A, 5B and 5C revetment would progressively increase in distance between the alternatives, but no one alternative would cover the entire 5 mile stretch. Beach access would not likely change where the project does not construct a revetment or berm. These areas would also be highly susceptible to flooding and erosion, where the beach would likely become more eroded over time. The revetted bluff would not disrupt the view of the Chukchi Sea, but the locations nearest the beach with revettment would no longer provide a clear view of the water. Residents would have to travel to either a raised section of the road or to the beach via an access point in the revetted berm.

Consequences of the Beach Nourishment Alternatives

For Alternatives 5D, 6A, 6B, and 6C, construction would likely cause temporary displacement of people using the beach while the area is under active construction, but access would be available on either side of the construction area. These alternatives would help maintain the beach that would extend beyond the proposed revetments. All other impacts would be similar to the TSP

3.5 Subsistence

Subsistence practice over the last 11,500 years in the Arctic region have been reconstructed through archaeological data, ethnographic information, and traditional ecological knowledge (Grover and Laughlin 2012). The coastal areas of the arctic have been populated for at least the last 3,500 years, with the Iñupiat population subsisting on a range of different animals for food and resources for survival. However, the majority of the subsistence resources consisted on the reliance of hunting large marine mammals including whales, walrus, and seals (Langdon 2002). Subsistence practices have continued into modern day, fulfilling several different functions. These include: mitigating substance abuse, protection from labor downturns, maintaining Native Alaskan involvement with natural resource co-management, and helping local communities continue to be current with environmental knowledge (Kerkvliet and Nebesky 1997). The whale harvest brings in approximately 1.1 to 2 million pounds of food, which saves the community approximately $11 to 30 million dollars in beef per year (IWC 2018).

3.5.1 Primary Subsistence Food

One of the most important food sources for the Iñupiat in the Barrow region are whales, specifically the bowhead whale *Balaena mysticetus*. These large mammals are hunted in the spring or fall, depending on migration routes. Whaling crews are highly organized, and are led by an *umialik* (captain), and may consist of a number of boats per village. Traditionally, these hunts would use a number of *umiaks* (skin boats), however many traditional tools and equipment have been modernized. After a successful kill, they would pull the whale onto the shoreline for butchering. The captain's wife would then portion out the meat and blubber to the crew and their families (Friesen 1999).

Beluga (Belukha) whales were also harvested in areas of the arctic. This would happen from mid-July to late August. As beluga whales are smaller than bowheads, hunting for them is less organized and involves small groups of individuals for harvest. Traditionally this was done with a number of kayaks, with the hunters driving the belugas into shallow water and then killing them, rather than kill them in open water (Friesen 1999). While dated, the NSB's statistics for beluga harvest between 2007-2011 averaged 48 landed belugas out of the Beaufort Sea (0.1% of estimated population) which includes the communities of Barrow, Diomede, Kaktovik, Kivalina, Nuiqsut, and Point Hope, and 62 belugas landed out of the East Chuckchi Sea (1.7% of estimated population), consisting of the communities of Wainwright and Point Lay (NSB 2018).

3.5.2 Other Subsistence Resources

Alongside the hunting of whales, the Iñupiat hunt a number of smaller sea mammals that are in the area, including three species of seals, bearded *Erignathus barbatus*, ringed *Pusa hispida*, and spotted *Phoca largha*, and the walrus *Odobenus rosmarus*. While the successful hunt of bowhead whales would have the advantage of lessening the need to hunt or fish on winter ice, these other sea mammals provided needed materials for tools and clothing as well as a supplemental food source (Langdon 2002). While many materials have been replaced with modern western tools and equipment, some subsistence materials are still utilized. Walrus skins are still used for the construction of *umiaks*, and ivory, bone, antler, and baleen are utilized for art. The subsistence harvesting of caribou *Rangifer tarandus* also continues to supply meat to hunters, especially when not enough whale meat was harvested.

Fishing also supplied the diet, with the different species of whitefish being a large share of an alternative food source. Sockeye salmon *Oncorhynchus nerka* are also a common harvest, comprising of the second most caught fish by far. Another fish caught en mass are cisco *Coregonus artedi*, which is caught and used often as dog food. Also grayling *Thymallus thymallus* is also a popular fish. Geese are taken, including the snow goose *Chen caerulescens* and the Canada goose *Branata Canadensis,* to supplement the foods acquired. Another bird commonly hunted are eiders, including the common eider *Somateria mollissima*, the king eider *Somateria spectabilis*, the spectacled eider *Somateria fischeri*, and the Steller's eider *Polysticta sterreli*. Sometimes, eider eggs are also collected to eat (Bacon et al. 2011).

A baseline harvest profile by the Alaska Department of Fish and Game (ADF&G) displays that both bowhead whale and caribou were the largest subsistence resources harvested in 2014, the last time the data was published (Table 4). While the arctic region is a "mixed economy," research has found that cash income is sporadic and less reliable than subsistence, and so the population tends to favor heavily in relying on subsistence as a primary form of diet procurement (Ellanna and Wheeler 1989). Food is often shared with the elderly or disabled, and most of the community participates in some way, even if they are not directly hunting. This would include purchasing fuel, mending or creating new clothing, or helping butcher (Whitaker 2010).

Table 4. 2014 Dominant Subsistence Resources Identified from Harvest Records for Marine Resources in Barrow (ADF&G 2014).

Marine Resource	Pounds Harvested
Salmon	57262.3
Non-Salmon Fish	196047.4
Seal	340089.1
Walrus	103602.2
Beluga (Belukha)	24341
Bowhead	546085.1
Caribou	587897.1

3.5.3 Timing of Subsistence

Marine Mammals

Subsistence patterns in the arctic follow the seasons. Typically, villages in the region hunt for bowhead whales in the spring, however the Barrow community has been capable of harvesting them in both the spring and fall. Walrus, when available, are taken in July and August when they drift with the floe ice. And bearded seals have recently been taken in July and August as well (Bacon et al. 2011).

Terrestrial Mammals

The dominant terrestrial mammal taken in the arctic are caribou, which are harvested in July and August (Bacon et al. 2011). Some moose are taken in August and September, when the season has not been closed by the state. Caribou are an important food source, calculated to be second to bowhead in the amount of pounds of meat harvested (Bacon et al. 2011).

Fish

Freshwater fishing often begins during breakup in June, and continues into November. Arctic cod and some salmon can be taken through cracks in the sea ice, but this often happens in the fall. The whitefish are taken from June through October, but often beaks after September. Grayling can be taken from August through October, and Arctic cisco peaks in October (Bacon et al. 2011).

Birds

The hunting of migratory birds happens during the spring migration, the molt period, and the fall migration. Eider harvest reaches its peak in May, followed by the fall July and August return migration. Over 80% of the eider taken are king, with some common following second. The geese are harvested almost entirely in the month of May (Bacon 2011).

3.5.4 Environmental Consequences of Alternatives

Consequences of No-Action

With the No-Action Alternative barriers would not constructed and subsistence hunting and fishing access would continue as normal. There would be no changes to current practices or animal harvesting. There are no known species that actively use the beach or berms as part of their lifecycle that would benefit from this alternative. The No-Action Alternative could lead to negative health effects on many subsistence resources as debris and contaminants enter the freshwater, marine and terrestrial environments due to damage from continued coastal erosion and flooding. Continued erosion may also cause the loss of access to the NARL airstrip, which is currently used as a landing area to butcher whales after successful hunts. This may impact how the community conducts its primary subsistence taking of bowhead whales.

Consequences of the TSP

The TSP would include access points along sections of the barriers to allow residents to have multiple entrances to the beach and water. These access points would also be used by the construction teams as the barriers are being constructed to safely move from either side for construction. The access points would be open to local subsistence hunters and whalers use of these access points to deploy their boats from. There would be no change to the subsistence lifestyle nor any known detriment to local wildlife.

Consequences of Alternatives Protecting Limited Reaches

The effects of the various alternatives that protect a limited reach of coastline would involve the effects described above for the TSP and the No-Action Alternative. The overall effects of any of Alternatives 5A, 5B, 5C would involve differing proportion of coastline with the effects of revetment and the consequences of No-Action. Leaving section of coastline unprotected could lead to negative health effects on many subsistence resources as debris and contaminants enter the freshwater, marine and terrestrial environments due to damage from continued coastal erosion and flooding.

Consequences of Beach Nourishment Alternatives

Alternatives 5D, 6A, 6B, and 6C would lead to similar effects as the TSP. Subsistence access would not be affected by beach nourishment other than by the small increased distance to reach the edge of the water.

3.6 Socio-economic

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. The community faces risk of damage to personal property, including residential and non-residential structures and their contents. The high risk of flooding during storm events has negatively impacted the quality of life of local residents. Current erosion damage to Stevenson Street has resulted in hazardous road conditions during storms. In-depth discussion of socio-economic resources is located in the Economic Analysis Technical Appendix, Appendix E.

3.6.1 Environmental Consequences of Alternatives

Consequences of the No-Action Alternative

With the No-Action Alternative, expected coastal storm/flood damages would likely result in negative employment and income impacts, reduction in infrastructure, and a reduction in population. A large potential risk to employment and income in the study area is loss of the utility services provided by the underground Utilidor. 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.

The risk of flooding with the No-Action Alternative negatively impacts 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 City. Additionally, degradation of the landfill and sewage treatments plant barriers caused by flooding and erosion would leach contaminants and trash into the environment, causing significant negative affects to health, safety, and environmental resources.

Consequences of the Action Alternatives

All of the action alternatives, including the TSP, would not cause more than transitory effects or minor inconveniences to people, including low- income or minority people gathering fish or marine mammals. Each alternative would reduce the identified risks to personal safety and mortality associated with coastal flooding, erosion, and flood fighting activities. They would also reduce coastal storm and erosion damages to property. There would be an increase in the quality of life, a reduction in safety risk along the coastal roads for residence, protection of life saving infrastructure, and a decreased risk of coastal flood emergencies. There would be not significant negative impacts as a result of any action alternative.

Construction of every alternative, except 5A and 5B would protect major infrastructure, the landfill, and the sewage treatment ponds, thus reducing the risk of contamination into the environment.

All the alternatives are consistent with Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks, and none would increase danger to children.

3.7. Environmental Justice

Executive Order (E.O.) 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," directs Federal agencies to identify and address any disproportionately high and adverse human health or environmental effects of their actions on low-income, minority, and tribal populations, to the greatest extent practicable and permitted by law. An Environmental Justice (EJ) analysis typically includes the following elements (USEPA 2017):

a) Identification of any minority and/or low-income status communities in the project area
b) Identification of any adverse environmental or human health impacts anticipated from the project
c) Determination of whether those impacts would disproportionately affect minority and/or low-income communities.

3.7.1. Identification of Minority or Low-income Populations

The village of Barrow is considered the affected population for the purposes of this EJ analysis. The Barrow community includes minority populations, low-income populations, and populations that are both. As of the 2010 U.S. Census, Barrow was approximately 67% American Indian and Alaska Native alone or in combination. Alaska Native populations are treated as minorities under E.O. 12898. Income data from the U.S. Census Bureau's 2009-2013 American Community Survey show an estimated 14.1% of Barrow residents, regardless of minority status, have incomes below the Federal poverty level.

3.7.2. Identification of Adverse Impacts

The previous sections analyzed potential project impacts on a range of resource categories, and identified no adverse effects that cannot be mitigated to rise to a level of significance. The proposed action is intended to impact the population in strongly positive ways, enabling the EJ community to maintain its cultural identity and carry on traditional practices in a safe and sustainable setting. The potential impacts on another resource category of particular concern to this community, "Subsistence," were found to be minor.

3.7.3. Determination

The Corps has determined that there would be no disproportionate adverse impact on minority or low-income communities as a result of the proposed action. This decision was informed by the following considerations:

a) A substantial majority of the affected population, the City of Barrow, is minority, low-income, or both; this entire population is regarded as an EJ community for the purposes of the EJ analysis.
b) The City of Barrow has been an active participant in the design and approval of the proposed action.
c) Upon completion, the proposed action would provide protection against coastal erosion and flooding that negatively impacts the entire population of Barrow.

3.8 Cumulative Effects

Federal law (40 CFR 651.16) requires that NEPA documents assess cumulative effects, which are the impact on the environment resulting from the incremental impacts of the action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can result from individually minor, but collectively significant, actions taking place over a period of time. The past and present actions that have occurred within and adjacent to the project area include construction of the original road, past dredging and placement of beach nourishment and the continual construction of sacrificial beach berms which. Together, these actions have resulted in the existing conditions of the study area.

The reasonably foreseeable future actions under consideration in this analysis are identified below. The list includes relevant foreseeable actions within and adjacent to the study area, including those by the Corps, other Federal agencies, State and local agencies, and private and commercial entities.

- Continued construction of sacrificial berms along the roadway
- Continued armoring of the bluff area with a variety of non-permanent solutions such as gabion baskets, super sacks, and other measures

Regardless of any action taken or not taken, Barrow would likely continue to exist as a major city in the region and function as a hub for transportation and logistics to other communities. Construction of proposed project described in this assessment would provide much needed protection from storm damage, but it is unlikely to lead to an increase in development in Barrow or change its current functional role in the region.

3.8.1 Cultural and Historic Resources

The City of Barrow has a number of known historic properties ranging from the Cold War to precontact village sites. The proposed TSP would involve a 5 mile stretch of the beachfront, involving a precontact village listed on the NRHP. This site, the Utqiaġvik Village site (BAR-

002), is located on the bluff above the southern beach and experiences active erosion; this erosion has exposed cultural materials and human remains. Building the proposed barrier would cause damage to BAR-002 during construction; however, it would protect the site from future erosion and storm damage. There are concerns on the long term damage to the site by the loss of permafrost support combined with the weight of a revetment that would cause pressure on subsurface cultural materials and limit future archaeological recovery efforts. There are five additional historic properties in proximity to the project area (BAR-007, 009, 012, 016, and 060), but they are not impacted by the proposed alternative. The construction of the barrier would further protect these sites from future storm and flood damage. On 19 July 2018, the Corps found that the proposed revetment associated with the TSP would have an adverse effect on the Utqiaġvik Village site (BAR-002) (USACE 2018). On 21 August 2018, the SHPO Officer SHPO requested that the Corps reengage in consultation once more specific construction details are identified (SHPO 2018). The USACE expects the TSP to require a Memorandum of Agreement (MOA) among all interested parties in order to determine the appropriate mitigation of adverse effects on BAR-002.

3.8.2 Biological Resources

Biological resources include fish, wildlife, vegetation, Federal threatened and endangered species, other protected species. While historic development within and adjacent to the project area has modified the shoreline and the sediment regime, these actions occurred in a regulatory landscape that is different from today. While future development would likely have localized impacts on these resources, under the current regulatory regime these resources are unlikely to suffer significant losses. Any future Federal actions would require additional evaluation under the National Environmental Policy Act at the time of their development.

3.8.4 Land Use and Aesthetics

Land along the beach and nearshore environmental is currently being eroded away during high wave and flooding events, particularly during heavy storms. Access to the beach is limited to areas between the temporary berm which is maintained throughout the year. Future developments would likely increase access points along the beach from what currently exists by creating permanent boat and pedestrian ramps along the revetments. The temporary berm also limits the view of the beach. Construction of the project would enable the community to view the ocean and beach from the revetment since it would be a solid structure or part of a road that people can walk on or over.

3.8.4 Subsistence

There is no indication that any reasonably foreseeable future action near the project area would contribute to cumulative impacts on subsistence resources.

3.8.3 Socio-economic

There is no indication that any reasonably foreseeable future action near the project area would contribute to cumulative impacts on socio-economic resources.

3.8.3 Environmental Justice

There is no indication that any reasonably foreseeable future action near the project area would contribute to cumulative impacts on Environmental Justice.

3.8.6 Cumulative Effects Summary

The cumulative impacts analysis evaluated the effects of implementing the proposed action in association with past, present, and reasonably foreseeable future Corps' and other parties' actions within and adjacent to the project area. Past and present actions have resulted in the present conditions in the project area. Reasonably foreseeable future actions that have been considered included relevant foreseeable actions within and adjacent to the project area, including those of the Corps, other Federal agencies, State and local agencies, and private and commercial entities. The cumulative impacts associated with implementation of the proposed action were evaluated with respect to each of the resource evaluation categories, and no cumulatively significant adverse impacts were identified.

4.0 CONCLUSION

The proposed construction of coastal erosion protection by means of the TSP would not constitute a significant impact to the quality of the human environment because the project is already disturbed annually by coastal erosion and is constantly disturbed by human activity. The proposed activity, considering the construction and long-term existence of a new structure, and cumulative effects does not constitute a significant impact to the quality of the human environment and the preparation of an environmental impact statement (EIS) is not warranted. This draft Environmental Assessment will circulated to the public and concerned agencies.

5.0 AGENCY AND PUBLIC INVOLVEMENT

5.1 Public Scoping Meetings

As part of the scoping process, a planning charette held in Barrow from 11-13 September 2017, was conducted with the local sponsor and stake-holders. The Corp has also received comments from the NSB and public regarding impacts of coastal erosion and flooding, as well as the need to maintain beach access for subsistence and recreation. Additional public feedback would be solicited during concurrent review of the Draft Interim Feasibility Report to be initiated in September 2018. These comments would be addressed and incorporated into the final EA and FONSI.

5.2 Federal & State Agency Coordination

In-person meetings were held between biologists from the Alaska District Environmental Resources Section and biologists with the National Marine Fisheries Service (NMFS) (Protected Resource Division and Habitat Division) and the U.S. Fish and Wildlife Service (USFWS) (Project Planning and Endangered Species sections in Fairbanks). Both NMFS and USFWS informed the Corp biologists that they would not prepare a Coordination Act report. Both agencies would provide a letter after review of the draft Feasibility Report and Draft EA during the public comment period.

Coordination is ongoing with the Alaska State Historic Preservation Office. A letter has been sent to the SHPO informing them of the TSP. They responded Augusts 2018 agreeing with the Corps' assessment of impacts. Further coordination would be conducted during PED to determine a mitigation strategy (USACE 2018a, SHPO 2018, USACE 2018b) (Appendix H in the Feasibility Report).

5.3 Status of Environmental Compliance

Compliance with various authorities is described in Table 5.

Table 5. Status of Compliance

Federal Statutory Authority	Compliance Status	Compliance Date/Comment
Clean Air Act	FC	
Clean Water Act	NA	No in-water construction or fill
Coastal Zone Management Act	N/A	As of July 1, 2011, the CZMA Federal consistency provision no longer applies in Alaska. Federal agencies shall no longer provide the State of Alaska with CZMA Consistency Determinations or Negative Determinations pursuant to 16 U.S.C. 1456(c)(1) and (2), and 15 CFR part 930, subpart C.
Endangered Species Act	FC	"No Effect" determination made by Corps.
Marine Mammal Protection Act	FC	"No Effect" determination made by Corps.
Magnuson-Stevens Fishery Conservation and Management Act	N/A	No in-water construction
Fish and Wildlife Coordination Act	N/A	USFWS did not to prepare a Coordination Act report.
Marine Protection, Research, and Sanctuaries Act	N/A	
Migratory Bird Treaty Act	FC	
Submerged Lands Act	FC	
National Historic Preservation Act	PC	Upon completion of Section 106 coordination
National Environmental Policy Act	PC	Upon FONSI signature
Rivers and Harbors Act	FC	
Executive Order 11990: Protection of Wetlands	FC	
Executive Order 12898: Environmental Justice	FC	

Executive Order 13045: Protection of Children from Environmental Health Risks and Safety Risks	FC	
Executive Order 13112: Invasive Species	FC	
Executive Order 13186 Protection of Migratory Birds	FC	

FC: Fully Compliant; PC: Partially Compliant; N/A: Not Applicable

7.0 PREPARERS OF THIS DOCUMENT

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Appendix D: Environmental Assessment

Attachment 1: Barrow, Alaska Coastal Storm Damage Reduction Technical Report

Appendix H: Affected Environment

US Army Corps of Engineers
Alaska District

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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.

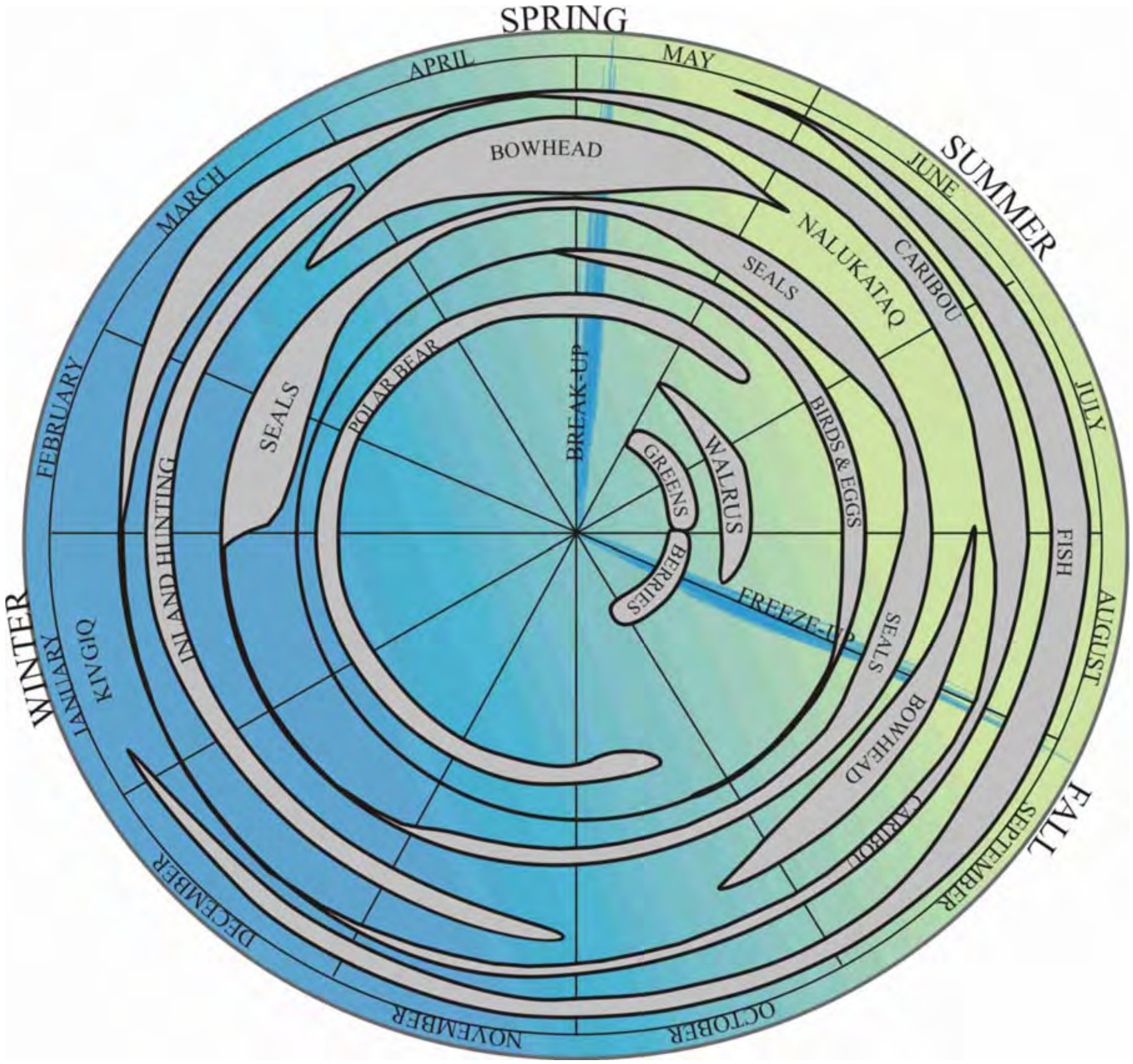

Figure 1. Generalized seasonal round of Barrow residents (compiled from Pedersen and NSB 1979; Braund and ISER 1993).

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).

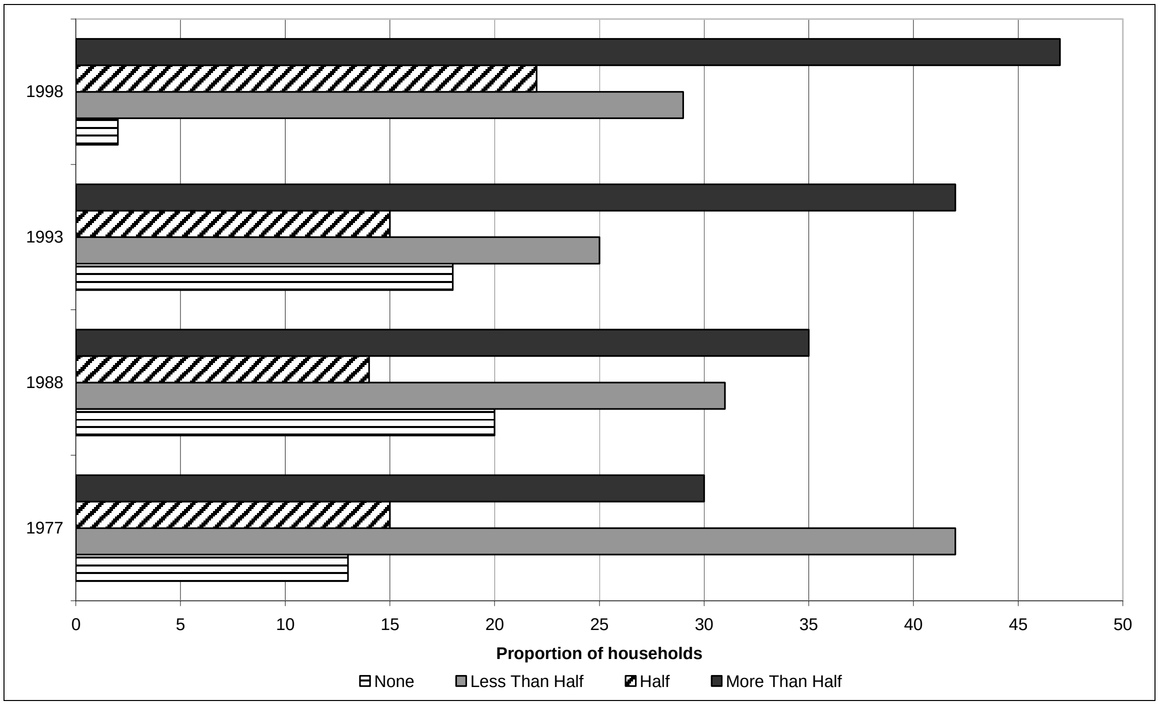

Figure 2. Proportion (in percent) of Inupiat household food obtained from subsistence activities (from North Slope Borough 1999 and DOI 2003).

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).

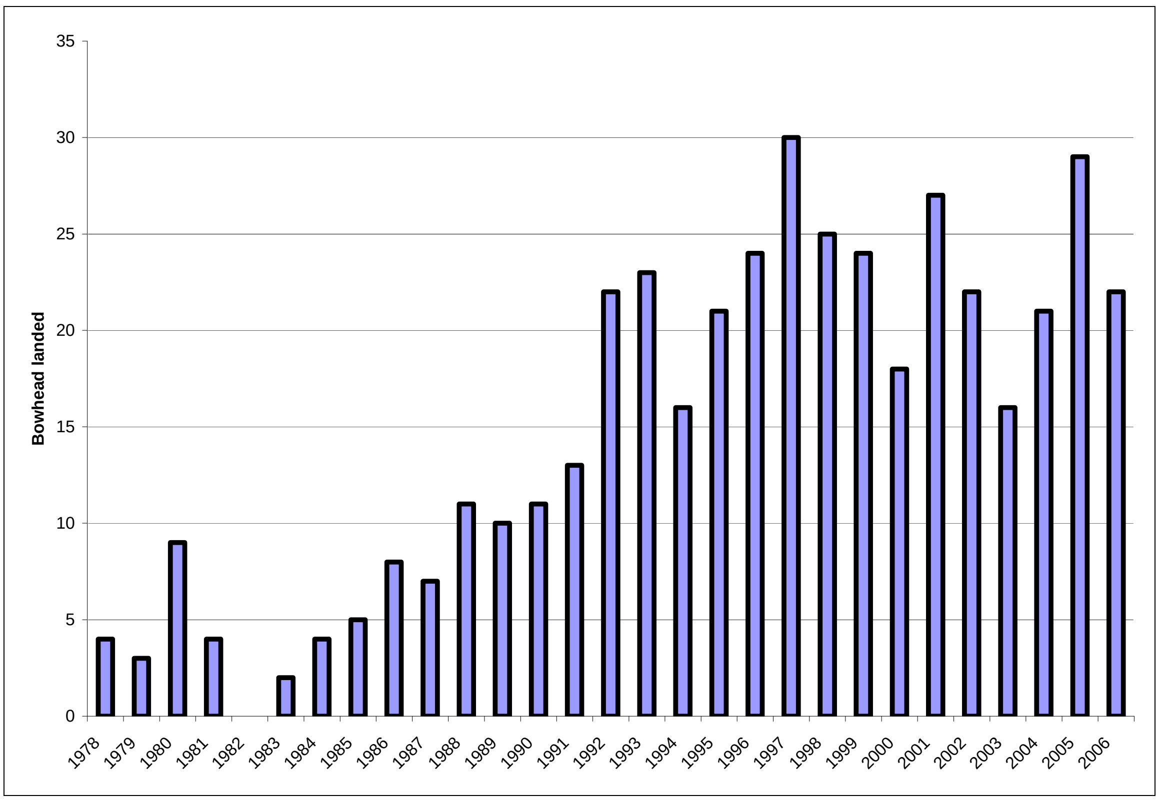

Figure 3. Bowhead landed by Barrow whaling crews 1978-2006 (from MMS 2006).

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.

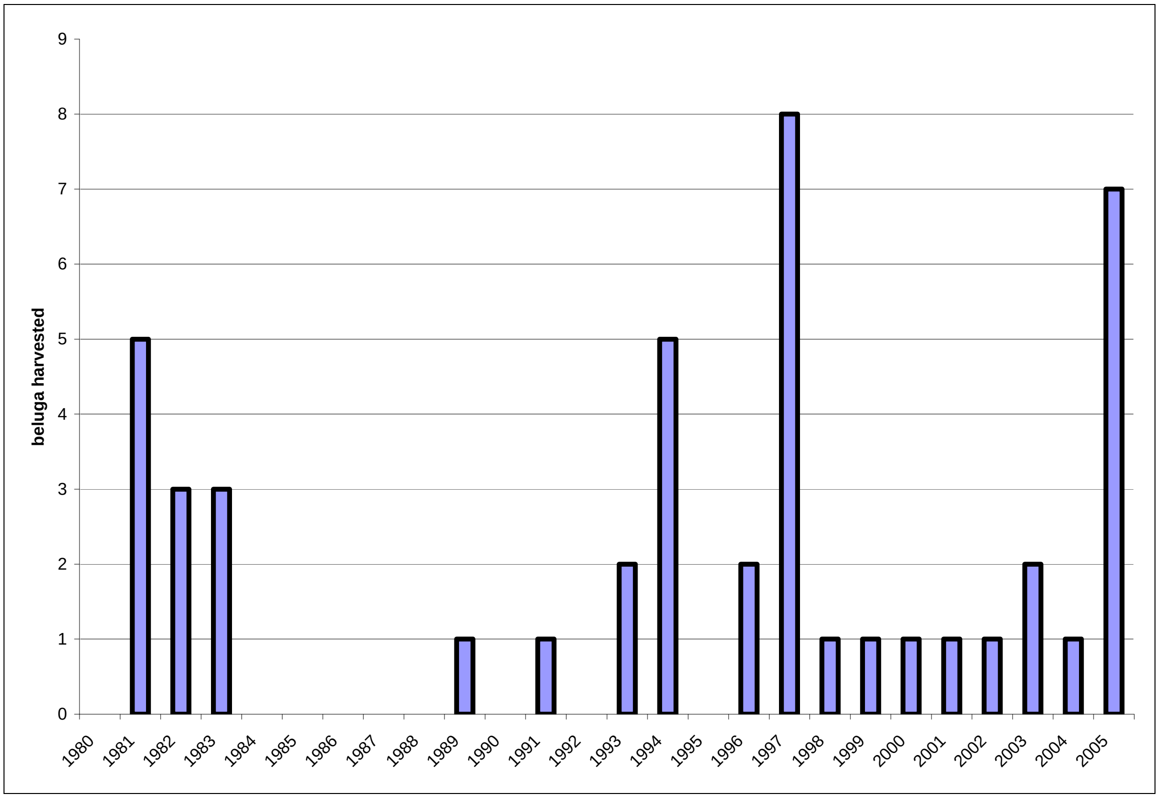

Figure 4. Beluga harvested by Barrow hunters 1980-2005 (from MMS 2006).

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

[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 bore-holes 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.

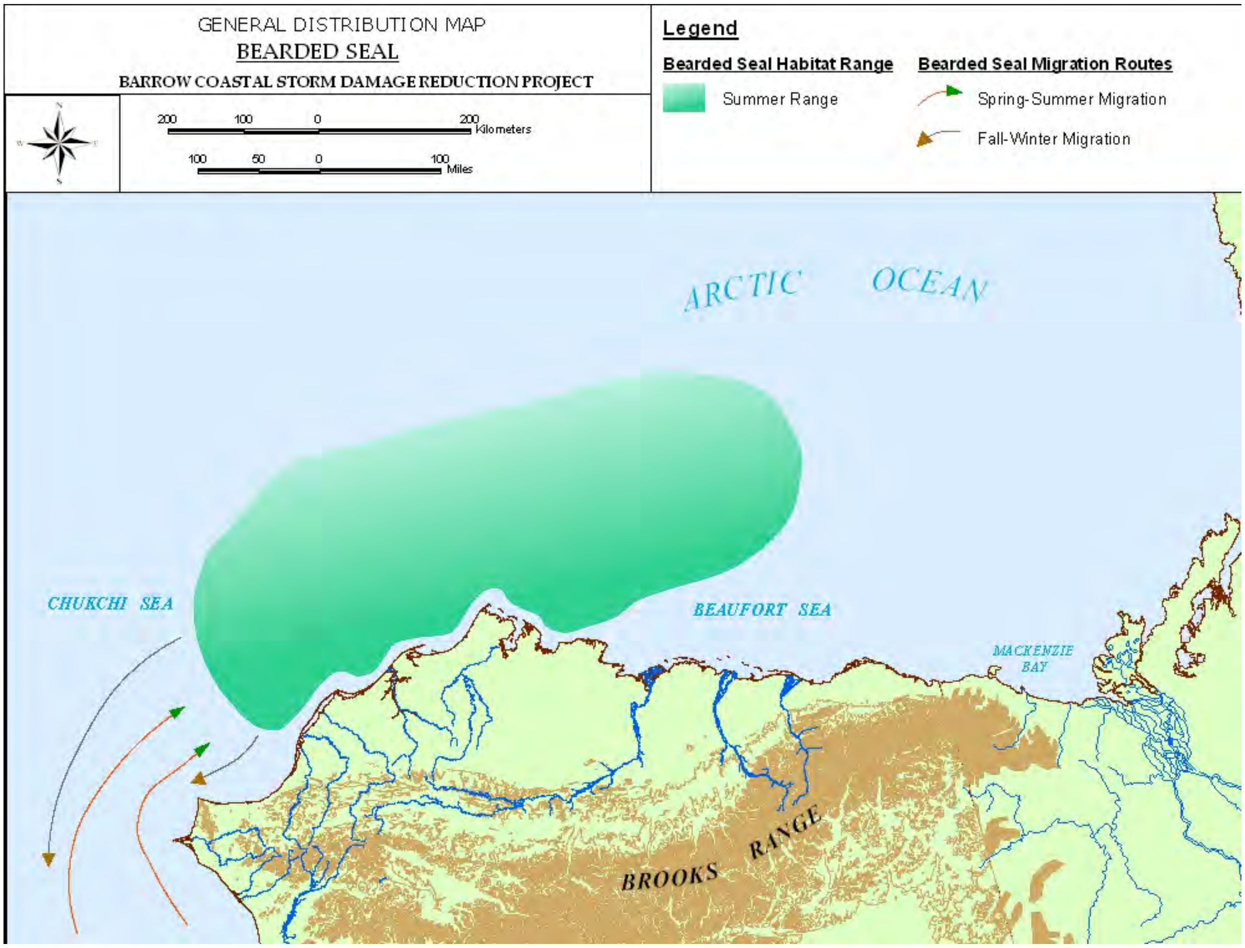

Figure 5. Seasonal movements of bearded seals through Bering Strait to the east Chukchi Sea and west Beaufort Sea.

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).

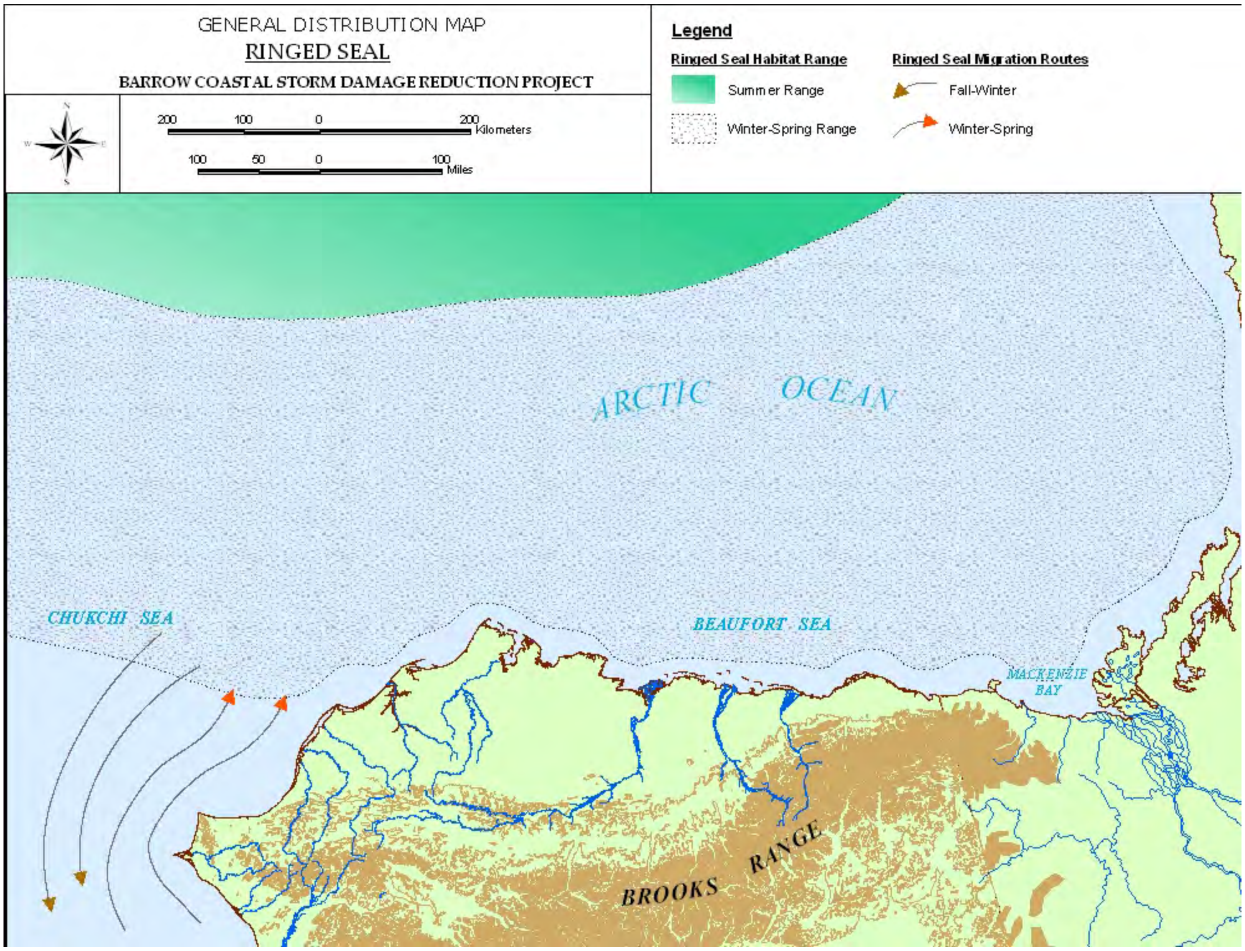

Figure 6. This figure shows the general direction of the spring and fall migration and dispersal patterns of ringed seals in the Bering and Chukchi seas.

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.

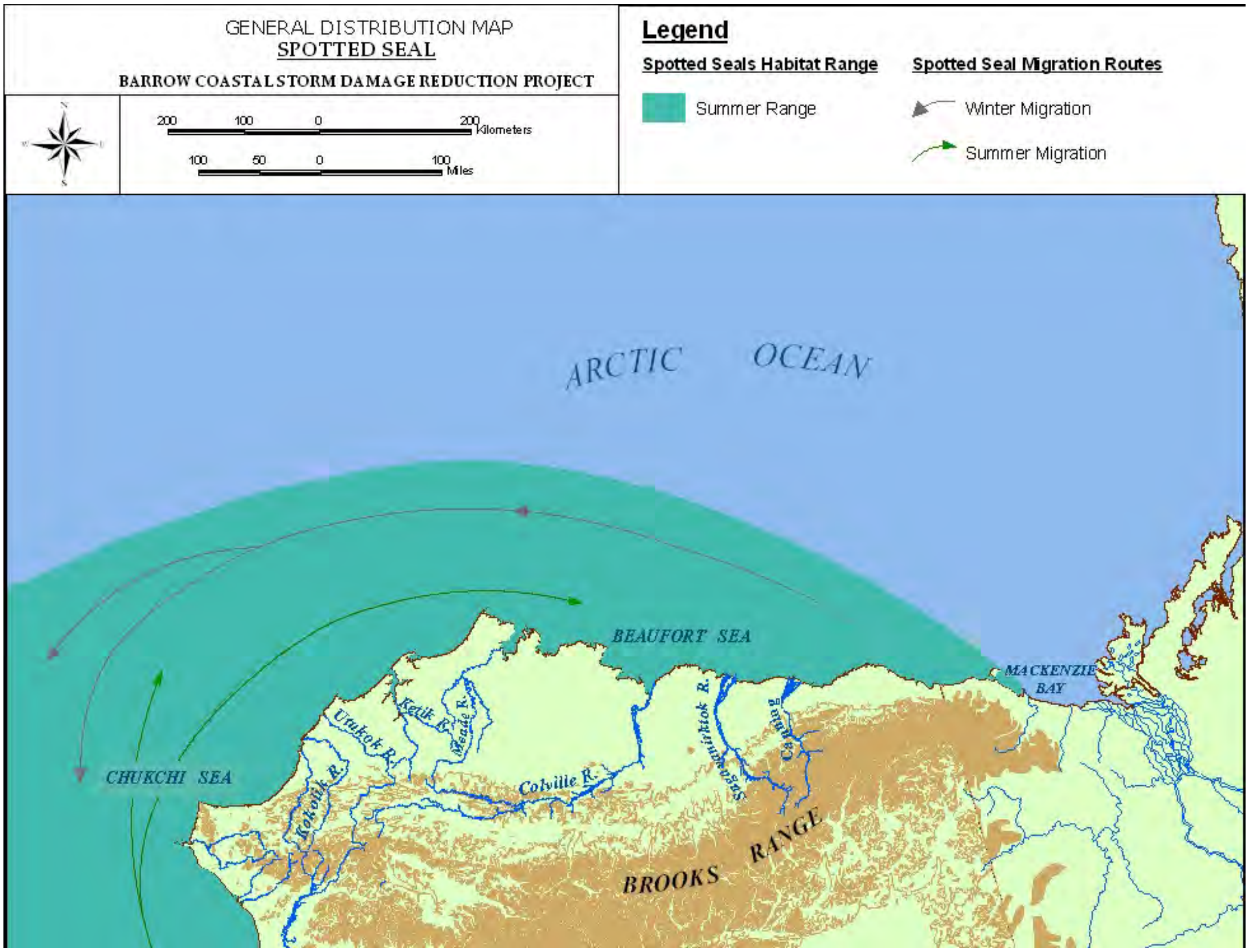

Figure 7. Seasonal movements of spotted seals through Bering Strait into the east Chukchi Sea.

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 (*~~Ob~~dobenus 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.

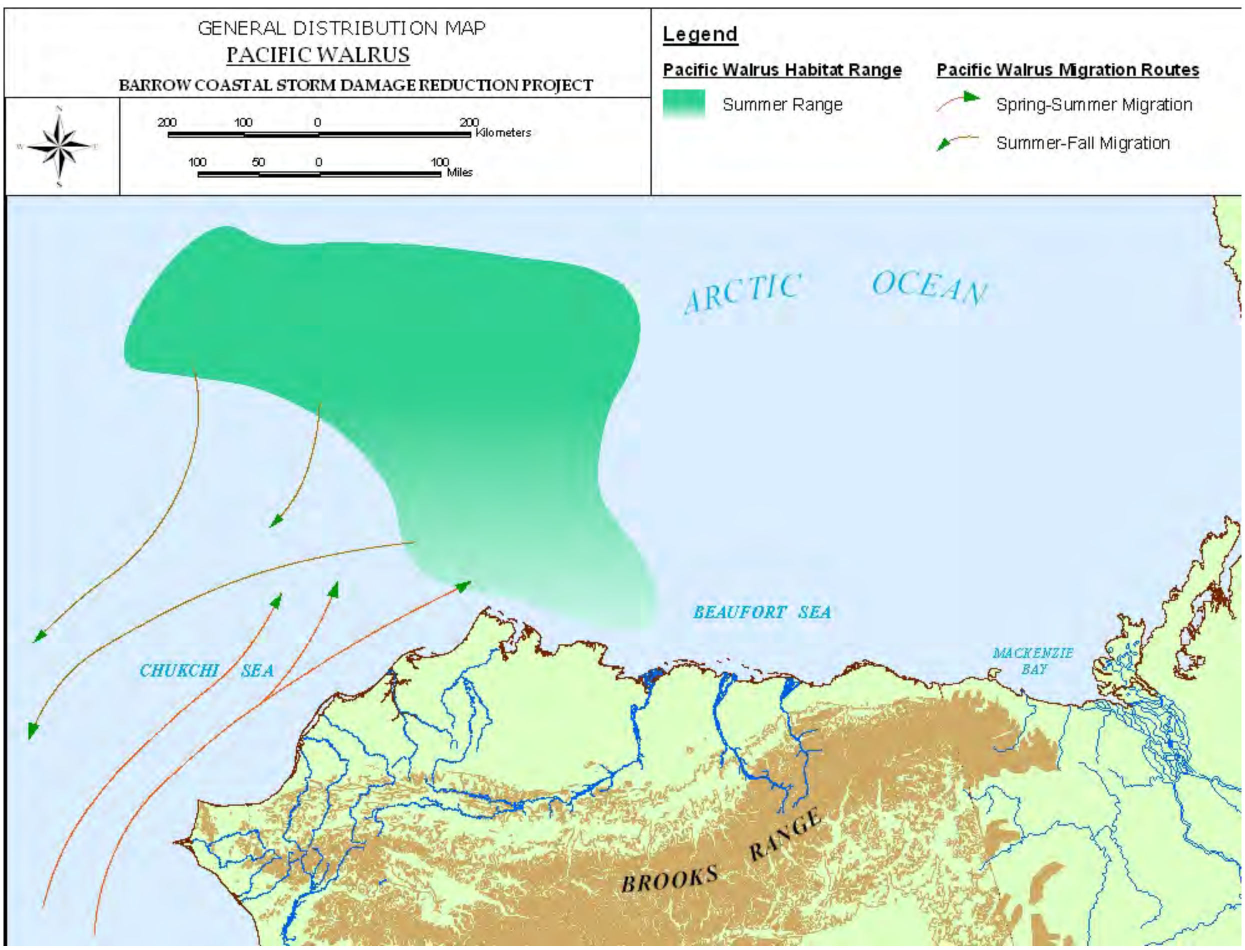

Figure 8. Seasonal movements of Pacific walrus through Bering Strait into the east Chukchi Sea and west Beaufort Sea.

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).

<u>Major Environmental Influences</u>. 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.

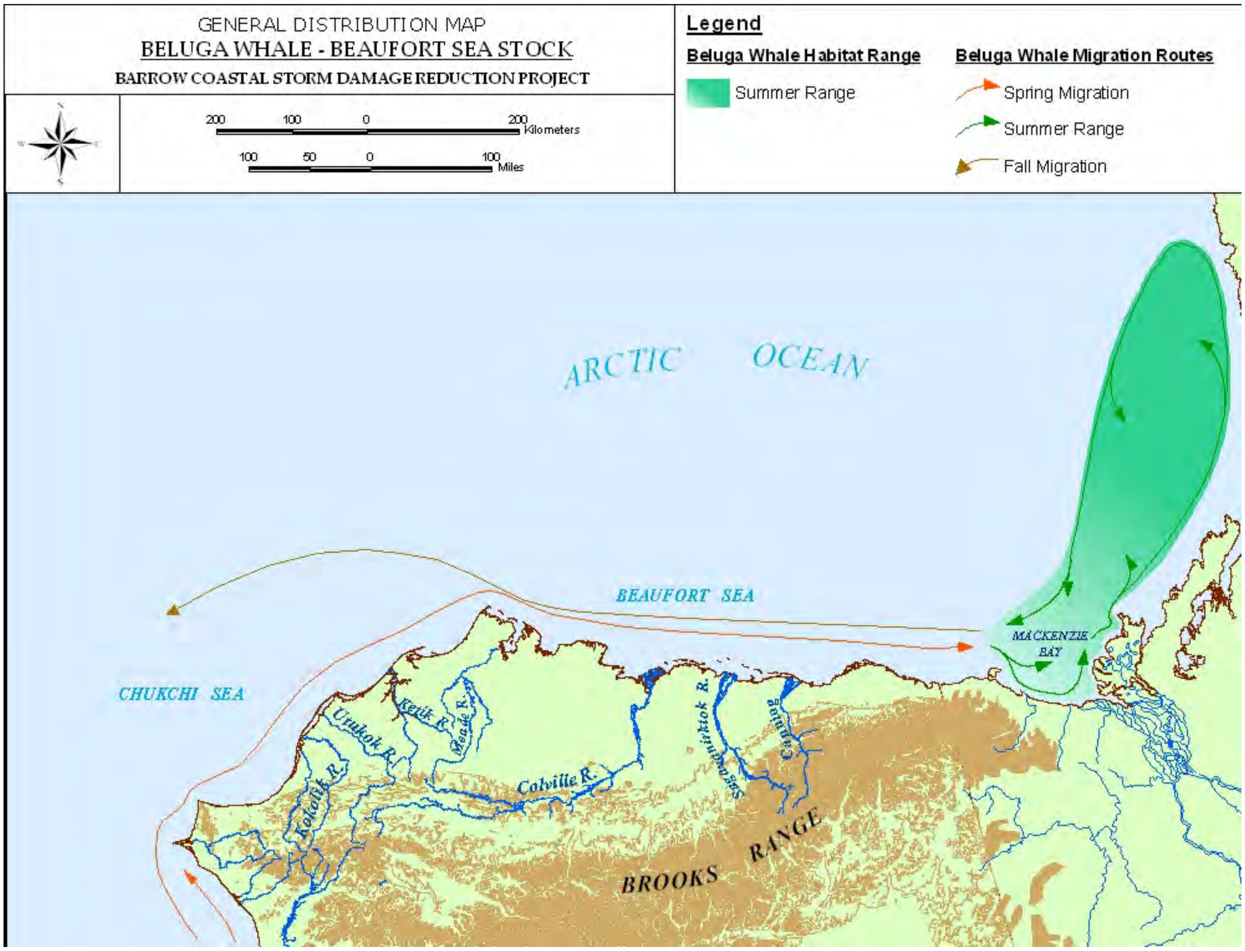

Figure 9. Seasonal movements of the Beaufort Sea stocks of beluga whale

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)

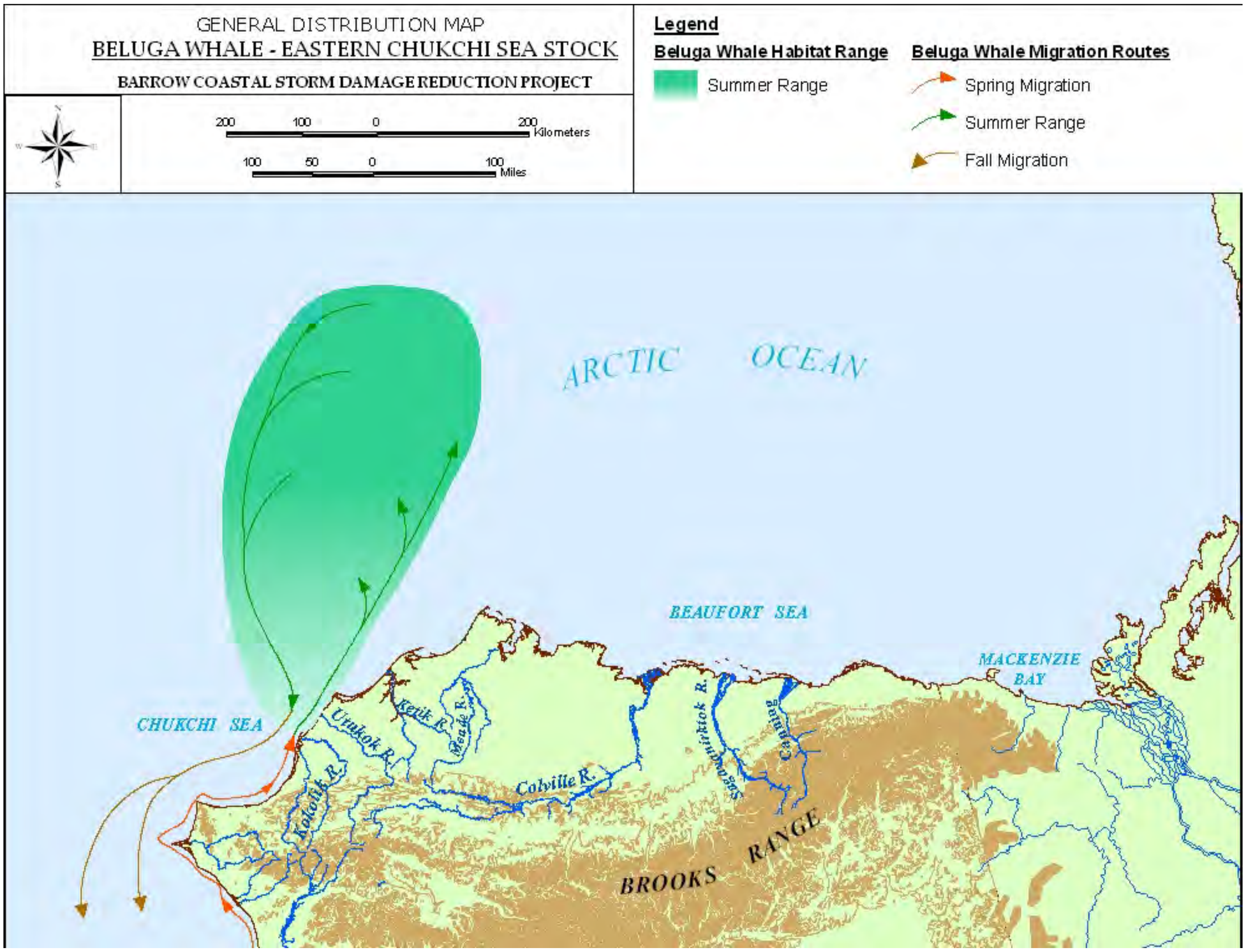

Figure 10. Seasonal movements of the eastern Chukchi Sea stocks of beluga whale.

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.

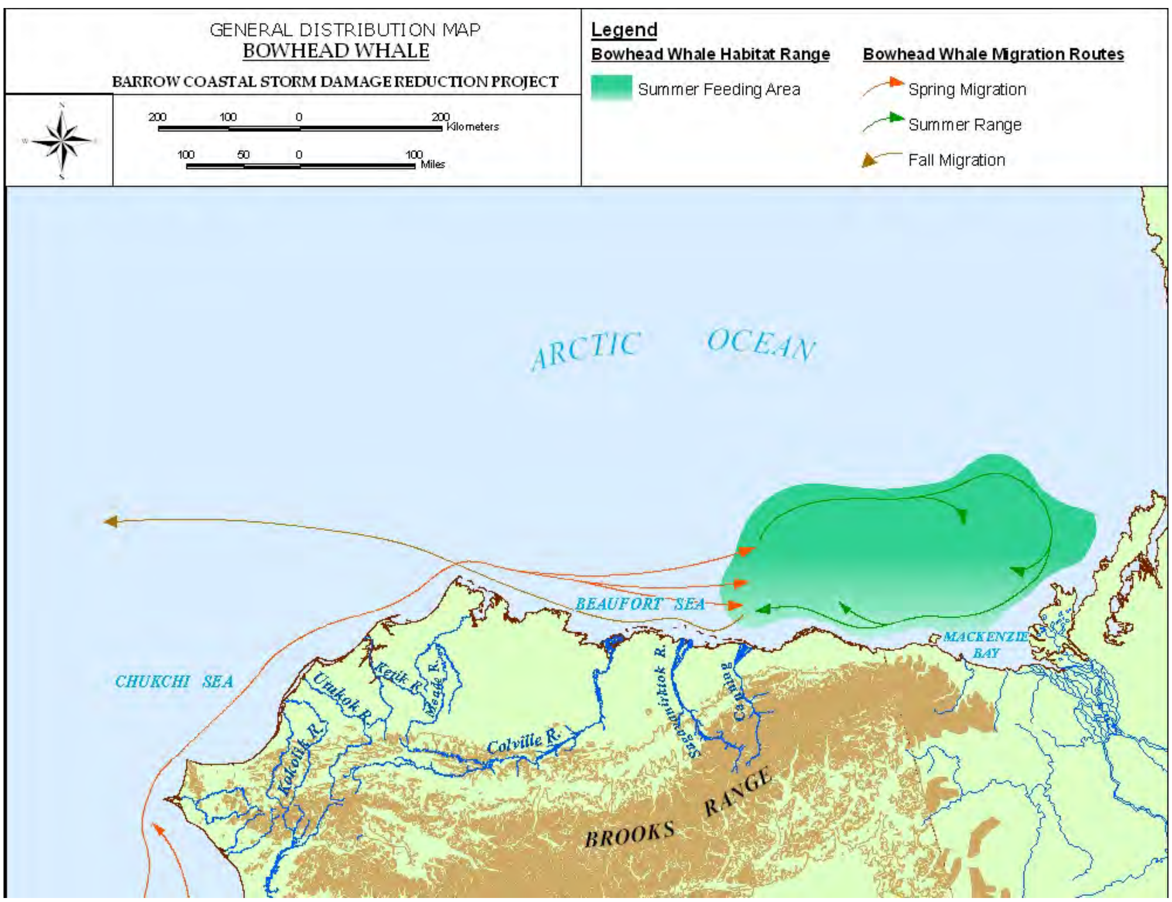

Figure 11. Seasonal movements of Bowhead whales through Bering Strait into the east Chukchi Sea and west Beaufort Sea

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

<u>Distribution.</u> 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.

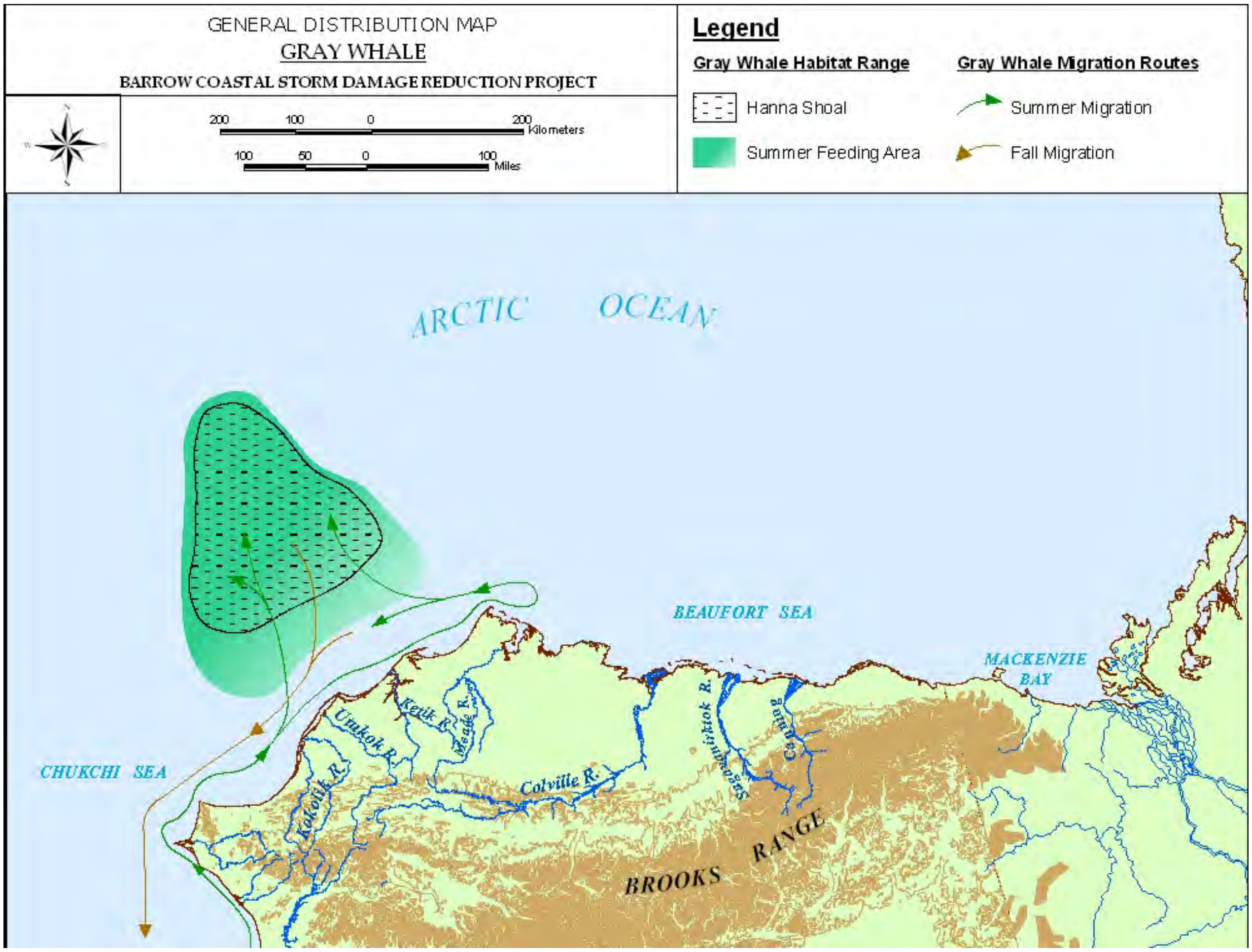

Figure 12. Seasonal movements of gray whales through Bering Strait into the east Chukchi Sea and west Beaufort Sea.

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).

<u>Major Environmental Influences.</u> 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).

Major Environmental Influences. 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.

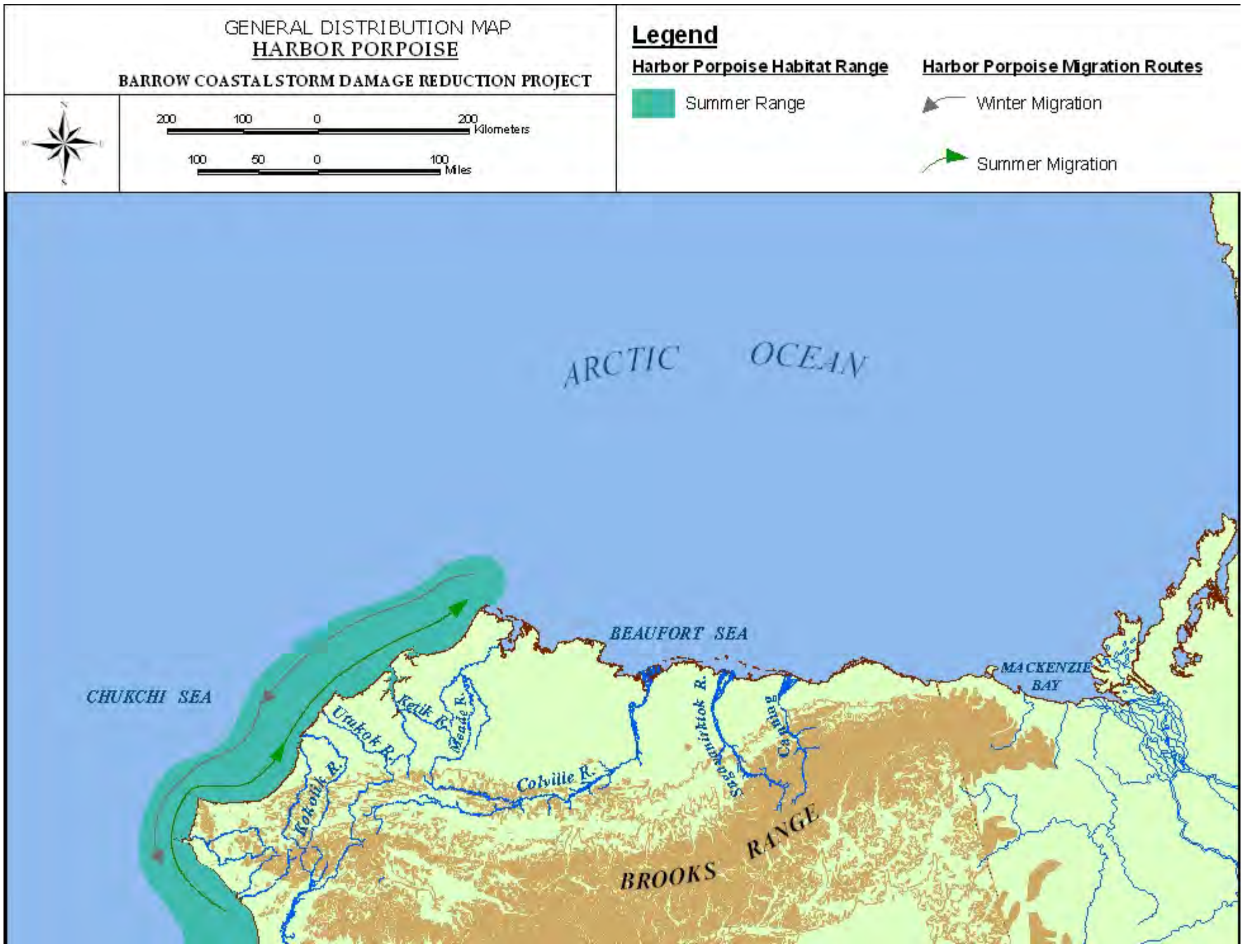

Figure 13. Seasonal movements of harbor porpoise through Bering Strait into the east Chukchi Sea and west Beaufort Sea.

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.

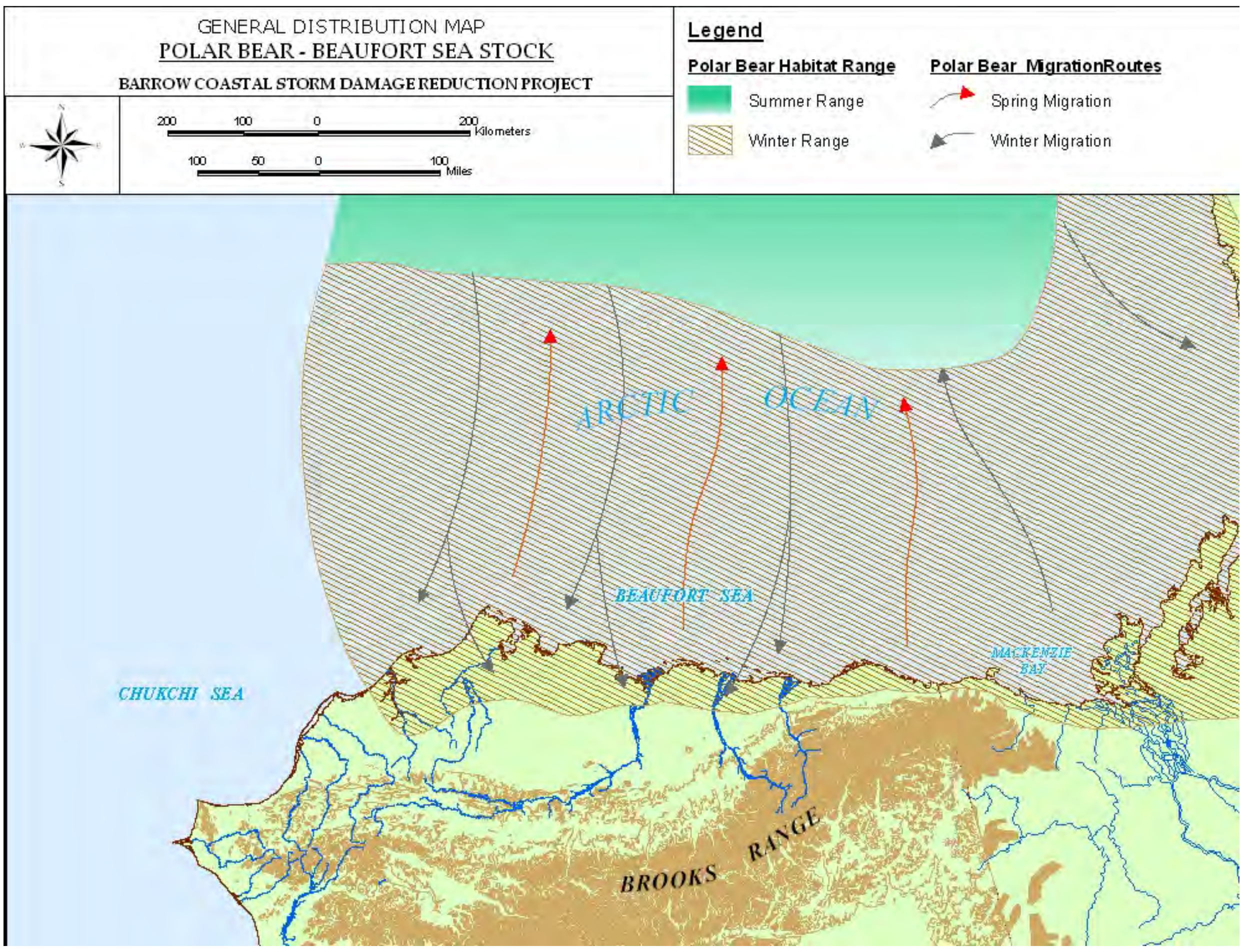

Figure 14. Seasonal movements of Beaufort Sea stock polar bears through the northern Bering Sea and Chukchi Sea.

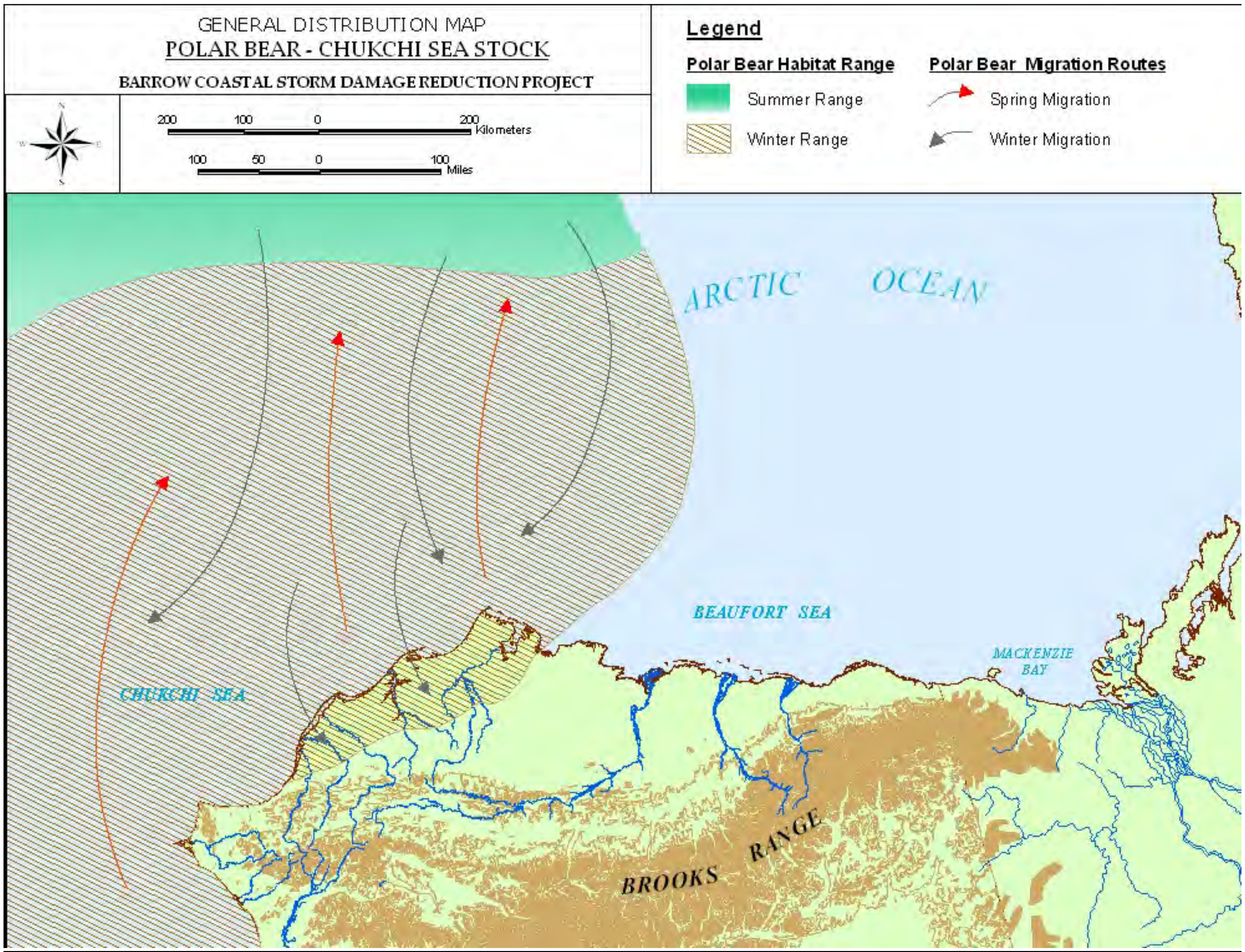

Figure 15. Seasonal movements of Chukchi Sea stock polar bears through the northern Bering Sea and Chukchi Sea.

<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.

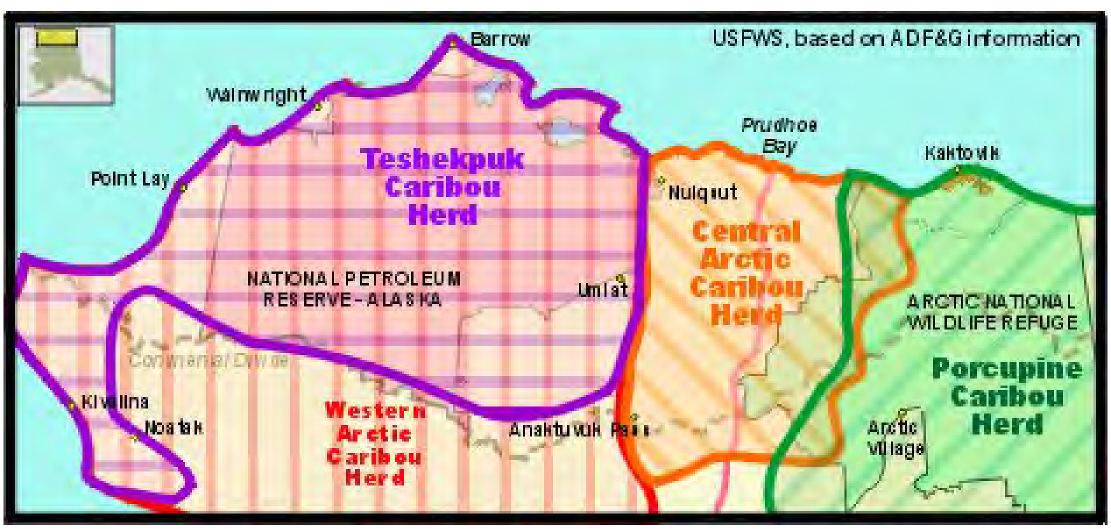

Figure 16. The range of Arctic Slope caribou herds in Arctic Alaska (Source: USFWS).

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).

<u>Small Mammals</u>. 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.

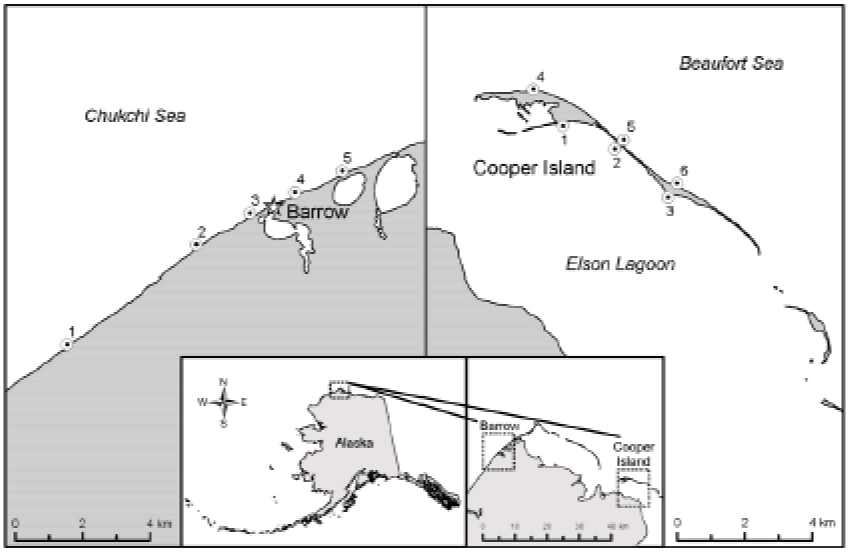

Figure 17. Benthic invertebrate sampling locations near Barrow and Cooper Island, in 2004.

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.

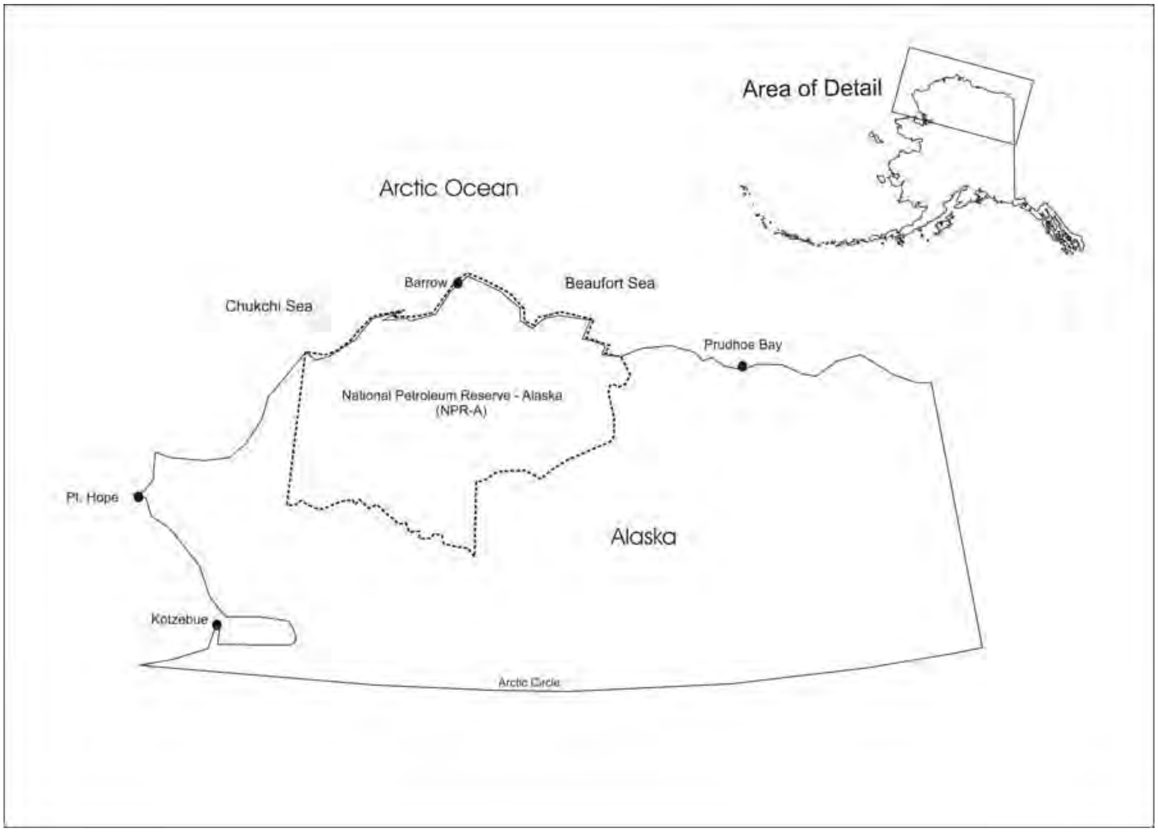

Figure 18. Arctic Alaska and the National Petroleum Reserve, Alaska (NPR-A).

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

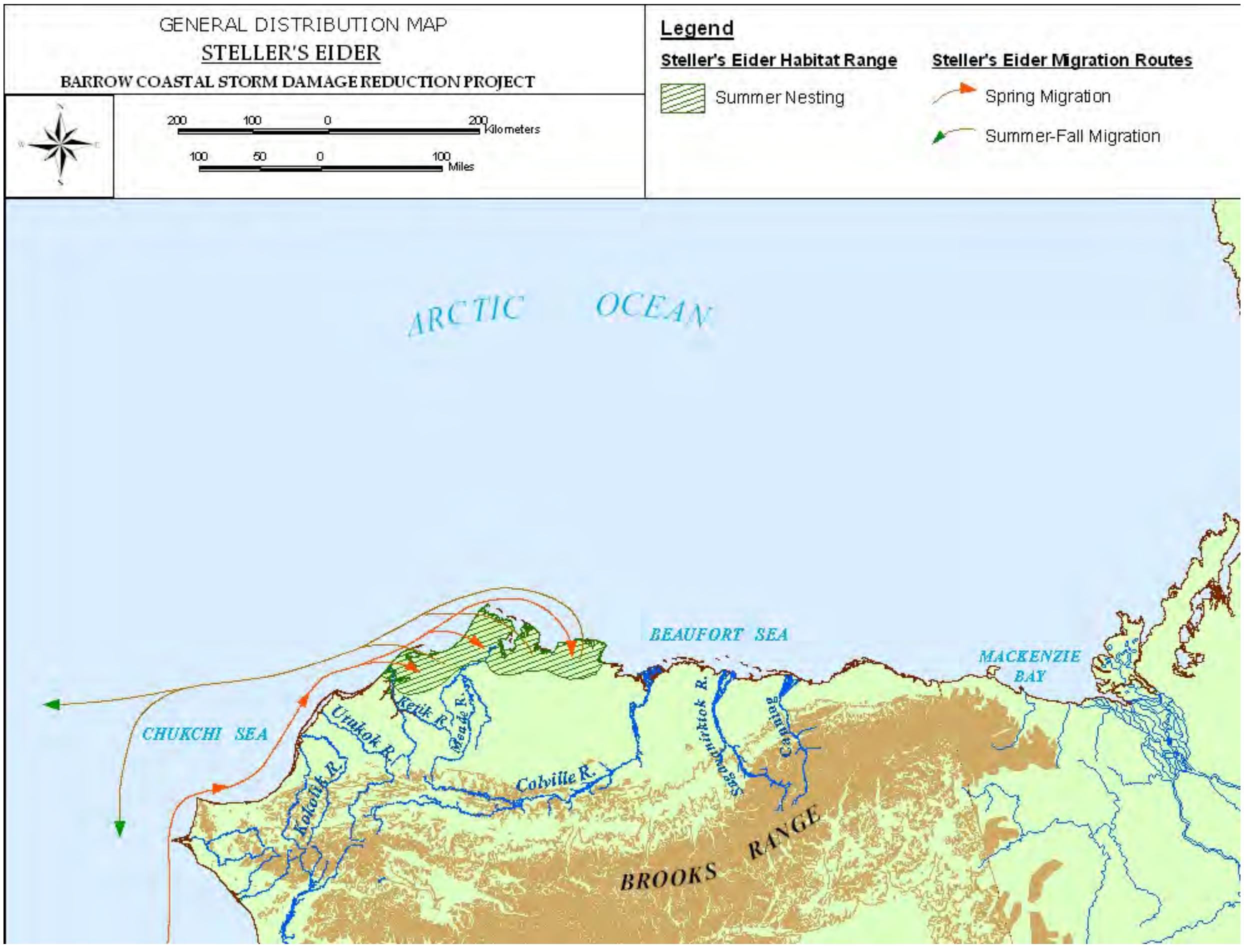

Figure 19. Steller's eider migration and nesting range.

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.

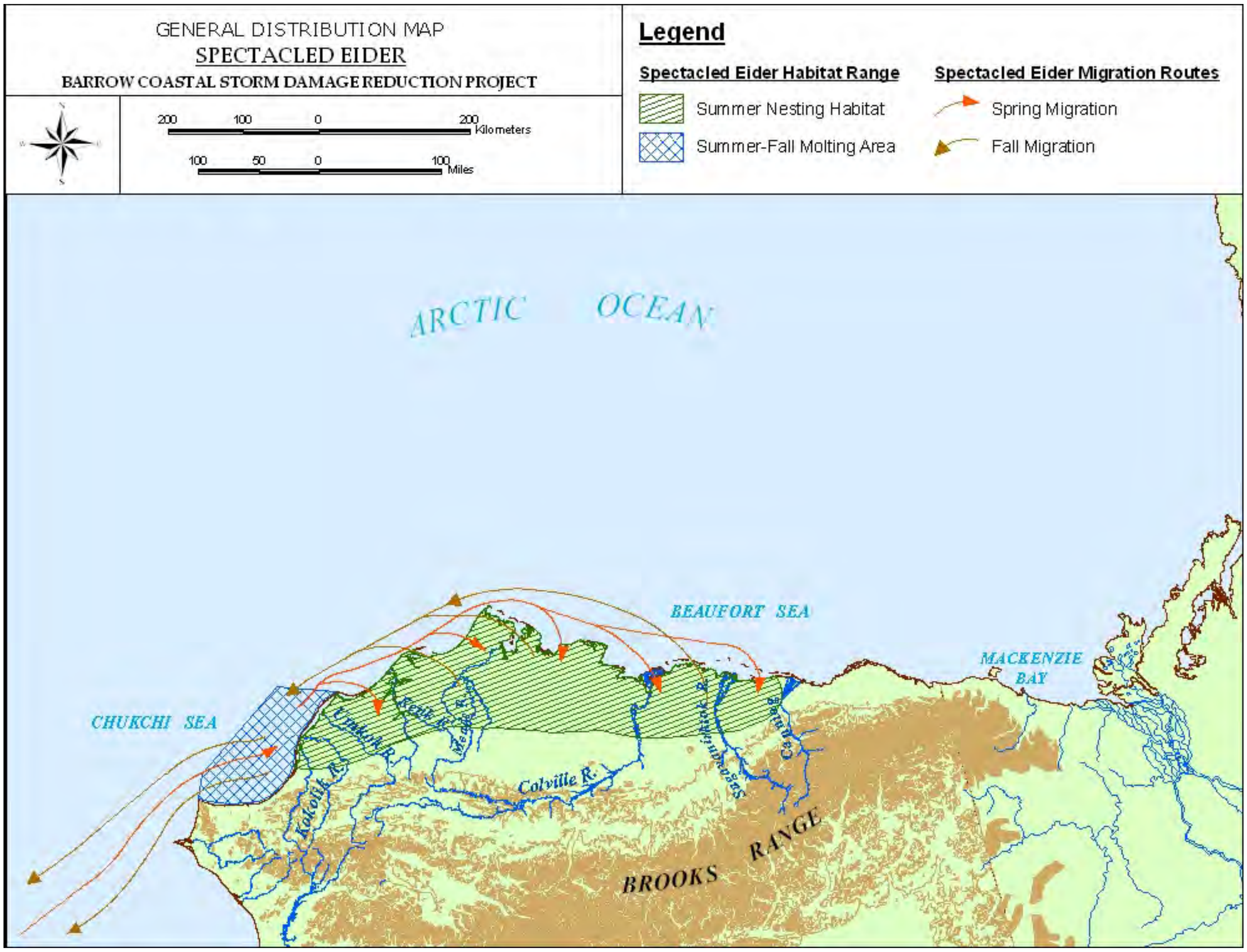

Figure 20. Spectacled eider migration route and nesting range.

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.

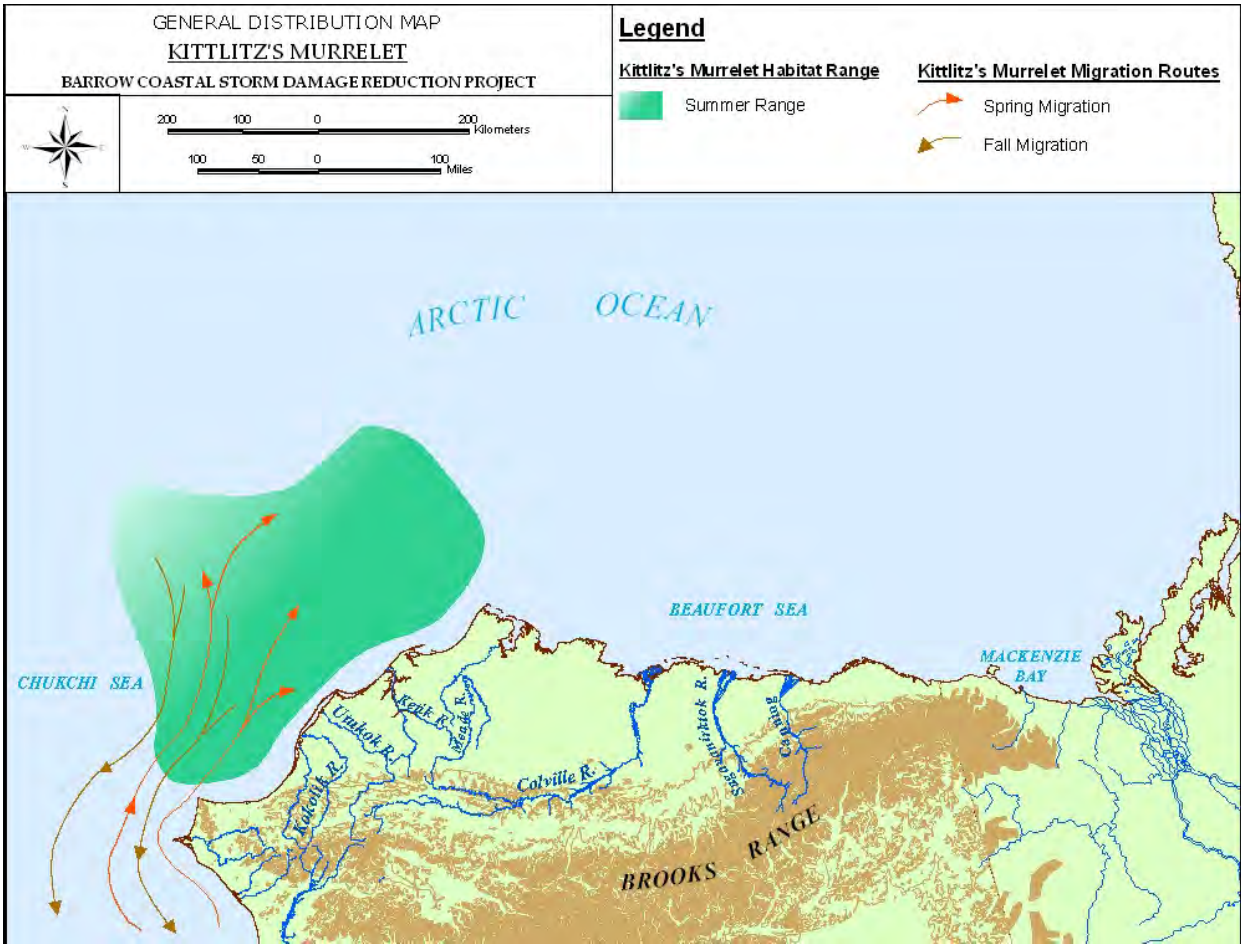

Figure 21. Range of Kittlitz's murrelet in the Chukchi Sea.

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).

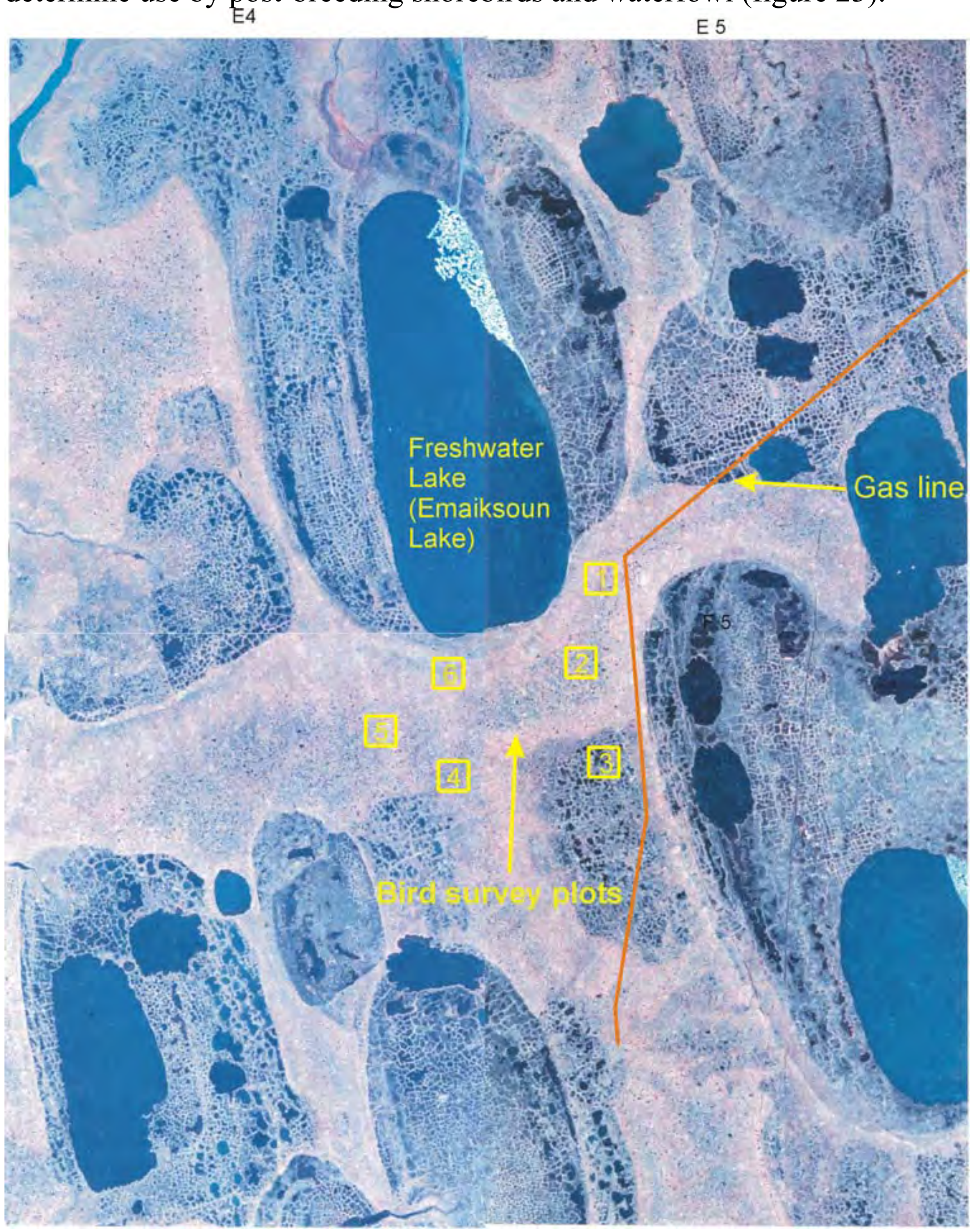

Figure 22. Breeding shorebird survey locations on the tundra south of Emaiksoun Lake.

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

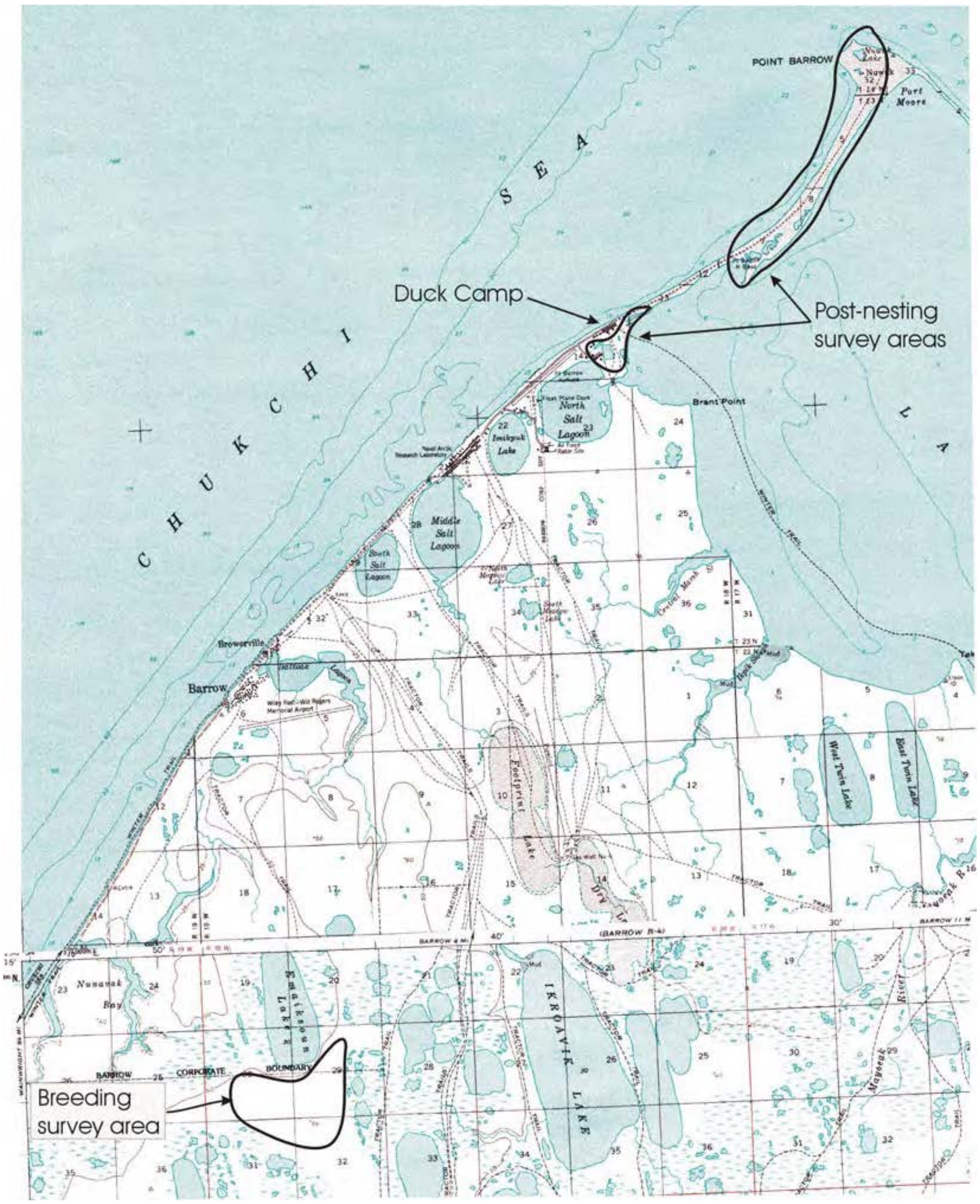

Figure 23. Barrow June and August 2005 shorebird surveys location map.

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.

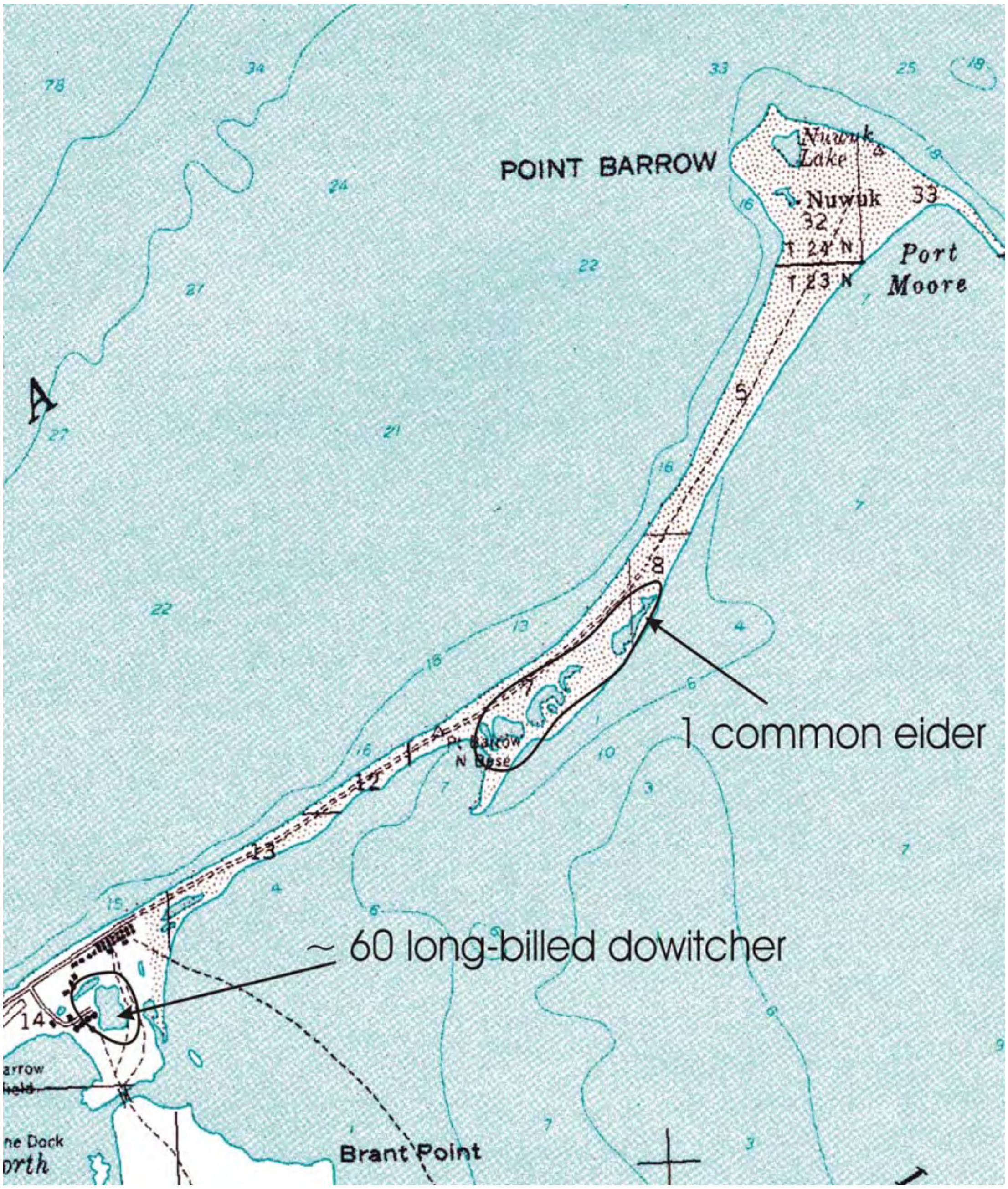

Figure 24. Bird observations near the base of the spit.

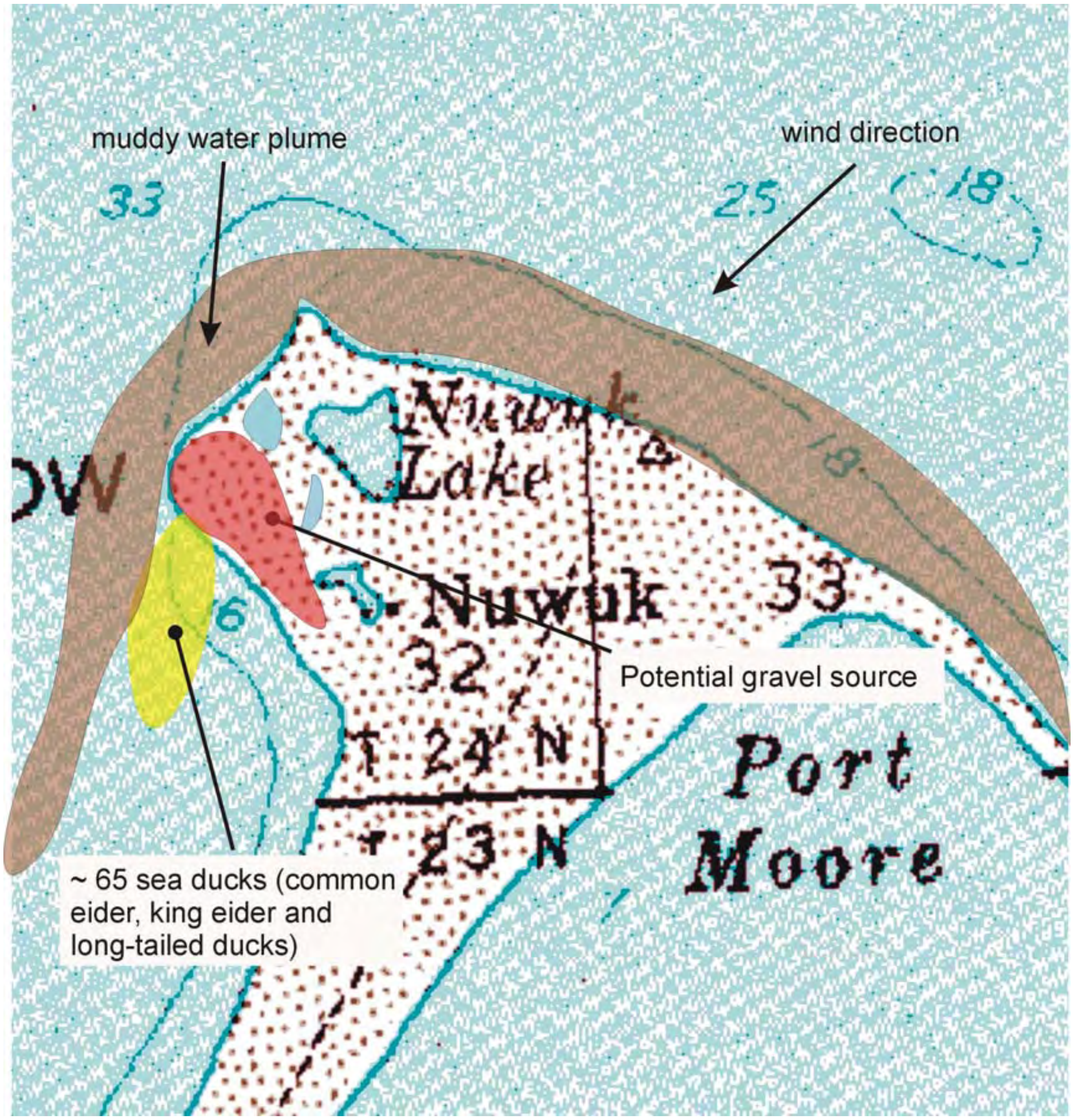

Figure 25. Bird observations near the tip of the spit.

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.

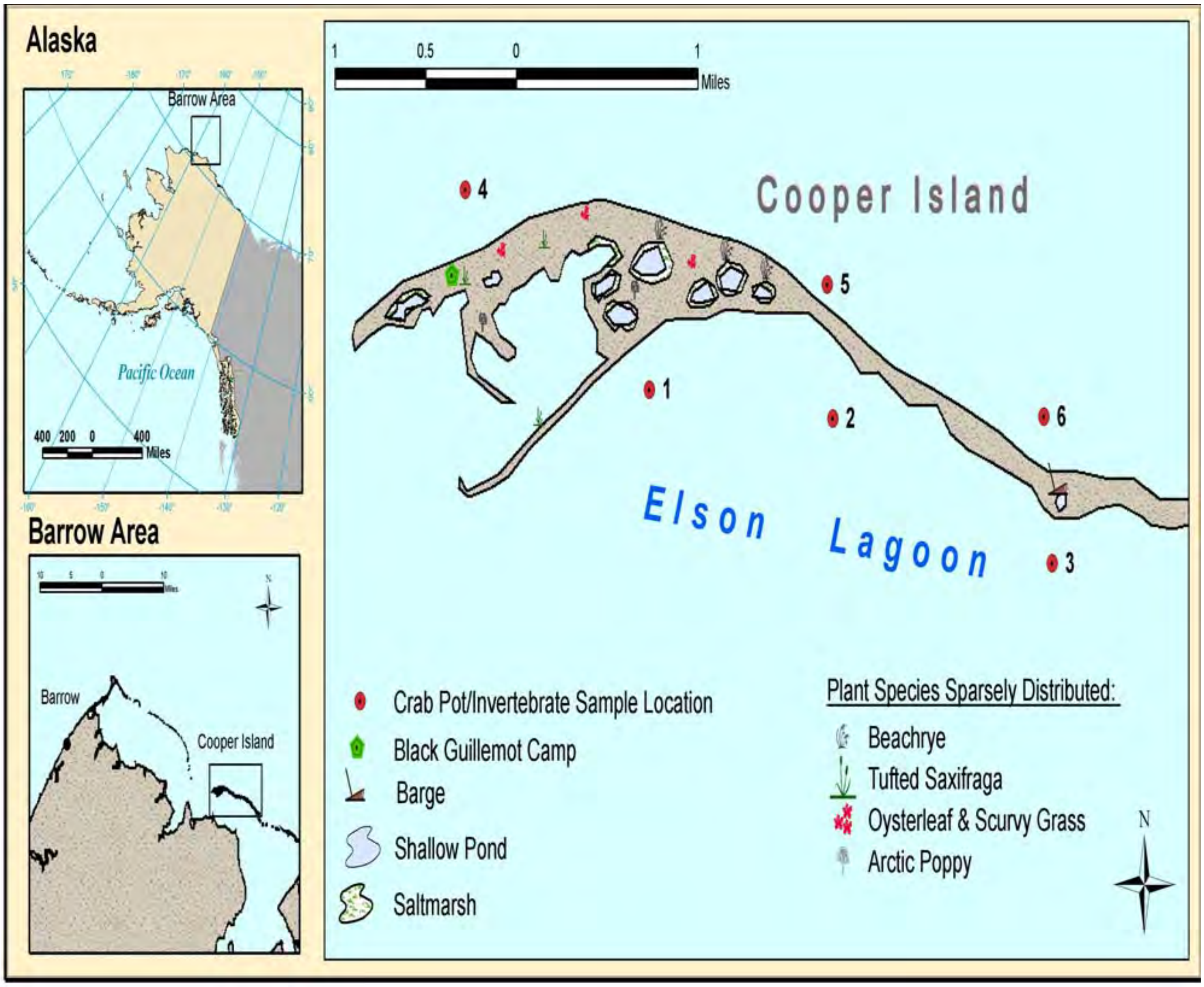

Figure 26. Cooper Island invertebrate sampling locations and vegetation map.

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.

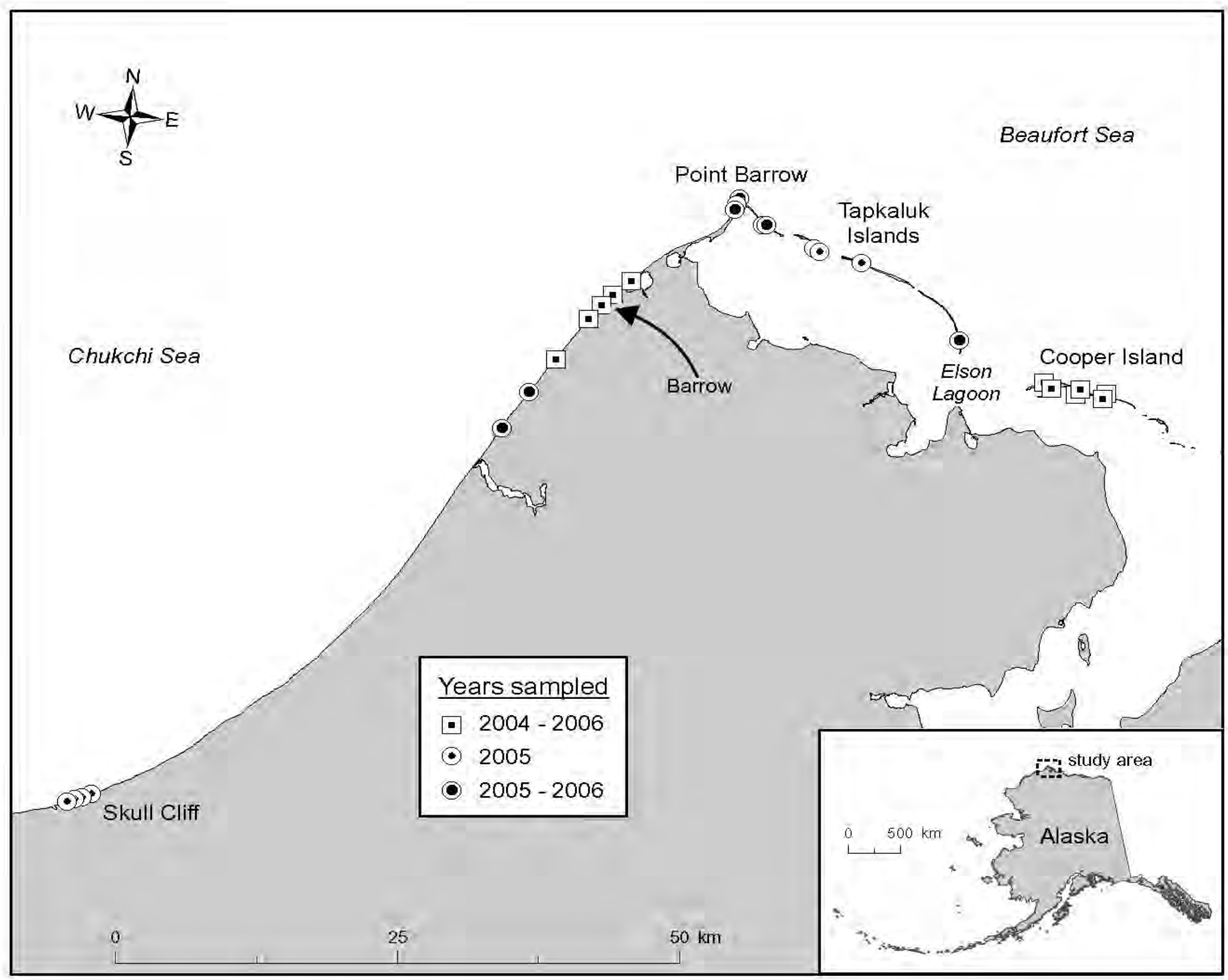

Figure 27. Sites sampled with a beach seine for fish assemblages near Barrow, Alaska. Eleven sites were sampled in 2004, 26 sites in 2005, and 18 sites in 2006.

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.

<u>2004-2006</u>

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.

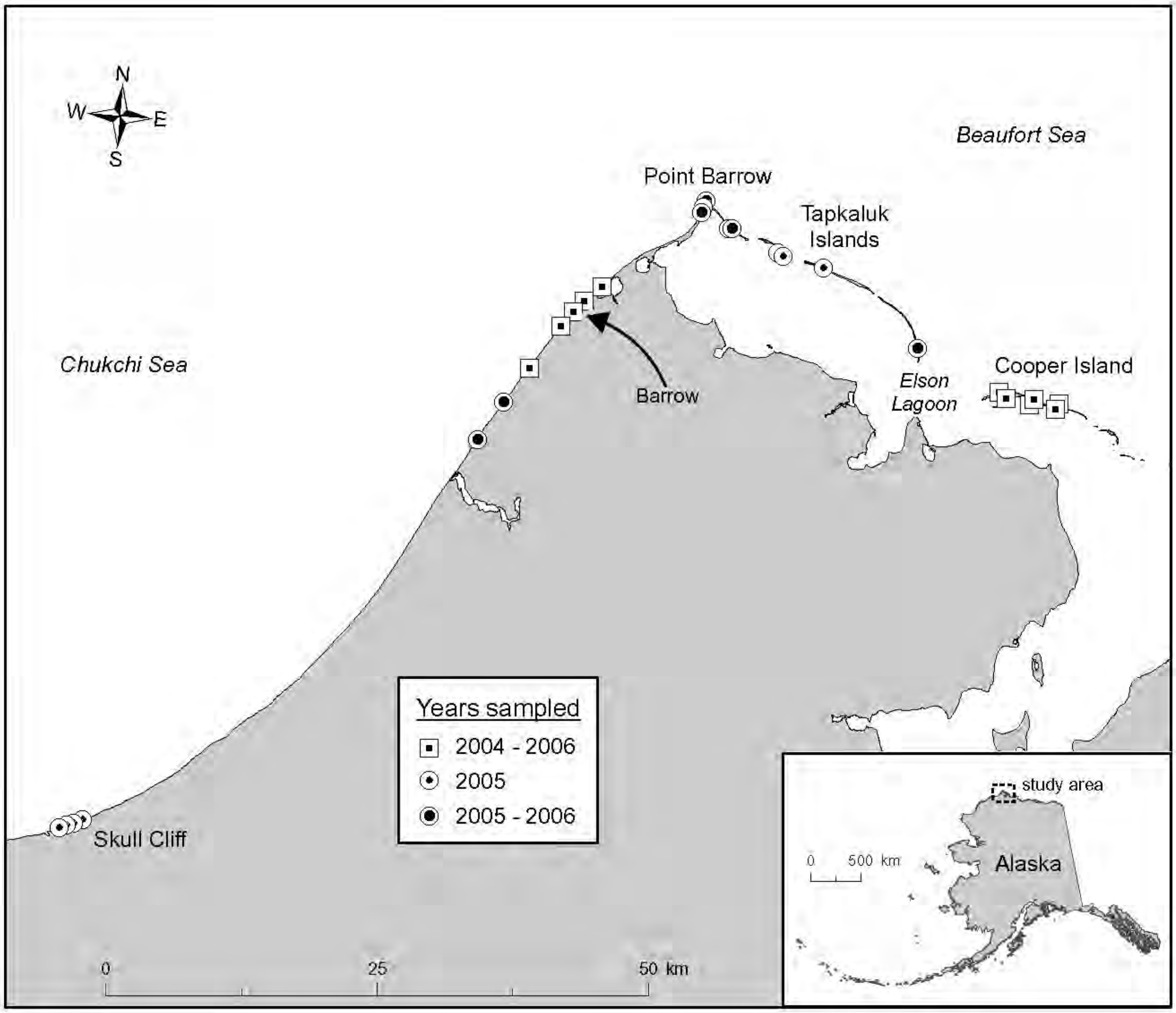

Figure 1. Sites sampled with a beach seine for fish assemblages near Barrow, Alaska. Eleven sites were sampled in 2004, 26 sites in 2005, and 18 sites in 2006.

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

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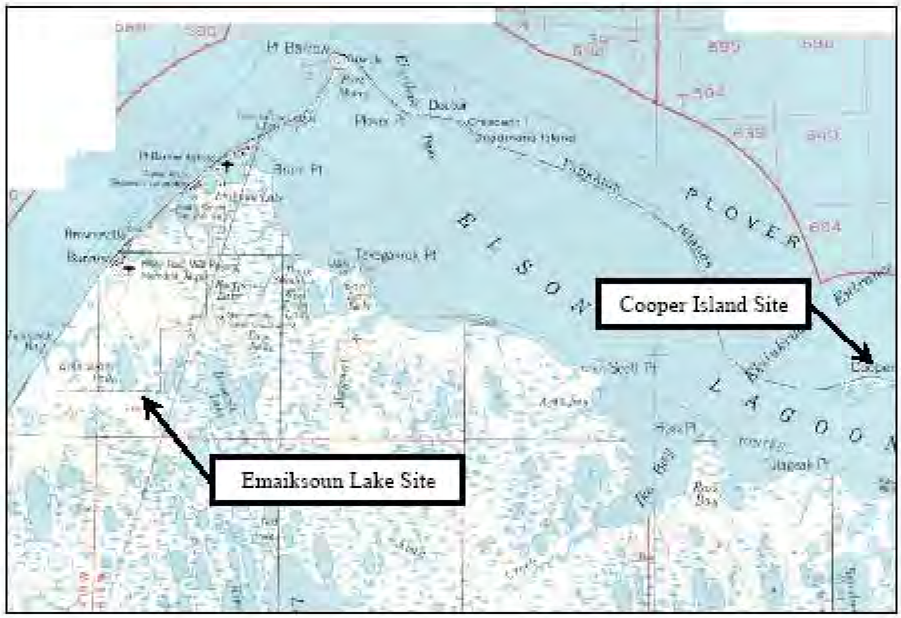

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Barrow Alaska Coastal Erosion Feasibility Study

Appendix E: Economics Analysis Technical Appendix

Barrow, Alaska

August 29, 2018

US Army Corps
of Engineers
Alaska District

BARROW ALASKA COASTAL EROSION FEASIBILITY STUDY

ECONOMIC ANALYSIS TECHNICAL APPENDIX

prepared for:

Alaska District
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August 2018

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1.0 PREFACE

The United States Army Corps of Engineers (Corps) has partnered with the North Slope Borough (NSB) to conduct the Barrow Alaska Coastal Erosion Feasibility Study. The study is being conducted under authority provided by Section 116 of the Energy and Water Development Appropriations Act of 2010 (PL 111-85) as amended. Section 116 provides authority for the Secretary of the Army to carry out structural and non-structural projects for storm damage prevention and reduction, coastal erosion, and ice and glacial damage in Alaska.

This feasibility study is a Corps 3x3x3 SMART Planning feasibility study being conducted in response to a request from the North Slope Borough (NSB) to resume a previous study effort by the Corps. This previous study effort, the Barrow Coastal Storm Damage Reduction Feasibility Study, culminated in a Technical Report in 2010, and is referred to as the 2010 study. Consistent with Corps SMART planning principles, the current feasibility study is utilizing existing and available information from the 2010 study combined with new data to support plan formulation and risk informed identification of a tentatively selected plan (TSP).

This economic analysis technical appendix documents methods and results of economic studies conducted as part of the current feasibility study. Specifically, the appendix includes:

1) Description of the study area
2) Documentation of current socioeconomic conditions in the study area
3) Documentation of expected without project National Economic Development (NED) damages
4) Overview of alternatives to reduce coastal erosion and flooding risk
5) Documentation of planning level cost estimates for alternatives
6) Evaluation of expected Regional Economic Development (RED) effects of alternatives
7) Evaluation of expected Other Social Effects (OSE) of alternatives
8) Evaluation of potential national economic development (NED) effects of alternatives
9) Documentation of evaluation framework to assess community resilience under without project conditions and expected Community Resilience Effects (CRE) with each alternative
10) Documentation of Cost Effectiveness and Incremental Cost Analyses (CE/ICA) to support recommendation of a TSP in accordance with Section 116 of the Energy and Water Development Act of 2010 and its associated Corps implementation guidance[1].
11) Identification of TSP
12) Description of significance of the TSP CRE for the study area

[1] As directed by the Section 116 Corps Implementation Guidance, when there is no NED Plan and/or the selection of a plan other than the NED Plan is based in part or whole on non-monetary units, the selection must be supported by a CE/ICA consistent with established evaluation procedures in ER 1105-2-100, Appendix E.

2.0 SUMMARY OF RESULTS

This section summarizes key results from this Economic Analysis Technical Appendix.

In accordance with the study direction set by the Project Delivery Team (PDT) (see Section 5 for more information), the NED benefits analysis for the alternatives under consideration was performed based primarily upon price level and interest rate updates of the 2010 study. As was expected based on the 2010 study, the NED analysis found that none of the alternatives were likely to result in positive net NED benefits, with benefit-to-cost ratios ranging from 0.07 for Alternative 6C to 0.40 for Alternative 5A.

The Section 116 Authority affords the opportunity to formulate and select a plan based upon all four accounts. The PDT developed a CE/ICA framework which evaluated and compared alternative plans in terms of their contribution to community resilience. Community resilience was defined in terms of multiple variables which spanned the four accounts, including direct damages, social/cultural effects, life safety risk, employment and income effects, and environmental risk. Based upon existing information from the 2010 study and recent information obtained from the NSB, the community resilience evaluation framework was employed to estimate Community Resilience Units for the alternatives. The IWR Planning Suite software was utilized to perform the CE/ICA.

In addition to the No Action, alternatives 5A, 5B, 5C, 2, and 6A were identified as cost effective, with alternatives 2 and 6A also identified as best buy plans. Alternative 2 had a total output of 2,925 community resilience units, and Alternative 6A had a 2,935 units of total output. Due to the inclusion of relatively expensive beach nourishment in Alternative 6A, there was a high incremental cost associated with choosing the alternative with the maximum output. As such, the PDT identified Alternative 2 as the TSP. This plan would provide protection along the full length of the project area and would utilize either a revetted berm seaward of Stevenson Street or raise and armor Stevenson Street itself to most efficiently provide protection while minimizing the intersection of the project footprint with existing property and infrastructure. Based upon current design, the selected plan would have a total construction cost (first cost plus contingency) of approximately $193 million. The PDT and sponsor judged the cost to be worth the improvements to community resilience in Barrow that would result from implementation of the TSP.

3.0 STUDY AREA

Barrow, AK is the northernmost community in North America, 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 9,800 persons[2] 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 4,500 residents[3], accounting for nearly half of the Borough's population.

[2] 2016 State Demographer estimate.
[3] 2016 State Demographer estimate.

Figure 1 – State of Alaska Location Map

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, with rainfall averaging 5 inches and annual snowfall averaging 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 November 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.

There are documented coastal erosion and flooding risks in the study area that pose threats to economic, social/cultural, and environmental systems in the community. The primary focus of the economic study of coastal flooding and erosion damages is the five-mile stretch of coast beginning in the neighborhood of Barrow and extending northwest through the neighborhood of Browerville, along Stevenson Street past the South Salt and Middle Salt lagoons, up to and including the Naval Arctic Research Laboratory (NARL) facility (**Figure 2**). The Barrow and Browerville neighborhoods are the most populous, and contain both residential and nonresidential structures and most of the city's infrastructure.

4.0 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 U.S. Census and Alaska Department of Labor and Workforce Development's 2016 Population Overview.

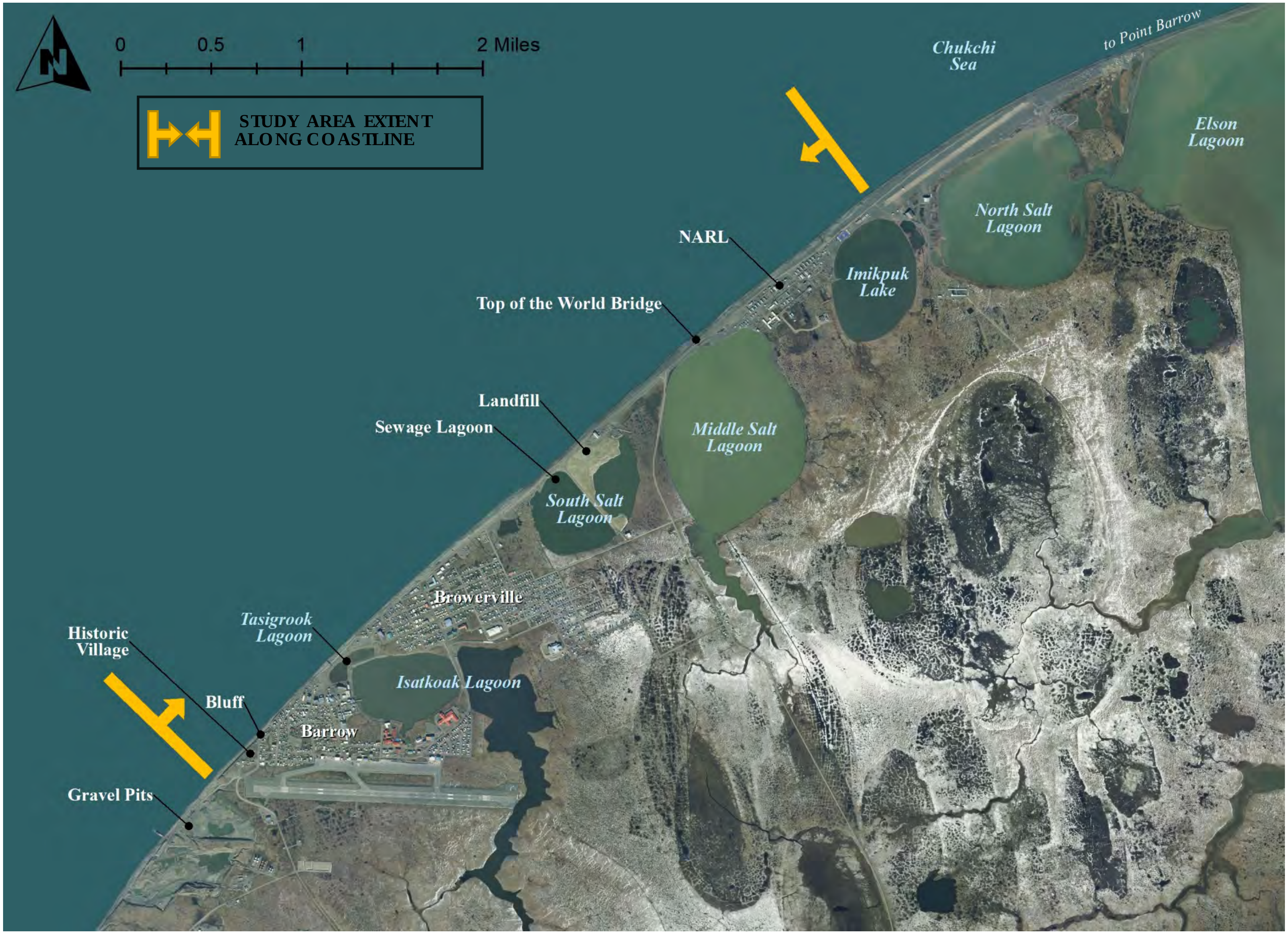

Figure 2 – Study Area

4.1 Population

Barrow's population was fairly steady over the period between 2010 and 2016, with a high of 4,548 in 2015, a low of 4,436 in 2012, and a 2016 population of 4,469. **Figure 3** shows the population change in Barrow over the period 1880-2005. The most recent detailed demographic data for Barrow is from the U.S. Census American Community Survey program for 2016 (2016 Census). At that time, 71% of the population was reported as Alaska Native alone (64%) or in combination with one or more races (7%). Of the remaining population, the largest racial groups were reported as white (12%) and Asian (12%). **Table 1** provides a summary of the racial composition of the Barrow population in 2016.

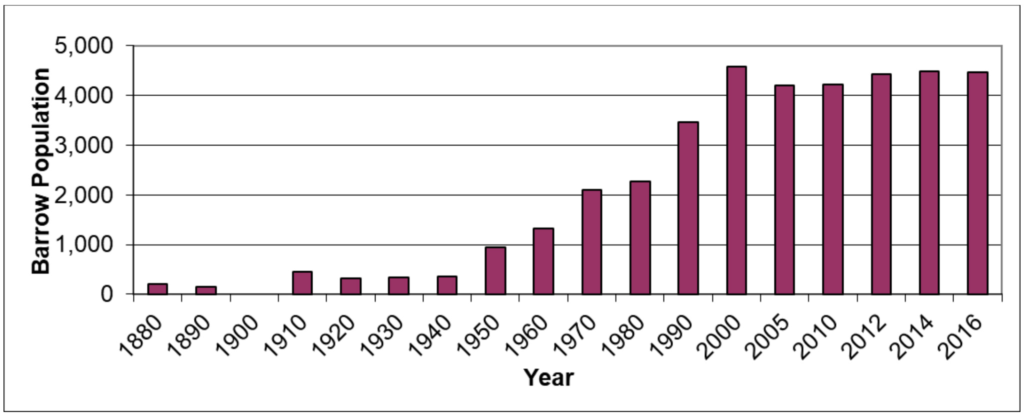

Figure 3 – Population Change in Barrow 1880-2016

Table 1 – Population by Race

Population in 2016: (Alaska State Demographer estimate)	4,469	
Population in 2016: (2016 American Community Survey)	4,316	
Racial Composition (2016 population):		
One Race Only:	3,995	93%
White:	511	12%
Alaska Native or Amer. Indian:	2,754	64%
Black:	10	1%
Asian:	513	12%
Hawaiian Native:	161	1%
Other Race:	46	1%
Two or More Races:	321	7%
All or Part Alaska Native/Indian:	3,043	71%
Hispanic Origin (Any Race):	213	5%
Not Hispanic (Any Race):	4,103	95%

The gender of Barrow's population in 2016 was approximately 52% male and 48% female. Approximately 39% of Barrow's population in 2016 was under the age of 20; with 45% between the ages of 20 and 54 and 16% over the age of 54. Barrow's median age was reported as 27. **Table 2** provides a summary of Barrow's 2016 population statistics by gender and age.

Table 2 – Population by Gender and Age

Male:	2,260	52%
Female:	2,056	48%
TOTAL POPULATION (2016):	4,316	100%
Age 4 and under:	469	10.90%
Age 5 - 9:	466	10.80%
Age 10 - 14:	400	9.30%
Age 15 - 19:	350	8.10%
Age 20 - 24:	308	7.10%
Age 25 - 34:	661	15.30%
Age 35 - 44:	489	11.30%
Age 45 - 54:	502	11.60%
Age 55 - 59:	243	5.60%
Age 60 - 64:	194	4.50%
Age 65 - 74:	155	3.60%
Age 75 - 84:	74	1.70%
Age 85 and over:	5	0.10%
Median Age:	27.0	
Pop. Age 18 and over:	2,725	63%
Pop. Age 21 and over:	2,584	60%
Pop. Age 62 and over:	338	8%

Documented coastal flooding and erosion risk in the study area present a likelihood of numerous adverse consequences to the population of Barrow. These consequences are presented in subsequent sections of this Appendix.

4.2 Housing

Barrow's 2016 population was grouped into 1,370 households and the City included 1,662 total housing units. The average household size was 3.11 persons. **Table 3** summarizes the 2016 Census data related to housing and household characteristics in Barrow.

Table 3 – Housing/Household Characteristics

Total Housing Units:	1,662	
Owner-Occupied Housing:	603	44%
Renter-Occupied Housing:	676	56%
Vacant Housing:	292	18%
Total Households:	1,370	
Average Household Size:	3.11	
Family Households:	999	73%
Average Family Household Size:	3.63	
Non-Family Households:	371	27%

The 2016 Census data characterizing Barrow's housing stock is presented in **Table 4**.

Table 4 – Housing Structure Types

Single Family (Detached):	1,093	66%
Single Family (Attached):	53	3%
Duplex:	115	7%
3 or 4 Units:	134	8%
5 to 9 Units:	11	1%
10 to 19 Units:	129	8%
20 plus Units:	116	7%
Trailers/Mobile Homes:	11	1%
TOTAL STRUCTURES:	1,662	100%

Documented coastal flooding and erosion risk in the study area present a likelihood of adverse consequences to housing infrastructure in Barrow. These consequences are presented in subsequent sections of this Appendix.

4.3 Employment and Income

Of the Census-estimated 4,316 people living in Barrow in 2016, approximately 67% were considered as being in the potential work force (age 16 years and over), with 2,053 in the labor force (employed or seeking work) and 857 not in the labor force (not seeking work). Of the labor force, 59% were reported as employed and 11% reported as unemployed. The largest employer was government, accounting for 864 of the 1,722 jobs in 2016 (50%). **Table 5** summarizes the employment statistics for Barrow from the 2016 Census. **Figure 4** presents a breakdown of employment in Barrow by category.

Table 5 – Employment

Total Potential Work Force (Age 16+):	2,910	
Unemployed (Seeking Work):	331	11.4%
Adults Not in Labor Force (Not Seeking Work):	857	29.5%
Total Employment:	1,722	59.2%
Breakdown of Employed Labor Force:		
Private Wage & Salary Workers:	818	48%
Self-Employed Workers (in own not incorporated business):	38	2%
Government Workers (City, Borough, State, Federal):	864	50%
Unpaid Family Workers:	2	0.10%

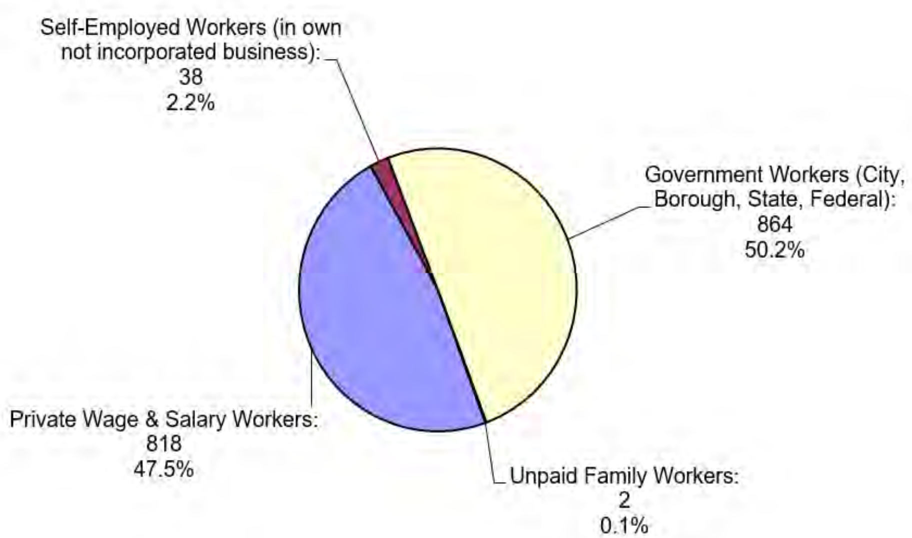

Figure 4 – Employment by Employment Category

Table 6 presents the breakdown of the 2016 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 43% of the jobs in Barrow.

Table 6 – Employment by Industry

Education, Health & Social Services:	426	24.7%
Public Administration:	321	18.6%
Transportation, Warehousing & Utilities:	194	11.3%
Other Services (Except Public Administration):	48	2.8%
Retail Trade:	169	9.8%
Construction:	193	11.2%
Professional, Scientific, Management, Administrative & Waste Mgmt.:	71	4.1%
Finance, Insurance, Real Estate, Rental & Leasing:	66	3.8%
Arts, Entertainment, Recreation, Accommodation & Food Services:	132	7.7%
Agriculture, Forestry, Fishing & Hunting, Mining:	74	4.3%
Information:	16	0.9%
Manufacturing:	0	0%
Wholesale Trade:	12	0.7%
TOTAL EMPLOYMENT:	1,722	100.0%

Barrow's Per Capita Income was reported at $28,137 in the 2016 Census data (18% lower than the state average of $34,191). **Table 7** presents summary income data for Barrow.

Table 7 – Income

Per Capita Income: (Reported in 2016 Census)	$28,137
Median Household Income: (Reported in 2016 Census)	$78,804
Median Family Income: (Reported in 2016 Census)	$94,107
Persons in Poverty: (Reported in 2016 Census)	609
Percent Below Poverty: (Reported in 2016 Census)	14.1%

Documented coastal flooding and erosion risk in the study area present a likelihood of numerous adverse consequences to the employment and income opportunities in Barrow. These consequences are presented in subsequent sections of this Appendix.

5.0 EXPECTED NATIONAL ECONOMIC DEVELOPMENT WITHOUT-PROJECT DAMAGES

National Economic Development (NED) benefits are effects which increase the economic value of the National output of goods and services. 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). At Barrow, potential beneficial NED effects are possible by reduction of damages from flooding and erosion that would be expected to occur without a project.

To expedite the study in response to the time-critical nature of the flood and erosion hazard in Barrow, an initial assessment of the likelihood of positive NED benefits was conducted. This assessment was made using the best available information (coastal modeling results and economic damage estimates from the 2010 studies) and professional judgement by the PDT that the previous analysis was the best information available and reasonably representative of current conditions. The intent of the 2010 update was to provide information about whether or not the project was likely to be justified based upon the NED account alone, and to inform a decision regarding the need for development and implementation of a cost effectiveness and incremental cost analysis evaluation framework in accordance with the Section 116 implementation guidance.

The NED benefits from the 2010 study were updated to current prices and the current Federal discount rate. Because no new engineering information was available there were no changes to underlying modeling assumptions and no new model runs were performed in Beach-Fx. Refinements to the 2010 engineering analyses are currently being conducted and will be used to refine design criteria in subsequent phases of the study. This update to the 2010 NED analysis includes price level and discount rate updates of the estimated future without project damages from that previous study. These updated values were then compared to the cost of the alternative plans formulated for the current study.

5.1 Discount Rate and Price Level Updates

The updated computation of without-project condition (WOPC) damages was based upon a fifty-year period of analysis beginning in the base year of 2020. The base year is defined as the year that significant project benefits will begin to accrue. All costs and benefits are presented in Q3 FY18 prices. Price level updates were performed using Engineering Manual 1110-2-1304, Civil Works Construction Cost Index System (Revision 30 Sep 2017), the Bureau of Labor Statistics Consumer Price Index, and the Marshall & Swift Valuation Service, as needed. Costs and benefits are converted to their equivalent values in the base year using the FY18 Federal discount rate for water resources implementation studies of 2.75% as published in Corps Economic Guidance Memorandum 18-01. Similarly, costs/benefits presented as average annual costs are amortized over a fifty-year period of analysis using the discount rate.

The general approach to efficiently converting WOPC damages to current price level and discount rate included:

1. Identification of all relevant damage categories and verification that each category was still applicable
2. Identification of the expected annual damages (EAD) value previously calculated for each applicable category
3. Conversion of the old EAD to a Present Value (PV) using the 2010 study's discount rate
4. Performance of a price level update to current prices
5. Amortization of the PV at current prices using the current Federal discount rate, yielding the updated EAD value

5.2 Updated Expected NED Damages

NED categories in the 2010 study were divided between coastal storm damages and coastal erosion damages. Coastal storm damages included structures and contents, spillway and associated utilities, and Utilidor damages. Coastal erosion damages included land loss, structure condemnation, beach berm emergency erosion maintenance (including storm-fighting), Stevenson Road repairs, and Utilidor damages.

Coastal Erosion Damages

Coastal erosion damage categories from the 2010 study that were determined to remain applicable for the current study include:

- Sacrificial beach berm erosion
- Frontage road erosion (largely Stevenson Street)
- Erosion/condemnation of structures
- Erosion of land
- Damages from erosion of the Utilidor

With price level and discount rate updates, total expected annual coastal erosion damages are estimated at $1,363,400. **Table 8** summarizes the present values of erosion damages for each category over the period of analysis and their average annual equivalent values.

Table 8 – Summary of Updated Coastal Erosion Damages

Damage Category	Estimated Present Value Damage	Estimated Annual Damage	%
Land Loss	$490,238	$18,159	1%
Structure Condemnation	$9,420,205	$348,933	26%
Beach Berm	$21,185,596	$784,734	58%
Stevenson Road Repairs	$3,948,505	$146,256	11%
Utilidor Damages	$1,763,518	$65,322	5%
Subtotal	**$36,808,062**	**$1,363,404**	**100%**

Coastal Storm Damages

Coastal storm damage categories from the 2010 study that were determined to remain applicable for the current study include:

- Inundation damage to structures and contents
- Flood damage to Tasigrook Dam spillway and utilities
- Flood damage to critical utilities and associated service from flooding of the Utilidor

With price level and discount rate updates, total expected annual coastal storm damages are estimated at $136,100. **Table 9** summarizes the present values of coastal storm damages for each category over the period of analysis and their average annual equivalent values.

Table 9 – Summary of Updated Coastal Storm Damages

Damage Category	Estimated Present Value Damage	Estimated Annual Damage	%
Structures & Contents	$1,367,304	$50,646	37%
Spillway & Utilities	$1,580,365	$58,538	43%
Utilidor	$726,874	$26,924	20%
Subtotal	**$3,674,543**	**$136,108**	**100%**

Summary of Future Without-Project NED Damages

The updated evaluation of economic damages associated with coastal storm damages and erosion in the study area identified total expected annual damages of $1,799,500 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. This amounts to a 27% increase in EAD as a result of the price level and discount rate update from the analysis completed and documented in the 2010 technical report. **Table 10** provides a summary of the expected annual without project damages from coastal flooding and erosion in the study area.

Table 10 – NED Update, Summary of Expected Annual Damages

Damage Category	Estimated Present Value Damage	Estimated Annual Damage	%
Coastal Storm Damages	$3,674,543	$136,108	9%
Coastal Erosion Damages	$36,808,062	$1,363,404	91%
TOTAL	**$40,482,605**	**$1,499,513**	**100%**

6.0 ALTERNATIVE PLANS

The planning process for the current study established and screened a range of alternatives to reduce flood and erosion risks for the community of Barrow. The final array of alternative plans was comprised of ten plans (including the No Action alternative). Detailed descriptions of the alternatives are included in the main Feasibility Report. Each alternative and its primary features are summarized below for reference.

Alternative 1: No Action
The No-Action alternative would not take action to reduce or halt erosion and flooding along the coastline of Barrow, Alaska. The study objective would not be met and no opportunities would be realized. Erosion would continue to take place and flooding would occur during storm events. Public and private infrastructure, historical buildings, and cultural resources would continue to be lost as the ground beneath them eroded away.

Alternative 2A: Rock Revetment at Bluff and Berm in Front of Stevenson Street
This alternative would provide erosion protection for the bluffs starting in front of the airport until the bluffs transition to low lying areas in front of Tasigarook Lagoon, approximately 1 mile of bluff protection. This alternative would also include flood protection for the low lying areas starting in front of Tasigarook Lagoon with a smooth transition from a protected rock revetment in front of the bluffs to a revetted berm in front of Stevenson Street. The revetted berm would then continue in front of Stevenson Street until it intersects with Dewline Road on the far side of NARL. The revetted berm would extend approximately 4 miles. This alternative would have a height of +14.5 ft MLLW.

Alternative 2B: Rock Revetment at Bluff and Raise Stevenson Street
This alternative would provide the same level of protection as Alternative 2A. The erosion protection for the bluff would still extend from in front of the airport to in front of Tasigarook Lagoon. Instead of constructing a revetted berm on the seaward side of Stevenson Street for the approximate 4-mile stretch, Stevenson Street would be raised. Stevenson Street would be raised to +14.5 ft MLLW and the seaward side of the street would be revetted. This would allow people driving on the road to still have a view of the ocean and could decrease the quantity of armor rock.

REVISED Alternative 2: Alternative 2 was selected as the TSP, with Options A and B (revetment vs street raise). Options A and B were later combined into a hybrid labeled Alternative 2: Rock Revetment, Berm, and Raise Stevenson Street.

Rock Revetment, Berm and Raise Stevenson Street. This alternative would provide erosion protection for the bluffs in front of Barrow starting in front of Wiley-Post Will Rogers airport and heading north until the bluffs start to decrease in height from +19 ft MLLW to +15 ft MLLW. A +14.5 ft MLLW berm will tie into the rock revetment and follow the shoreline north to where Tahak Street intersects Stevenson Street. Stevenson Street will be raised to a height of +14.5 ft MLLW with the seaward side revetted starting at this intersection and heading north to Dewline Road, just past NARL. Beach access points within the project area will be established during the Preconstruction Engineering and Design (PED) phase and will account for spring break-up, drainage, and public access. Design of the beach access points will be based on community feedback and modeling. Reaches within this alternative will be further refined during PED.

Alternative 5A: Protect Major Infrastructure
A revetted berm in front of the Tasigarook Lagoon would protect the community's fresh water source and it would be extended north-easterly to protect pump station #3 of the Utilidor. Infrastructure at greatest risk from flooding would be protected 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 exceedance probabilities and stage frequency flood plots that can be found in detail in Appendix A. This alternative also considered filling in a portion of Tasigarook Lagoon as an alternative to a berm revetment, which was considered in the 2010 Technical Report. This measure is not being considered within this study, however due to some information being carried over from the previous study, this measure may still remain as a relic that will be removed by the final report.

Alternative 5B: Barrow and Browerville Neighborhoods
Expanding on Alternative 5A, the Barrow and Browerville Neighborhoods alternative would include a rock revetment for the bluffs starting at the airport and extend the revetted berm to the end of Browerville, near the intersect of Stevenson Street and Ahmoagak Avenue.

Alternative 5C: Barrow and Browerville Neighborhoods plus NARL
In addition to Alternative 5B, the Barrow neighborhood from erosion and Tasigarook Lagoon and the Browerville neighborhood from flooding, this alternative would protect NARL from flooding by raising Stevenson Street in front of NARL.

Alternative 5D: Barrow and Browerville Neighborhoods plus NARL and old Navy landfill
In addition to Alternative 5C, the Barrow neighborhood from erosion and Tasigarook Lagoon, the Browerville neighborhood, and NARL from flooding, this alternative would protect the old Navy landfill from flooding by nourishing the beach.

Alternative 6A: Combination Rock Revetment, Raise Stevenson Street, and Revetted Berm with Limited Beach Nourishment
This alternative includes erosion and flood protection in front of the airport through the end of NARL with a secondary level of protection added as beach nourishment. Various protection measurements would be used for different stretches of the beach. The bluffs would be revetted, a revetted berm along with beach nourishment would be constructed in front of Tasigarook Lagoon and continue through the end of Browerville, and then Stevenson Street would be raised from the end of the berm through the end of NARL.

Alternative 6B: Combination Rock Revetment, Raise Stevenson Street, Revetted Berm, and Beach Nourishment
Alternative 6B is similar to 6A in the type of protection measures and length of coast protected. Instead of raising Stevenson Street in front of the salt lagoon and old Navy landfill, these areas would utilize beach nourishment for coastal protection.

Alternative 6C: Beach Nourishment Only
This alternative only includes beach nourishment as a protection measure. Beach nourishment would be placed along approximately five miles of coastline, from the airport through the end of NARL where Stevenson Street intersects with Dewline Road. The beach nourishment could be gravel or coarse sand

depending on the method of fill design. The interval of re-nourishment would depend on the size of material used for the initial nourishment.

7.0 COSTS OF ALTERNATIVES

Planning level cost estimates[4] were developed for the final array of action alternatives. The nine alternative estimates were developed in Q3 2018 prices. For the purpose of the economic analysis, estimated construction durations and OMRR&R estimates were also developed. Interest during construction and amortized costs were calculated over the 50-year period of analysis using the FY18 Federal discount rate. The cost estimate back-up information, which includes detailed spreadsheet cost estimates, unit prices, quantity calculations and abbreviated risk analysis, can be found in **Appendix G**.

7.1 Quantities

Quantities for the earthwork, rock, lagoon fill, and beach nourishment have all been calculated by the Corps Alaska District cost engineering staff. The quantities were checked for reasonableness within the provided spreadsheet, and have been used in the alternative estimates with no modifications.

7.2 Unit Prices

Unit prices for the alternative estimates were taken from various sources that include vendor quotes, RS Means, previous cost estimates, available bid data, and previous study documents. All unit prices have been adjusted with local multipliers that modify the base unit price to reflect localized, labor, equipment and material prices.

1. Mobilization and Demobilization – Assumes 10% of the construction costs for each alternative.
2. Excavation – Unit cost assumes excavation to be completed with use of hydraulic excavators, and material would be stockpiled on-site prior to disposing.
3. Hauling – Unit price assumes hauling with 12-cubic yard (cy) dump trucks to a local disposal site in Barrow. No tipping fee is assumed to be required.
4. Armor Rock, B-rock, Core Rock and Gravel – Unit prices assume all rock for the berms and revetments would be delivered to Barrow from other locations in Alaska. The likely source of the rock would be from Nome, where the material would be loaded onto barges for delivery to Barrow. Other locations are possible, but may require longer shipping distances and thus higher costs. The prices used in the current estimate are based on quotes provided by several contractors familiar with the Nome quarry and with shipping of construction materials throughout Alaska. A document of discussions with these contractors, and the pricing information they provided, is provided in **Appendix G**.
5. Filter Fabric – Unit price assumes placement of filter fabric at designated locations.
6. Local Material – Unit price assumes the gravel pit in Barrow has sufficient material to provide as local fill. This material would be delivered by truck to the placement location, placed and then compacted.
7. Structure Raise and/or Relocation – The exact requirements for the structure relocations are not set. Previous USACE cost estimates and documentation included approximately $150k for certain structure relocations. Given escalation factors, and potential for historic structures to require relocations, $200k per structure has been used until more details are developed.

[4] Consistent with guidelines in ER 1110-2-1302 for Class 4 estimates for Feasibility Alternatives.

8. Beach Nourishment Material – Unit price assumes that beach nourishment material would be purchased, and excavated from a source located along the Colville River. The material would be loaded onto barges and delivered to Barrow for placement. Material would be dumped from barges in the deeper locations, and potential could be dumped by land at the near shore locations.

7.3 Feature Accounts

The cost estimates have been separated by feature account. The features included are as follows:

01 Land and Damages – No costs are included for this account in the economic analysis as real estate costs were under development. Real estate costs for alternatives in the 2010 cost estimates ranged from .1 to 1.9% of construction costs. These values were assessed and determined to have no effect on the results of project formulation and identification of a TSP.

02 Relocations – Costs in this account consist of structure relocations that require relocation in order to construct the berm and/or raise Stevenson Street.

16 Bank Stabilization – Costs in this account consist of the majority of construction alternatives. The revetment, berm, and raising of Stevenson Street all fall under this account. All mobilization and demobilization required also is included here.

17 Beach Replenishment – Costs for this account consist of the placement of the beach nourishment materials.

18 Cultural Resources – Costs for this account consist of the need for an on-site archeologist that would likely be required for duration of construction activities.

30 Planning, Engineering and Design (PED) – Cost for this account have been assumed to be 10% of total construction costs.

31 Construction Management (CM) – Costs for this account have been assumed to be 6% of total construction costs.

7.4 Contingencies

Contingencies represent allowances to cover unknowns, uncertainties and/or unanticipated conditions that are not possible to adequately evaluate from the data on hand at the time the cost estimate is prepared, but must be represented by a sufficient cost to cover the identified risks. An abbreviated risk analysis (ARA) has been prepared for this project to calculate alternative specific contingencies.

7.5 Operations, Maintenance, Repair, Rehabilitation and Replacement (OMRR&R)

OMRR&R costs have been calculated for each alternative. Assumptions based on the features required in each alternative were used to estimate a quantity of rock or beach nourishment that would be required to be replaced over an assumed duration of time. The following assumptions were used to estimate OMRR&R costs for the alternative estimates:

- Annual minor maintenance and inspections - $25,000 per year (every alternative)
- Revetments rock replacement - 7.75% of armor, b-rock and core rock replaced every 5-years
- Raise Stevenson Street - 7.75% of armor, b-rock and core rock replaced every 5-years
- Berm rock replacement – 7.75% of armor, b-rock and core rock replaced every 5-years
- Beach nourishment material – 85% of nourishment material replaced every 25-years

7.6 Cost Summary

The summary of the alternative costs developed for use in the economic analyses, including the CE/ICA, is shown in **Table 11**.

Table 11 – Alternative Costs

Alt.	Project Costs	Duration (months)	Interest During Construction ($ PV)	OMRR&R ($ PV)	Total Cost ($ PV)	Annualized Cost ($, 2.75%)
2A	$ 191,241,000	25.30	$5,420,865	$33,489,000	$ 230,150,865	$ 8,525,000
2B	$ 192,790,000	25.10	$5,418,960	$31,728,000	$ 229,936,960	$ 8,517,076
5A	$ 92,563,000	12.80	$1,261,912	$7,034,000	$ 100,858,912	$ 3,735,907
5B	$ 146,779,000	14.60	$2,309,468	$16,305,000	$ 165,393,468	$ 6,126,326
5C	$ 186,334,000	23.90	$4,972,109	$22,887,000	$ 214,193,109	$ 7,933,910
5D	$ 258,905,000	25.70	$7,461,953	$42,689,000	$ 309,055,953	$ 11,447,717
6A	$ 257,058,000	26.50	$7,653,395	$52,579,000	$ 317,290,395	$ 11,752,728
6B	$ 346,553,000	25.20	$9,782,117	$89,199,000	$ 445,534,117	$ 16,502,993
6C	$ 438,873,000	15.50	$7,367,429	$140,363,000	$ 586,603,429	$ 21,728,330

PV = Present Value, Q3 2018

8.0 REGIONAL ECONOMIC 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.

8.1 Alternative 1 (No Action)

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 results of the modeling in the 2010 study, 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 12% of Barrow's total of 1,722 jobs as reported in the 2016 U.S. Census. Approximately 75% of the 210 at-risk jobs are in the public sector and approximately 25% are in commercial establishments. Based upon mean annual earnings of $63,100 in the 2016 Census American Community Survey, the value of income of employees in at-risk facilities is estimated at approximately $51,000 per day (assuming a five-day work week: ~$1.02M per month; ~$12.24M 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.

8.2 Alternatives 2A, 2B, 6A, 6B, and 6C

Because these alternatives are designed to provide protection throughout the study area, effects would be similar for each.

In the short term, the study area is expected to experience positive income and employment effects from construction of any of these alternatives. Construction is expected to occur from June to October for several seasons, which will employ a construction crew. 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, these alternatives 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 alternatives 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.

8.3 Alternatives 5A, 5B, 5C, and 5D

These alternatives offer incrementally increasing levels of protection for the study area.
In the short term, the study area is expected to experience positive income and employment effects from construction of any of these alternatives. However, implementation of successively larger alternatives would be expected to increase the magnitude of these positive effects as a result of increased construction cost, duration, and crew size, all of which could increase impacts.

Construction is expected to occur from June to October for several seasons, which will employ a construction crew. Opportunities for direct local employment associated with project construction are possible but expected to be limited. Opportunities for 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, these alternatives 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. Alternative 5A, which protects critical infrastructures, would achieve the largest increment of beneficial regional effects. Successively larger plans would achieve additional benefits from protecting Browerville, NARL, and the South and Middle Salt lagoons.

9.0 OTHER SOCIAL EFFECTS OF ALTERNATIVES

9.1 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 and other support services (see Section 3.4 in 2008 Economics Appendix enclosed as Attachment A). 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. 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.
- **Alternatives 2A, 2B, 6A, 6B, and 6C:** These alternatives would reduce the identified risks to personal safety and mortality associated with coastal flooding, erosion, and flood fighting activities. The alternatives would also reduce coastal storm and erosion damages to property. Because these alternatives are designed to provide protection throughout the study area, effects would be similar. 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. 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 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.
- **Alternatives 5A, 5B, 5C, and 5D:** These alternatives would reduce the identified risks to personal safety and mortality associated with coastal flooding, erosion, and flood fighting activities. The alternatives would also reduce coastal storm and erosion damages to property. The magnitude of these positive effects increases with each alternative as additional areas are protected. All these alternatives offer protection of the Utilidor at Pump Station #4 from erosion damage would reduce the potential losses human health and safety risks that would be associated with an interruption in utility service. With alternatives 5A, 5C, and 5D, 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, as well as improved safety of the local community in eastern Barrow and in Browerville which would result in an increased quality of life for residents. Incrementally larger alternatives 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.

9.2 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. All the action alternatives would substantially reduce the risk of utility outages from flooding or erosion at Pump Station #4 or damages to utilities spanning Tasigrook and Isatkoak lagoons.

9.3 Recreational Opportunities

The primary traditional recreational opportunity affected by the final alternatives is recreational beach combing. The relative effects expected with each alternative are described below. With the No-Action Alternative, future opportunities for recreational beach combing are expected to remain in the study area. For the action alternatives, opportunities may experience minor adverse changes depending upon the structure proposed for a given reach of the study area. At the bluff, the revetment may reduce opportunities due to the narrow beach that would be further occupied by the revetment. Similarly, areas protected by a berm may see a reduction in beach area. Continuous protection 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 protective structure.

9.4 Subsistence

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.

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.

9.5 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.

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.

Alternative 5A is the only action alternative that would not protect the bluff at the Utqiagvik Village Site from continued erosion, and effects would be similar to the No Action. All other action alternatives would protect the 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.

9.6 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.

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. The action alternatives would result in a reduction of the flooding and erosion damage risk in Barrow. All the alternatives would reduce the risk of critical infrastructure failure and utility loss. The magnitude of other 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 as the level of protection increases.

9.7 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.

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.

All of the action alternatives that include a protective structure would be built to 19 feet at the bluff and 14.5 feet throughout the remainder of the study area. 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.

The aesthetic effects associated with beach nourishment are expected to be similar to those presented for the revetted berms. 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.

10.0 POTENTIAL NED EFFECTS OF ALTERNATIVES

The data in **Table 12** provides a comparison of the annual costs for the final array of alternatives to the maximum annual benefits that could occur if the alternative were to eliminate all expected annual without-project damages. This level of benefits overstates the protection provided by the alternatives, especially for alternatives that do not include protection throughout the entire study area such as 5A, 5B, and 5C[5]. However, given the resultant benefit-to-cost ratios based on this existing data, the table serves to illustrate the low likelihood of achieving positive net benefits based only upon the NED account. This determination allowed the PDT to focus on plan evaluation through CE/ICA as directed in the Section 116 implementation guidance and as documented in **Section 10** of this appendix.

[5] Qualitative discussion of the effectiveness of each alternative and the residual risk is provided in the following section on the CE/ICA analysis

Table 12 – Estimated Benefits with Updated NED Damages

Alternative	Annual Costs ($, 2.75%)	Max Annual Benefits ($, 2.75%)	BC Ratio
2A	$8,525,000		0.18
2B	$8,517,076		0.18
5A	$3,735,907		0.40
5B	$6,126,326		0.24
5C	$7,933,910	$1,499,513	0.19
5D	$11,447,717		0.13
6A	$11,752,728		0.13
6B	$16,502,993		0.09
6C	$21,728,330		0.07
This BCR calculation includes the simplifying assumption that every alternative would eliminate all damages, resulting in zero residual damages. Analysis will be refined in subsequent phases.			

11.0 COMMUNITY RESILIENCE ASSESSMENT

The Section 116 Authority is intended to support development of Corps projects in rural Alaska which improve communities' resilience to flooding and erosion hazards. In pursuit of a project implemented under this authority, it is the responsibility of the Corps to identify the recommended plan in a manner consistent with Corps planning principles and procedures. While current information suggests that positive net NED benefits may not justify the project alone, there are significant other risks to the Barrow community which can be quantified in terms of local and regional economic impacts, risk to life and public health and safety, and risk of environmental contamination.

As directed by Section 116 Implementation Guidance, when there is no NED Plan and/or the selection of a plan other than the NED Plan is based in part or whole on non-monetary units, the selection must be supported by a CE/ICA consistent with established evaluation procedures in ER 1105-2-100, Appendix E. The implementation guidance further states that the alternatives evaluation should present the tradeoffs of impacts in the four accounts for the plans contained in the final array and describe in detail the compelling justification for any plan that is not the NED Plan. The guidance allows for consideration of non-monetary benefits. Examples provided in the guidance include public health and safety; local and regional economic opportunities; and, social and cultural value to the community.

The PDT developed a framework for evaluating the effects of alternatives based upon the concept of community resilience. The proposed community resilience evaluation framework provides the data required for a CE/ICA to compare alternatives in terms of their contribution to improving community resilience at Barrow. Development of the framework was based upon Corps approaches to consideration of resilience, applied to the project context at Barrow.

11.1 Defining Resilience

Increasingly frequent extreme events, such as natural disasters, amplified by increasing urbanization and impacts from climate change, result in severe and costly impacts wherever they occur. Resilience is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions (EO 13653). Resilience – of a person, project, system, and/or communities of any size – can help reduce the extent and duration of negative consequences from adverse events. Resilience represents a comprehensive, systems-based, lifecycle approach to both acute hazards and changes over time, and the concept of resilience is used to convey a broad-based, collaborative approach to finding creative solutions to such challenges (Corps 2017 and 2018).

Figure 5 conceptually illustrates resilience in terms of response to a hazard event, where the combination of event severity and resilience result in different possible responses to the event (Linkov et al. 2014). Under WOPC, Barrow best fits the category of High Risk & Low Resilience.

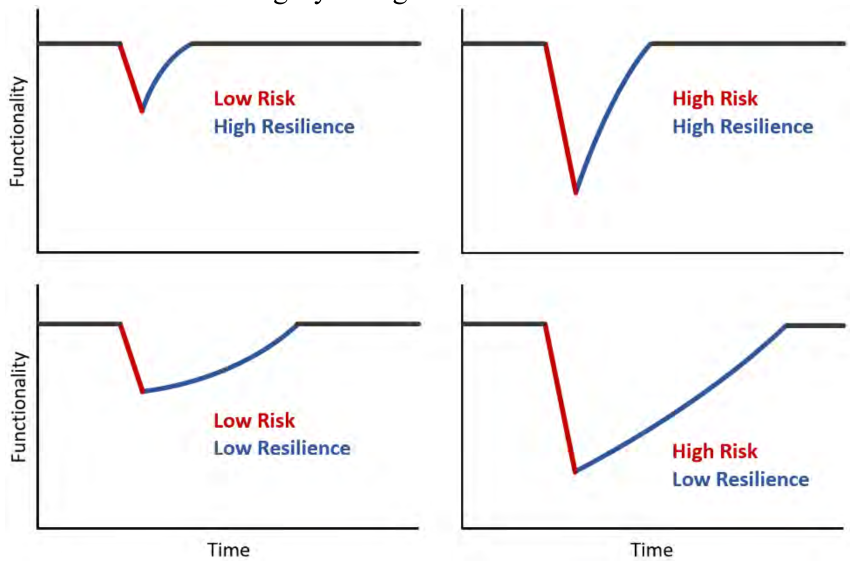

Figure 5 – Resilience Over Time (Linkov et al. 2014)

<u>Resilience Goal:</u> The Corps defines its role in fostering resilience in terms of projects. The goal for resilience in projects is to increase performance reliability in anticipated use, reduce the risk of failure during extreme events, maintain primary function during changing conditions, and/or help meet specific community resilience goals (Corps 2017).

At Barrow, the community resilience goal is well-aligned with the planning objectives, which both convey the need to address immediate risks associated with regularly occurring storms and long-term risks associated with lower-probability (higher magnitude) storm events and the effects of coastal erosion, especially in consideration of changing global weather patterns which have resulted in delayed freeze-up and longer open-water storm seasons.

<u>Levels of Resilience:</u> As shown in **Figure 6**, the Corps identifies three interdependent levels of applied resilience: (1) project, (2) system, and (3) community (Corps 2017).

- *Project Resilience* refers to Corps or other projects and their own resilience. For example, a measure of project resilience might be a levee, berm, or revetment's performance over the probable storm frequency curve.
- *System Resilience* refers to a set of integrated projects which have a system-wide resilience. This might include the combined ability of the levee and an upstream storage reservoir to protect against probable storms. Some systems may be all Corps projects, or may have non-Corps projects, or may have no Corps projects.
- *Community Resilience* refers to the combined resilience of all the systems in a community (system of systems). Community resilience encompasses the entirety of all aspects that make up a community. It is complex and complicated, and each community is different (Corps 2018a).

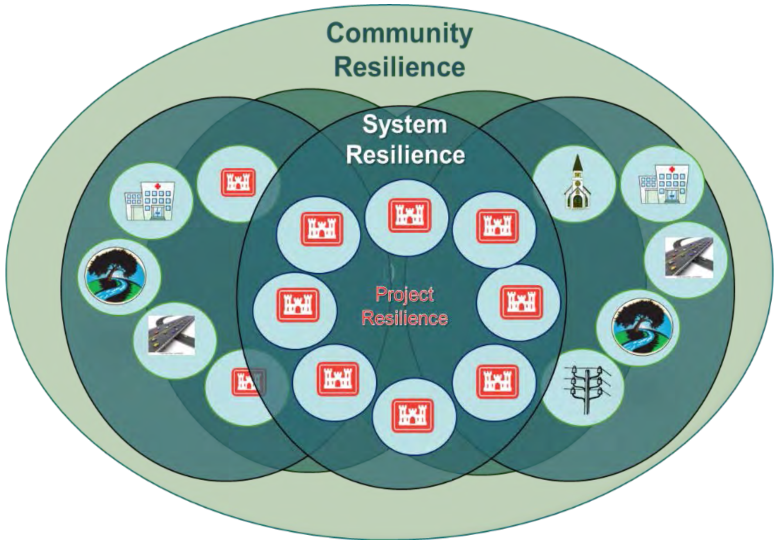

Figure 6 – Three Levels of Resilience (Corps 2017)

The Community Resilience evaluation framework described in this section of the appendix provides a methodology to assess and compare the relative contributions of each alternative to community resilience to erosion and flooding in Barrow.

<u>Four Resilience Actions:</u> To help organize resilience activities and describe how resilience measures can be applied, the Corps has divided resilience into four key principles (or actions): prepare, absorb, recover, and adapt. These principles provide a lifecycle perspective for resilience-related actions in recognition of the fact that adverse events happen and conditions change over time (Corps 2017). These four principles are illustrated graphically in **Figure 7**, which considers a system's resilience in terms of its reaction to a hazard event over time (Linkov et al. 2014). As shown in the figure, all four principles of resilience contribute to a system's response to a hazard event.

Figure 7 – Four Resilience Principles (Linkov et al. 2014)

NSB staff **plan** and prepare for storms through an ongoing maintenance program that involves shoring up the sacrificial berms in advance of each storm season and readying equipment and materials for emergency maintenance during storms. The community's ability to **absorb** the impacts of a storm rely heavily on this active flood and erosion fighting during the event, as well as the availability of resources to **recover** from (rebuild and restore) any damages following the event. The community's efforts to **adapt** have been limited by available resources, and have focused on essential upgrades to specific utility components, such as elevating man holes and pump stations in flood and erosion hot spots. Despite the community's concerted and commendable efforts to plan for and adapt to the risks of coastal erosion and flooding, Barrow remains minimally resilient to the occurrence of coastal storm events and has limited capacity and resources to absorb and recover from them.

11.2 Measuring Resilience

In the discussion of a resilience framework, the Corps highlights the importance of resilience at the local level, contributing to greater community resilience. The way that the Corps can contribute to community resilience is through delivery of resilient projects. In Barrow, a resilient coastal storm project would not only be independently resilient, but would also improve the resilience of existing transportation and utility systems in the community, reduce risks to public health and safety, and protect cultural and environmental resources in the study area.

To facilitate characterization of community resilience across systems, a community may be described using a triple bottom line framework with economic, social/cultural, and environmental components (or "resilience areas") (Corps2018 and 2018a). In the context of the Barrow Alaska Coastal Erosion Feasibility Study, a triple bottom line community resilience evaluation framework has been applied for assessing holistic without project conditions and the effects of alternatives for application in a CE/ICA.

The framework evaluated alternatives in terms of their reduction of adverse effects compared to the without project condition (i.e. each alternative's positive contribution to community resilience). **Figure 8** highlights the evaluation framework in terms of known risk areas at Barrow. **Table 13** provides a cross-walk between the ten identified adverse consequence categories and the three resilience areas. As shown in the table, consequence categories may have more than one relevant unit of measure and may apply to more than one resilience area. **Figure 9** shows key geographic locations related to these consequences on a map.

Figure 8 – Barrow Community Resilience Framework

Table 13 – Resilience Consequence Categories and the Triple Bottom Line

Consequence Category	Figure 9 Consequence Map Item	Community Resilience		
		Economic	**Social / Cultural**	**Environmental**
1) Flooding of Structures & Contents	▪ Structures in Barrow and Browerville Neighborhoods	▪ Direct Damages	-	-
2) Erosion Loss of Structures & Contents	▪ Structures in Barrow Neighborhood		-	-
3) Erosion Land Loss	▪ Land in Barrow		-	-
4) Erosion of Bluff (Historic Village Site)	▪ Utqiagvik Cultural Site in Barrow Neighborhood		▪ Cultural Resources Lost	-
5) Flood Damage to South and Middle Salt Lagoons (Sewage System & Old Navy Landfill)	▪ South Salt Lagoon Sewage Lagoons ▪ Old Navy Landfill (Both just north of Browerville Neighborhood)		-	▪ Landfill Contaminants Released ▪ Sewage Lagoon Breached
6) Flooding of Isatkoak Lagoon (Water Supply and Utilities)	▪ Spillway and Utilities at Tasigrook Dam ▪ Water Supply Behind Isatkoak Dam ▪ Utilities on Isatkoak Dam	▪ Direct Damages ▪ Job Opportunities Lost	▪ Utility / Water Supply Service Lost	-
7) Flooding of Utilidor (Loss of Service for Critical Utilities)	▪ Pump Station 4 (PS#4) in Barrow Neighborhood ▪ Pump Station 3 (PS#3) in Browerville Neighborhood			-
8) Erosion Damage to Utilidor (Loss of Service for Critical Utilities)				-
9) Flooding Damage to Stevenson Street	▪ Throughout study area along or near beach	▪ Direct Damages	-	-
10) Flooding Damage to Beach Berm and Emergency Maintenance to Restore Protective Berm During Flood Events	▪ Throughout study area along beach		▪ Days Flood Fighters at Risk	-

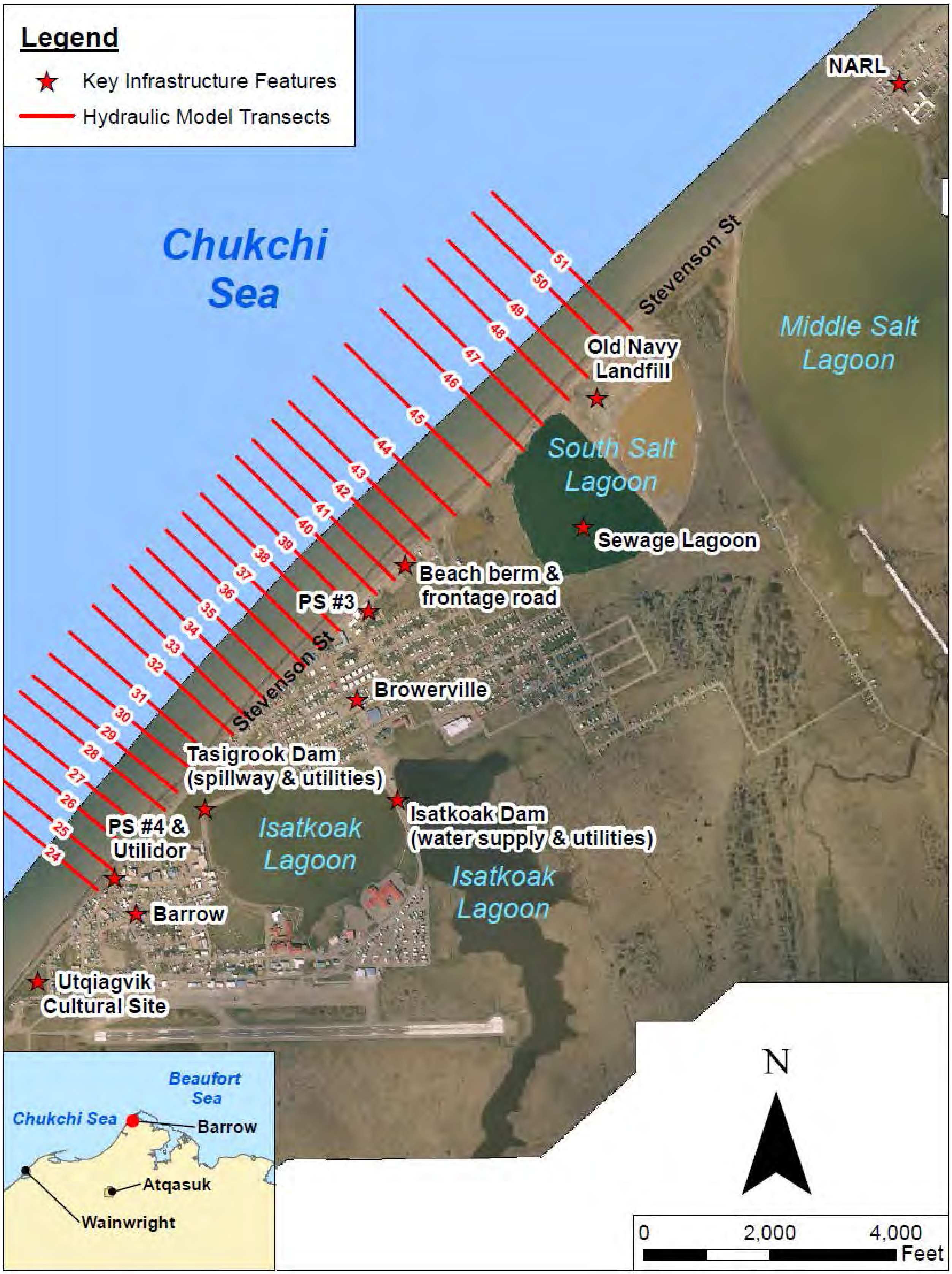

Figure 9 – Key Locations for Consequence Categories

The evaluation framework was applied to develop a quantified measure of community resilience under without project conditions and to quantify and compare the effects of alternatives. This quantified unit of measurement is called a Community Resilience Unit (CRU). In this application, CRUs are based upon a set of output variables which may serve as measurement tools for the types of consequences that were presented in **Table 13**. Six such variables were identified for this framework. The bullets below describe the variables, and a crosswalk of these variables, how they address the three resilience areas, and the identified consequence categories are shown in **Figure 10**. Subsequent sections document the process for derivation of the CRUs.

Economic Resilience Variables

- *Direct Dollar Damage (DDD)*: This variable accounts for dollar damages and costs as a direct result of flood and/or erosion damage; such as structure and content losses, or storm response costs.
- *Full Time Equivalent Job Impacts (FTE)*: This variable accounts for the number of person days (full time equivalent) job opportunities lost due to estimated downtime of critical utility services due to coastal erosion and/or flooding.

Social/Cultural Resilience Variables

- *Cultural Resource Acres at Risk (CRA)*: This variable accounts for the known area of significant cultural resources associated with the old original Utqiagvik village site in the Barrow Neighborhood. Areas are quantified in terms of the total area at risk of loss to coastal erosion.
- *Person-days without Critical Utilities (PDU)*: This variable accounts for the threat to public health and safety associated with loss of critical life sustaining utility services in the harsh arctic environment of the study area. The variable is based upon the affected population and the expected duration of service interruption due to either breach or damage to the water supply and utility infrastructure at Isatkoak Lagoon, Tasigrook Dam, or the Utilidor.
- *Person-days in High-Risk Flood Fighting Activity (PDH)*: This variable accounts for risk to human health and safety and is quantified in person-days of high-risk emergency maintenance flood fighting activity. During coastal storms the NSB frequently must perform emergency berm repair and shore protection during the storm, necessitating that machinery operators work during dangerous conditions; including operation of heavy equipment in the surf, seaward of the protective berm.

Environmental Resilience Variables

- *Cubic Yards Contaminated Fill (CYF)*: This variable accounts for the damage to the environment surrounding the study area. It is based upon the estimated volume of potentially contaminated materials at risk of spill from flooding or erosion; including both the community sewage lagoons and known contaminated solid waste in the adjacent old Navy Landfill.

After estimating effects (risk reduction) in terms of each variable for each alternative, results can be presented at the triple bottom line level by combining the effectiveness scores across variables for each resilience area. For input into CE/ICA, a single derived variable termed Community Resilience Units (CRU's) was generated by combining effects across the 3 resilience areas (Economic, Social/Cultural, and Environmental) and their constituent output variables. Using estimated CRU's for each alternative, a CE/ICA model was run using the IWR Planning Suite software.

Figure 10 – Output Variable Cross-Walk

11.3 Cost Effectiveness and Incremental Cost Analyses (CE/ICA)

Four main steps were conducted for the CE/ICA. This section describes each step and the CE/ICA outputs. The four steps include:

1) Quantify without project adverse effects by consequence category and output variable
2) Quantify each alternative's potential contribution to community resilience by estimating how much each alternative would reduce the adverse effects for each output variable
3) Compute CRU's for each alternative based on the percent reduction in adverse effects (increase in resilience) estimated for each alternative
4) Assemble CE/ICA Input Data
5) Perform CE/ICA in IWR Planning Suite

STEP 1 – Quantify without project adverse effects by consequence category and variable.

The quantification of resilience effects for the future without project condition (No Action Alternative - Alternative 1) are shown in **Table 14**, followed by a brief description of the derivation of these values.

Table 14 – WOPC Adverse Effects

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
1) Structures & Contents, Flood	$50,646					
2) Structures & Contents, Erosion	$348,933					
3) Land loss, erosion	$18,159					
4) Bluff (historic village)	$13,906		5			
5) South and Middle Salt Lagoons, Flood (sewage system & old Navy landfill)	$106,562					2,608,760
6) Isatkoak Lagoon (water supply and utilities)	$182,242	397		258,960		
7) Utilidor, Flood (critical utilities)	$13,462	122		48,914		
8) Utilidor, Erosion (critical utilities)	$165,955	244		97,829		
9) Stevenson Street	$146,256					
10) Berm/Emergency Maintenance	$784,734				72	
Total	**$1,830,856**	**763**	**5**	**405,703**	**72**	**2,608,760**

DDD: For the structures and contents (consequence categories 1 and 2), outputs for the DDD variable were generated by updating the price level and discount rate for the modeling results from the 2010 study. This same approach was also taken for land loss from erosion (category 3), Stevenson Street repairs (category 9), and berm/emergency maintenance during storms (category 10). DDD outputs related to the bluff and historic village (category 4) were based upon a rough estimate of one-time cultural resource recovery/protection costs in the event of major erosion of the bluff. A similar approach was taken for discounting the estimated response costs associated with major impacts to the South Salt and Middle Salt lagoons (category 5). For consequences associated with the water supply lagoon and its dam/associated utility crossing (category 6), information was available to equate initiation of those consequences with an annual exceedance probability based upon the 2010 study. Erosion impacts associated with the Utilidor (category 8) were estimated by performing a price level and discount rate update of the 2010 analysis, with adjustment to reflect loss of the facility earlier in the period of analysis, given the passage of time between the previous analysis' base year and the current one. Finally, consequences associated with flooding of the Utilidor were also based upon the 2010 study, but reduced to 50% of the price-updated value given that the NSB has elevated the entrance to Pump Station #4 since the 2010 analysis.

FTE: FTE's are estimated for consequence categories 6, 7, and 8, which equate to those categories dealing with risk of major disruption to utility service in the study area. Based upon previous studies of the utility system and confirmation of basic downtime and population affected assumptions with the NSB, potential FTE outputs were estimated for a major storm or erosion event that resulted in a prolonged period of utility outage which would preclude normal business operations. The ASCG Report estimated the number of establishments affected by such an event, which was factored according to the average employees per establishment in Barrow per the 2012 Economic Census.

CRA: Quantified cultural resource acres are limited to the historic village site atop the bluff at the southwest end of the study area at this stage. The potential acreage was measured in GIS.

PDU: Person-days without critical utilities quantifies human health and safety risk associated with outages of the electrical, gas, water, or sewer systems. Due to the extreme conditions in Barrow, the ability for residents to heat their homes and have power is critical for much of the year. Additionally, Barrow's major power-generation infrastructure is gas-powered, meaning that loss of natural gas service would quickly lead to loss of electrical generation. If unpowered for a significant duration, the community's constant circulation systems which prevent freezing of water and sewer pipes would be at risk of failure. Any combination of these outages would result in substantial risk to human health and safety. Quantification of this variable is based upon the affected population and the expected duration of service interruption due to either breach or damage to the water supply and utility infrastructure at Isatkoak Lagoon, Tasigrook Dam, or the Utilidor. Affected populations for critical systems and duration of service interruptions were identified in coordination with the NSB and previous utility failure scenario investigations (Corps 2005).

PDH: Person-days of high-risk job activity was identified as a human health and safety risk borne by the NSB under their current flood/storm fighting regime, where equipment operators must work in dangerous conditions, including operating heavy machinery in the surf during storms, to maintain the sacrificial berms which protect critical infrastructure. The preliminary values used at this stage are in the process of being refined through coordination with the NSB, which is finalizing a detailed accounting of resource use (including labor) during the recent 2017 storm.

CYF: Cubic yards of fill provided a straightforward way to quantify the risk associated with release of contaminated materials into the ecosystem. At this stage, the variable was estimated based upon simple GIS calculations of the surface area of the South Salt and Middle Salt lagoons and an assumed 1 yard of depth. Future study phases may refine this calculation.

STEP 2 – Quantify each alternative's potential contribution to community resilience by estimating how much each alternative would reduce the adverse effects for each output variable.

The effects for each action alternative were quantified by estimating the percent reduction in without project adverse effects that would be accomplished by each action alternative.

For erosion risk; The PDT concluded that only alternative 5A did not completely address erosion risk because it excludes any protective structure in front of the bluff at the southwest end of the study area.

For flood risk, the PDT incorporated annual exceedance information from the 2010 study. As introduced in Section 5, the PDT chose to perform the CE/ICA based upon existing engineering inputs to assess the potential for positive net benefits. For each consequence category, the PDT identified a representative transect, stage-frequency curve, and damage initiation elevation from the 2010 Hydraulics Appendix. This data was the best available information to support the assessment and was judged by the PDT to be reasonably representative of current conditions to be used in the analysis. These curves were used to estimate the without project level of protection (annual exceedance probability) at each relevant transect. Then, the design bank heights for each alternative were plotted on the curves to estimate the reduction in annual exceedance probability that would be provided at each transect. This approach allowed the PDT to quantify the reduction in the probability of coastal storm damage initiation for each consequence category and alternative. **Figure 11** illustrates this approach at Pump Station 4 (Transect 25). Given a current elevation of 12.9 feet (the recently elevated height of the entrance), the pump station has a 2.6% probability of being exceeded every year. Under Alternative 2A, which would place protection to 14.5 feet, the probability of damages being initiated in each year drops to 1.1%, an approximate 58% reduction in annual exceedance probability. Provided at the end of this subsection, **Figure 12** through **18** provide maps showing the stage-frequency curves for the transects selected to represent each coastal flooding consequence category.

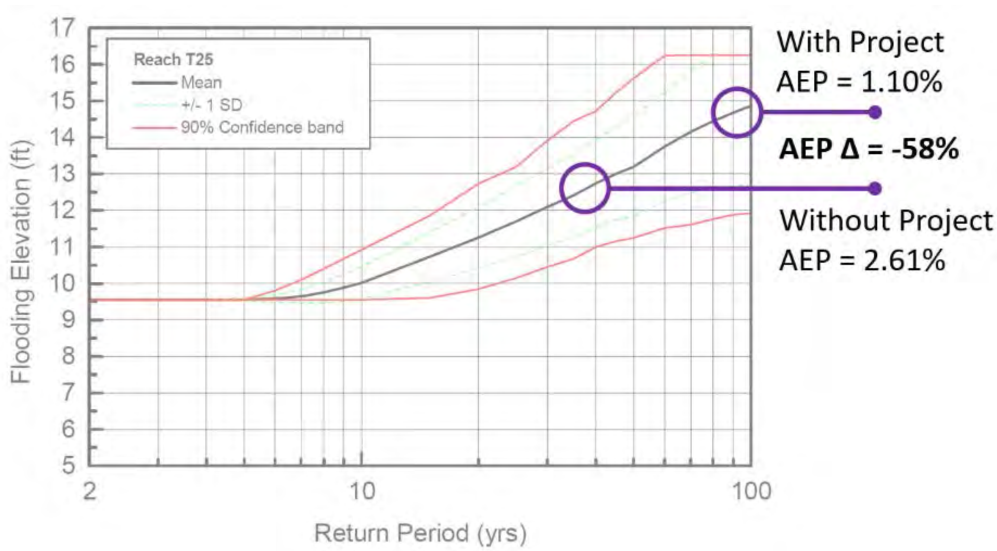

Figure 11 – Estimating Reduction in Flooding Effects

Continuing with the example of Alternative 2A, this tabulation is repeated for all consequence categories and variables. **Table 15** illustrates the resultant estimates of reduction in adverse effects by output variable for Alternative 2A. As shown in the table, the 58% reduction is carried through in the Utilidor-Flood consequence category. To generate the weighted total for each variable, the WOPC output data from **Table 14** is used as the weights for each cell in **Table 15**. **Tables 16-23** present the estimates of reduction in adverse effects by output variable for remaining alternatives. **Table 24** presents the summary of resultant weighted scores by alternative for each variable.

Table 15 – Resilience Outputs by Variable for Alt 2A

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
Structures & Contents - Flood	-86%					
Structures & Contents - Erosion	-100%					
Land loss from erosion	-100%					
Bluff (historic village)	-100%		-100%			
Mid & South Lagoons (landfill) - Flood	-99%					-99%
Dam (water supply) - Flood	-97%	-97%		-97%		
Utilidor - Flood	**-58%**	-58%		-58%		
Utilidor - Erosion	-100%	-100%		-100%		
Stevenson St	-100%					
Berm/Erosion Emergency Maintenance	-100%				-100%	
WEIGHTED TOTAL	**-99%**	**-92%**	**-100%**	**-93%**	**-100%**	**-99%**

Table 16 – Resilience Outputs by Variable for Alt 2B

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
Structures & Contents - Flood	-86%					
Structures & Contents - Erosion	-100%					
Land loss from erosion	-100%					
Bluff (historic village)	-100%		-100%			
Mid & South Lagoons (landfill) - Flood	-99%					-99%
Dam (water supply) - Flood	-97%	-97%		-97%		
Utilidor - Flood	-58%	-58%		-58%		
Utilidor - Erosion	-100%	-100%		-100%		
Stevenson St	-100%					
Berm/Erosion Emergency Maintenance	-100%				-100%	
WEIGHTED TOTAL	-99%	-92%	-100%	-93%	-100%	-99%

Table 17 – Resilience Outputs by Variable for Alt 5A

Consequence Category	Output Variable					
	DDD	FTE	CRA	PDU	PDH	CYF
Structures & Contents - Flood	-27%					
Structures & Contents - Erosion	-50%					
Land loss from erosion	-50%					
Bluff (historic village)	0%		0%			
Mid & South Lagoons (landfill) - Flood	0%					0%
Dam (water supply) - Flood	-99%	-99%		-99%		
Utilidor - Flood	-58%	-58%		-58%		
Utilidor - Erosion	-100%	-100%		-100%		
Stevenson St	-18%					
Berm/Erosion Emergency Maintenance	-18%				-18%	
WEIGHTED TOTAL	-39%	-93%	0%	-95%	-18%	0%

Table 18 – Resilience Outputs by Variable for Alt 5B

Consequence Category	Output Variable					
	DDD	**FTE**	**CRA**	**PDU**	**PDH**	**CYF**
Structures & Contents - Flood	-53%					
Structures & Contents - Erosion	-100%					
Land loss from erosion	-100%					
Bluff (historic village)	-100%		-100%			
Mid & South Lagoons (landfill) - Flood	0%					0%
Dam (water supply) - Flood	-99%	-99%		-99%		
Utilidor - Flood	-58%	-58%		-58%		
Utilidor - Erosion	-100%	-100%		-100%		
Stevenson St	-45%					
Berm/Erosion Emergency Maintenance	-45%				-45%	
WEIGHTED TOTAL	-65%	-93%	-100%	-95%	-45%	0%

Table 19 – Resilience Outputs by Variable for Alt 5C

Consequence Category	Output Variable					
	DDD	**FTE**	**CRA**	**PDU**	**PDH**	**CYF**
Structures & Contents - Flood	-86%					
Structures & Contents - Erosion	-100%					
Land loss from erosion	-100%					
Bluff (historic village)	-100%		-100%			
Mid & South Lagoons (landfill) - Flood	0%					0%
Dam (water supply) - Flood	-99%	-99%		-99%		
Utilidor - Flood	-58%	-58%		-58%		
Utilidor - Erosion	-100%	-100%		-100%		
Stevenson St	-67%					
Berm/Erosion Emergency Maintenance	-67%				-67%	
WEIGHTED TOTAL	-77%	-93%	-100%	-95%	-67%	0%

Table 20 – Resilience Outputs by Variable for Alt 5D

Consequence Category	Output Variable					
	DDD	**FTE**	**CRA**	**PDU**	**PDH**	**CYF**
Structures & Contents - Flood	-86%					
Structures & Contents - Erosion	-100%					
Land loss from erosion	-100%					
Bluff (historic village)	-100%		-100%			
Mid & South Lagoons (landfill) - Flood	-92%					-92%
Dam (water supply) - Flood	-99%	-99%		-99%		
Utilidor - Flood	-58%	-58%		-58%		
Utilidor - Erosion	-100%	-100%		-100%		
Stevenson St	-100%					
Berm/Erosion Emergency Maintenance	-100%				-100%	
WEIGHTED TOTAL	-99%	-93%	-100%	-95%	-100%	-92%

Table 21 – Resilience Outputs by Variable for Alt 6A

Consequence Category	**Output Variable**					
	DDD	**FTE**	**CRA**	**PDU**	**PDH**	**CYF**
Structures & Contents - Flood	-86%					
Structures & Contents - Erosion	-100%					
Land loss from erosion	-100%					
Bluff (historic village)	-100%		-100%			
Mid & South Lagoons (landfill) - Flood	-99%					-99%
Dam (water supply) - Flood	-99%	-99%		-99%		
Utilidor - Flood	-58%	-58%		-58%		
Utilidor - Erosion	-100%	-100%		-100%		
Stevenson St	-100%					
Berm/Erosion Emergency Maintenance	-100%				-100%	
WEIGHTED TOTAL	-99%	-93%	-100%	-95%	-100%	-99%

Table 22 – Resilience Outputs by Variable for Alt 6B

Consequence Category	**Output Variable**					
	DDD	**FTE**	**CRA**	**PDU**	**PDH**	**CYF**
Structures & Contents - Flood	-86%					
Structures & Contents - Erosion	-100%					
Land loss from erosion	-100%					
Bluff (historic village)	-100%		-100%			
Mid & South Lagoons (landfill) - Flood	-92%					-92%
Dam (water supply) - Flood	-99%	-99%		-99%		
Utilidor - Flood	-58%	-58%		-58%		
Utilidor - Erosion	-100%	-100%		-100%		
Stevenson St	-100%					
Berm/Erosion Emergency Maintenance	-100%				-100%	
WEIGHTED TOTAL	-99%	-93%	-100%	-95%	-100%	-92%

Table 23 – Resilience Outputs by Variable for Alt 6C

Consequence Category	**Output Variable**					
	DDD	**FTE**	**CRA**	**PDU**	**PDH**	**CYF**
Structures & Contents - Flood	-83%					
Structures & Contents - Erosion	-100%					
Land loss from erosion	-100%					
Bluff (historic village)	-100%		-100%			
Mid & South Lagoons (landfill) - Flood	-92%					-92%
Dam (water supply) - Flood	-99%	-99%		-99%		
Utilidor - Flood	-56%	-56%		-56%		
Utilidor - Erosion	-100%	-100%		-100%		
Stevenson St	-100%					
Berm/Erosion Emergency Maintenance	-100%				-100%	
WEIGHTED TOTAL	**-99%**	**-92%**	**-100%**	**-94%**	**-100%**	**-92%**

Table 24 – Resilience Outputs by Alternative

Alt	DDD % Δ	FTE % Δ	CRA % Δ	PDU % Δ	PDH % Δ	CYF % Δ
1	0%	0%	0%	0%	0%	0%
2a	99%	92%	100%	93%	100%	99%
2b	99%	92%	100%	93%	100%	99%
5a	39%	93%	0%	95%	18%	0%
5b	65%	93%	100%	95%	45%	0%
5c	77%	93%	100%	95%	67%	0%
5d	99%	93%	100%	95%	100%	92%
6a	99%	93%	100%	95%	100%	99%
6b	99%	93%	100%	95%	100%	92%
6c	99%	92%	100%	94%	100%	92%

All values are percent reduction in adverse effect expected under without project conditions.

The outputs shown in **Table 24** are the total weighted outputs for each of the six variables. These outputs may also be summarized using the triple bottom line approach of economic, social/cultural, and environmental resilience areas. In deriving the total score for each area, all variables were assumed to have equal weight and equal the average of the percent reductions in adverse effects shown in **Table 24** for the variables applicable to the resilience area. The economic resilience area reflects the DDD and FTE variables. The social/cultural resilience area includes the CRA, PDU, and PDH variables. The environmental resilience area includes only the CYF variable. **Table 25** shows the resulting estimate of resilience output by alternative for each resilience area. **Figure 12** demonstrates the tradeoffs across the resilience areas and across the alternatives.

Table 25 – Resilience Outputs for the Triple Bottom Line

Alt	Community Resilience Scores		
	Economic	**Social/Cultural**	**Environmental**
1	0%	0%	0%
2a	95%	98%	99%
2b	95%	98%	99%
5a	66%	38%	0%
5b	79%	80%	0%
5c	85%	87%	0%
5d	96%	98%	92%
6a	96%	98%	99%
6b	96%	98%	92%
6c	95%	98%	92%

All values are percent reduction in adverse effect expected under without project conditions.

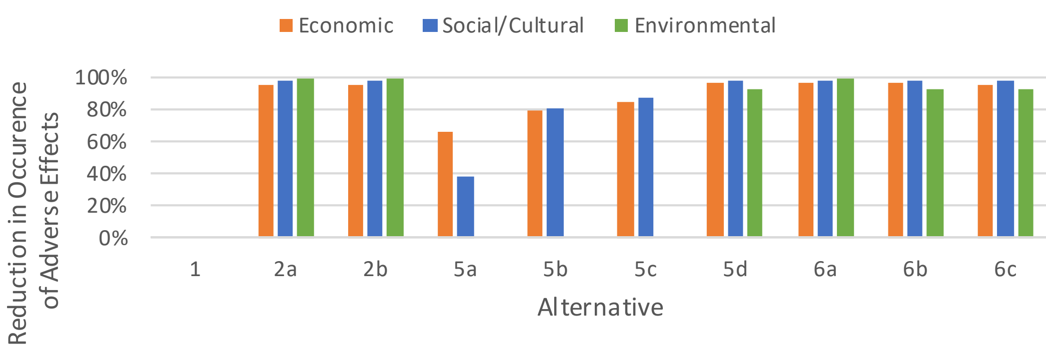

Figure 12 – Triple Bottom Line Alternative Performance

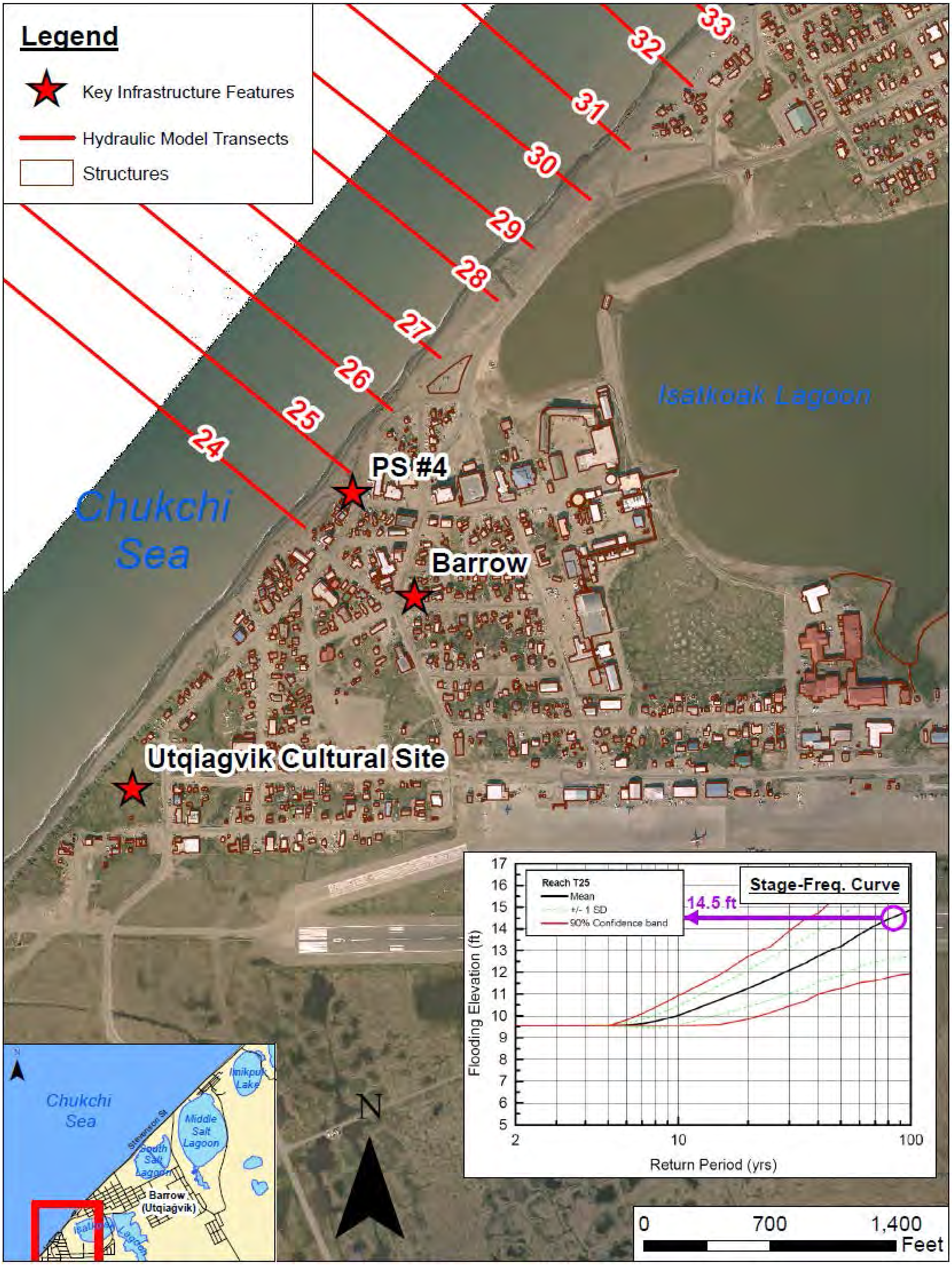

Figure 13 – Barrow Flood Analysis

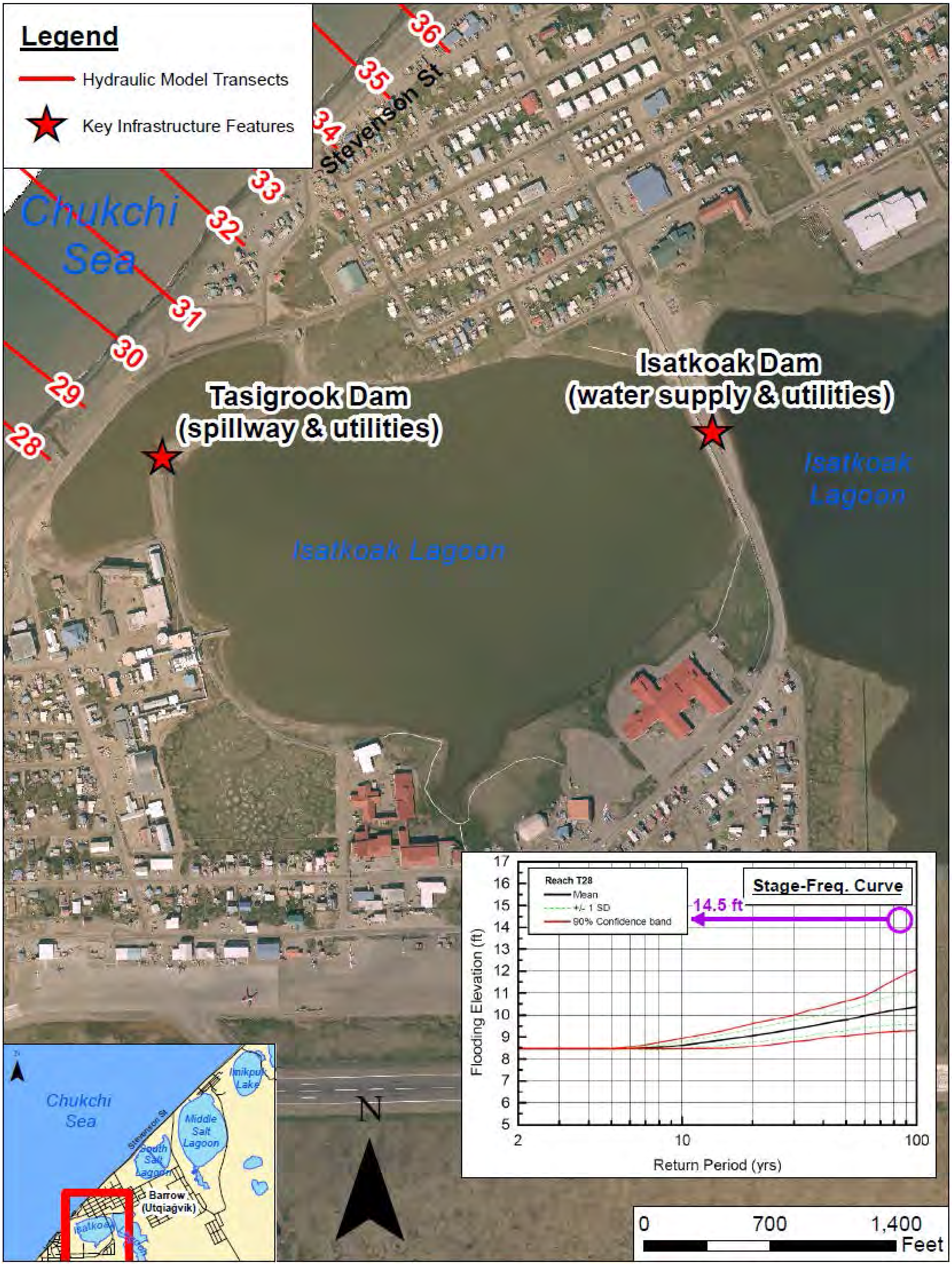

Figure 14 – Lagoon Flood Analysis

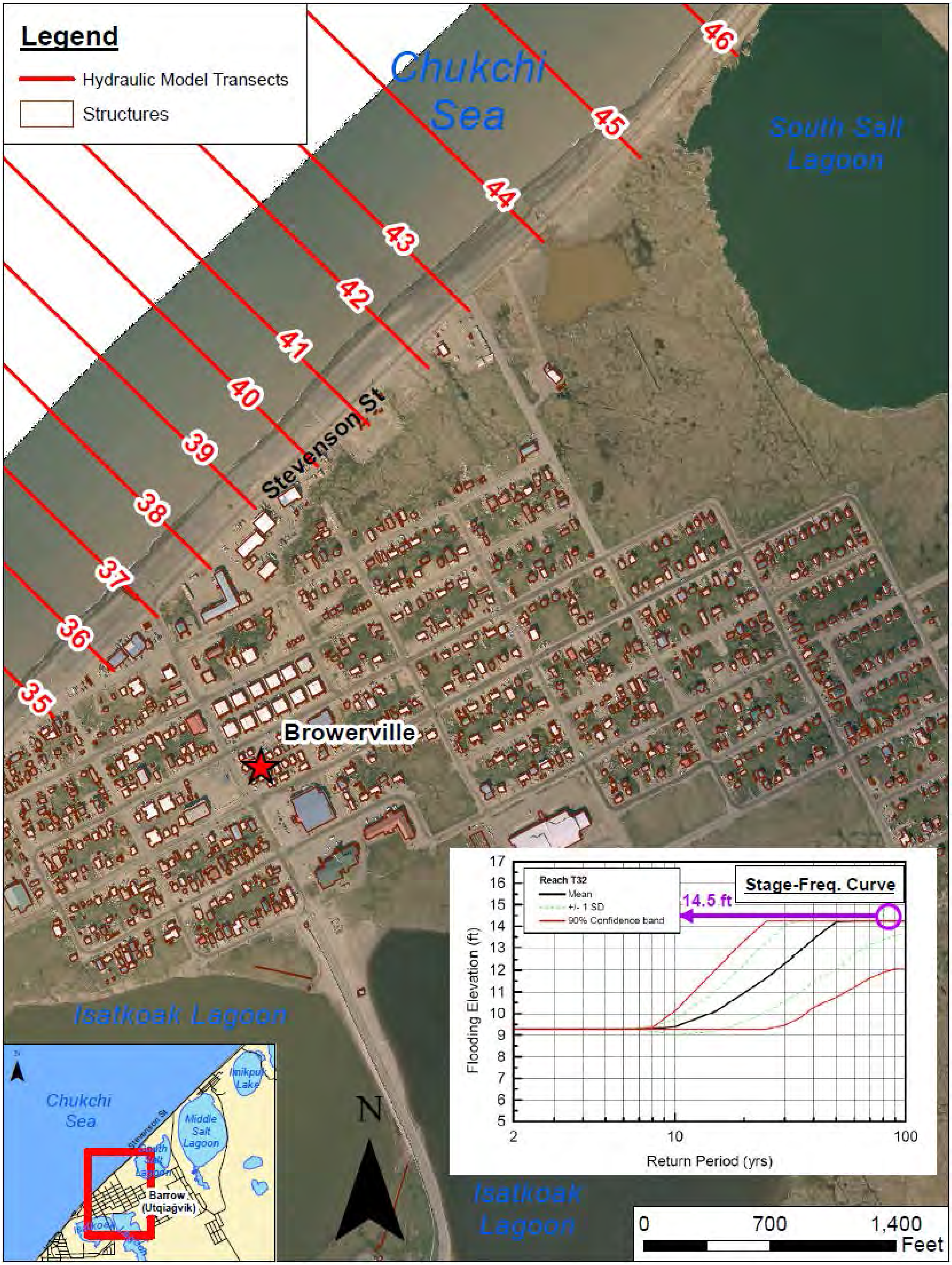

Figure 15 – Browerville Flood Analysis

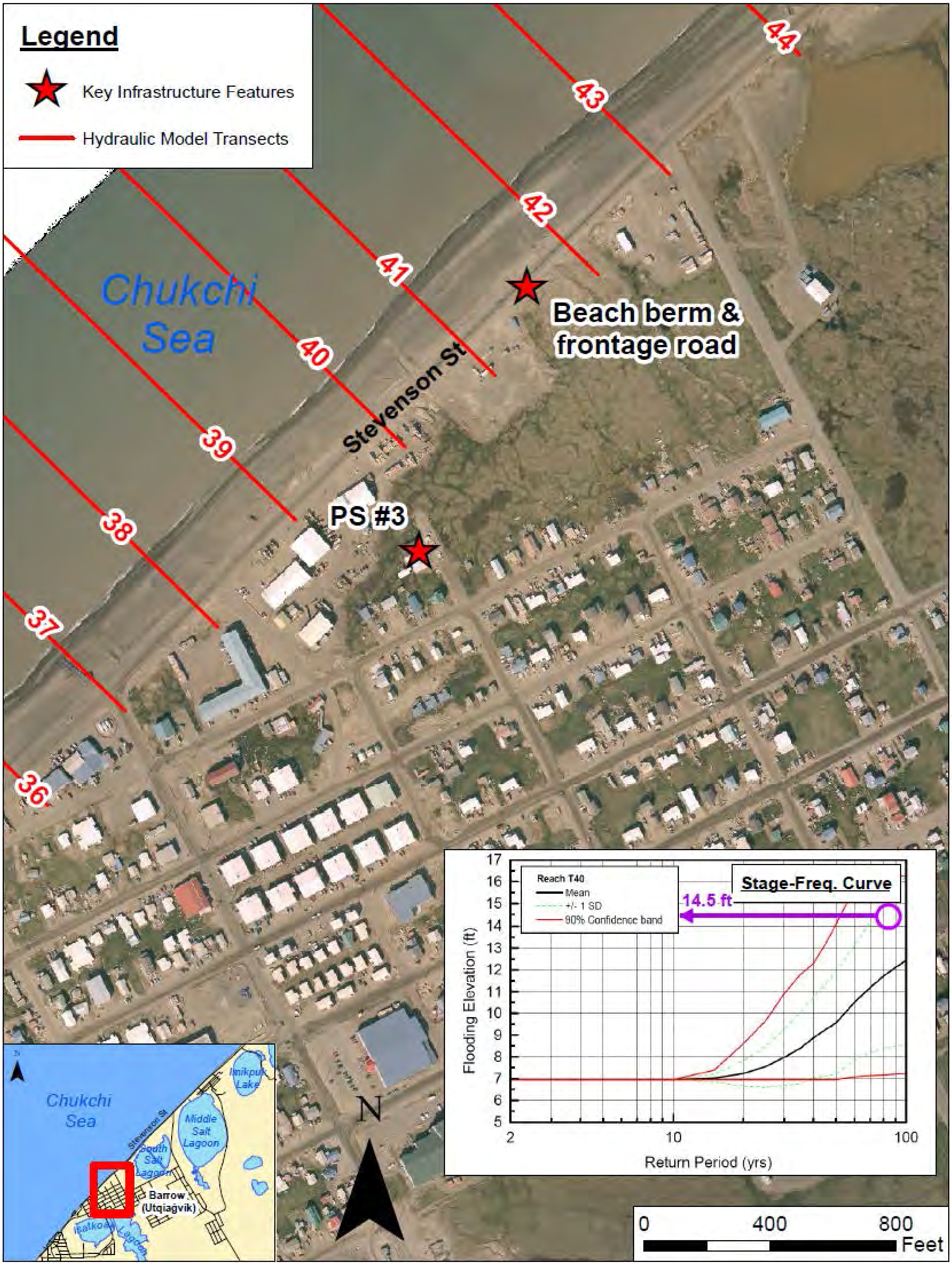

Figure 16 – PS #3 Flood Analysis

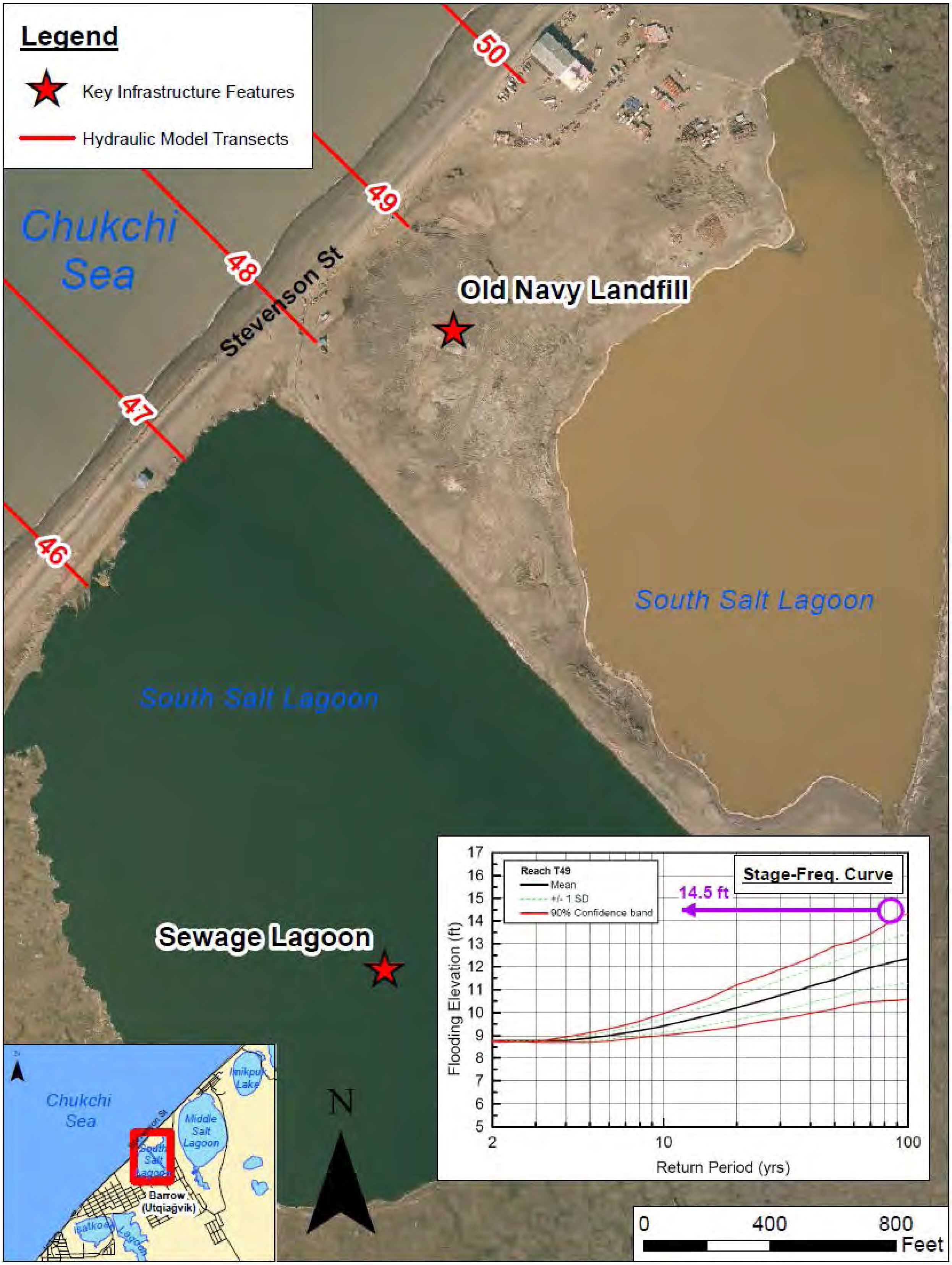

Figure 17 – South & Middle Salt Flood Analysis

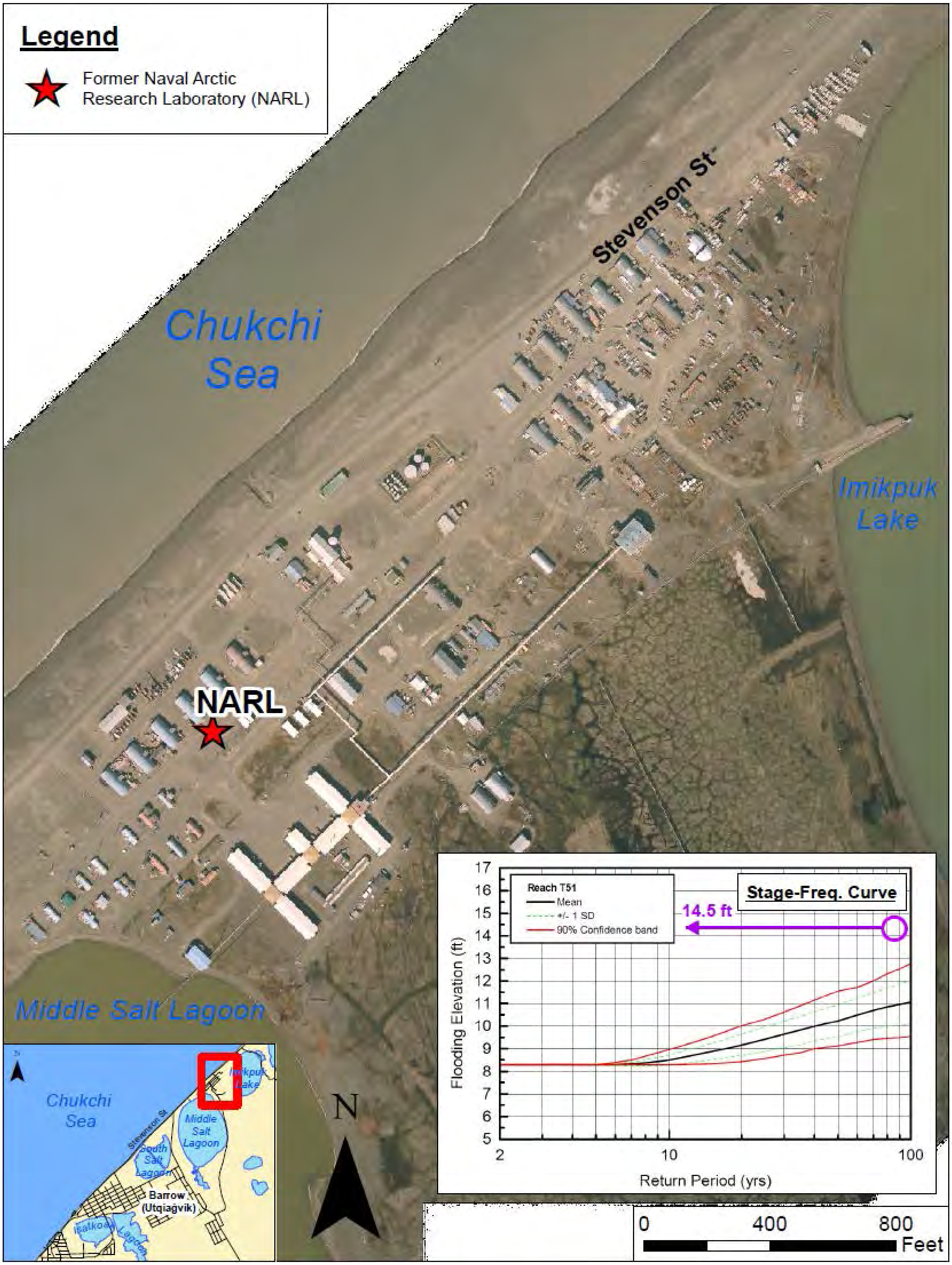

Figure 18 – NARL Flood Analysis

***STEP 3** – Compute CRU's for each alternative based on the percent reduction in adverse effects (increase in resilience) estimated for each alternative*

Equally weighting each of the three resilience areas, Community Resilience Units (CRU's) for each alternative were calculated by summing the percent reductions (in decimal form) across the three resilience areas. To improve readability, a scale factor of 1000 is used, which results in total CRU's having a maximum value of 3000, which would equate to an alternative that reduced 100% of risk in all three resilience areas [(1+1+1)*1000]. Because the percent reductions used in previous steps were relative to the No Action, the estimated total CRU's are inherently net of the No Action alternative. The total CRU's may also be averaged over the period of analysis to show average annual CRU's. **Table 26** shows the estimated total CRU's and average annual CRU's for each alternative.

Table 26 – CRU's by Alternative

Alt	CRU's	Average Annual CRU's
1	0	0.00
2a	2,925	58.50
2b	2,925	58.50
5a	1,038	20.77
5b	1,588	31.77
5c	1,720	34.41
5d	2,862	57.24
6a	2,935	58.71
6b	2,862	57.24
6c	2,856	57.12

***STEP 4** – Assemble CE/ICA Input Data*

The CE/ICA requires as inputs average annualized cost and annual output by alternative. In review of the preliminary design, costs, and outputs, the PDT determined that alternatives 2A and 2B were very similar in structure, cost, and performance. As shown in **Table 26**, alternatives 2A and 2B have the same output. Similarly, in **Table 11**, the cost of these alternatives is also close, differing by less than a percent at this phase of design. The difference between these alternatives is the choice between a revetted berm seaward of Stevenson Street, or instead raising and revetting Stevenson Street itself. Given the current level of design and expected costs and benefits, the PDT judged these two alternatives to be interchangeable at this stage. The PDT determined that optimization of the mix between a seaward berm and raising the road could be investigated during the PED phase. For the purpose of the CE/ICA and discussion of the alternatives going forward, alternatives 2A and 2B have been combined and are referred to simply as Alternative 2. To present a conservative analysis, the cost for Alternative 2 was taken from the estimate for 2A, which was slightly higher than 2B. **Table 27** presents the input data to the CE/ICA. This approach to the discussion of Alternative 2 is consistent with the presentation of alternatives in the main report.

Table 27 – CE/ICA Input Data

Alt	Annualized Cost ($)	Average Annual CRU's
1	$0	0.00
2	$8,525,000	58.50
5a	$3,735,907	20.77
5b	$6,126,326	31.77
5c	$7,933,910	34.41
5d	$11,447,717	57.24
6a	$11,752,728	58.71
6b	$16,502,993	57.24
6c	$21,728,330	57.12

STEP 5 – *Perform CE/ICA in IWR Planning Suite*

The CE/ICA was performed using IWR Planning Suite for consistency with standard practices. Annualized cost (**Table 11**) and average annual CRU's (**Table 26**) were entered for each alternative and the CE/ICA was run. Based upon current costs and outputs, alternatives 1, 2, and 6A were identified as Best Buy plans, alternatives 5A, 5B, and 5C were identified as cost-effective plans, and alternatives 5D, 6B, and 6C were not cost effective.

Figure 19 presents a scatter plot of all the alternatives, differentiated. **Table 27** presents the incremental cost calculations for the best buy plans 1, 2, and 6A. Finally, **Figure 20** presents the incremental cost box plot.

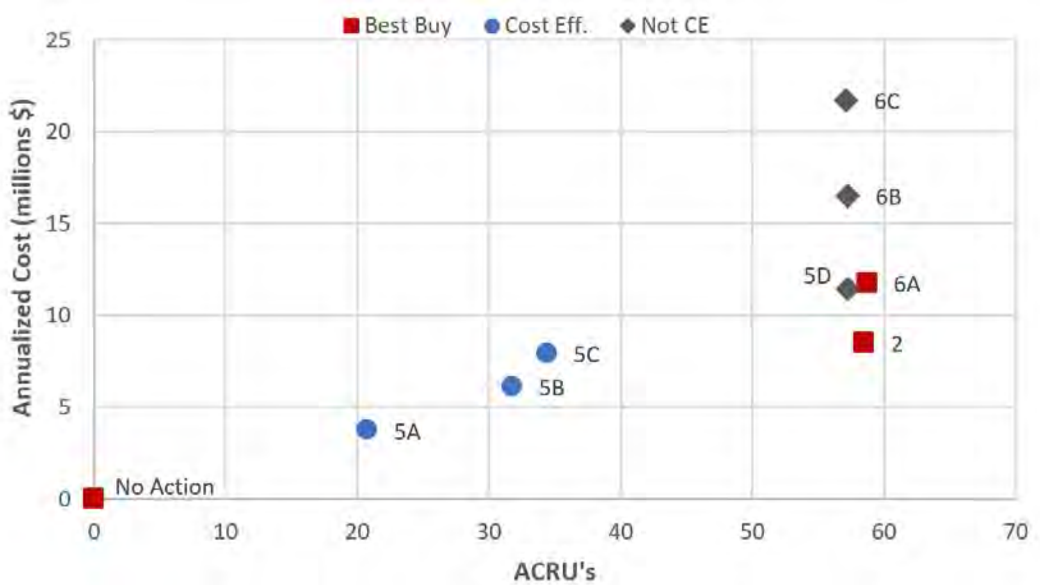

Figure 19 – All Plans Differentiated

Table 28 – Incremental Cost Summary

Best Buy #	Alternative	Average Annual Cost ($)	Annual CRU's	Incremental Cost	Incremental Output	Incremental Cost per Unit Output
1	**1**	$0	0.00	$0	0.00	$0
2	**2**	$8,525,000	58.50	$8,525,000	58.50	$145,719
3	**6a**	$11,752,728	58.71	$3,227,728	0.20	$15,807,609

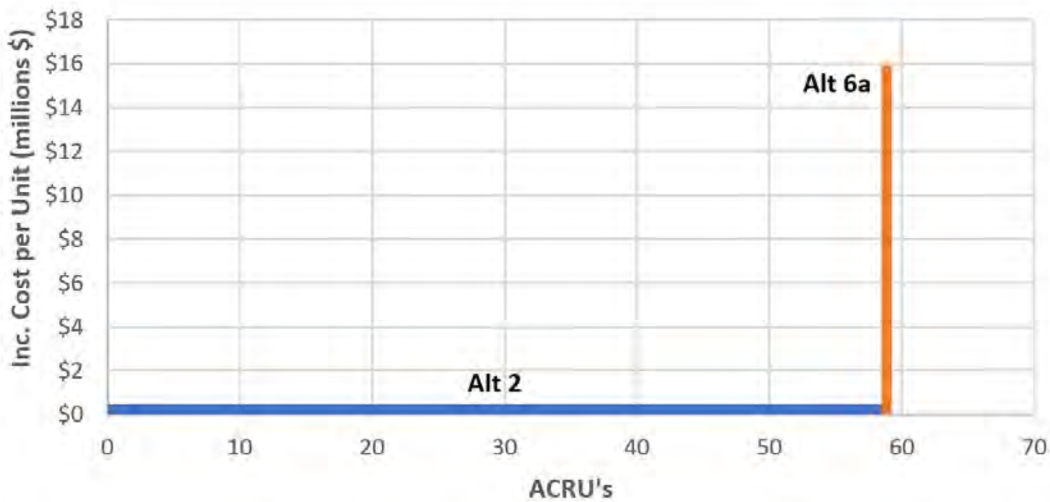

Figure 20 – Incremental Cost Box Chart

Section 116 implementation guidance requires a tradeoff analysis across the four plan evaluation accounts of National Economic Development (NED), Regional Economic Development (RED), Other Social Effects (OSE), and Environmental Quality (EQ). The alternatives in this study were formulated to address all the objectives which address reduction of adverse impacts across all accounts and therefore do not have give-and-take tradeoffs across alternatives. The alternatives do however offer varying levels of reduction of adverse impacts across alternatives as described in this appendix. Splitting the economic resilience category into its two component variables (Direct Dollar Damages (DDD) to reflect NED effects; and Full Time Equivalent Employment and Income Effects (FTE) to reflect RED effects) allows comparison of effects across variables that reflect all four accounts. **Figure 21** presents the same data as shown in **Figure 18** organized in this manner to show the tradeoffs across alternatives in terms of reduction in adverse effects across each account.

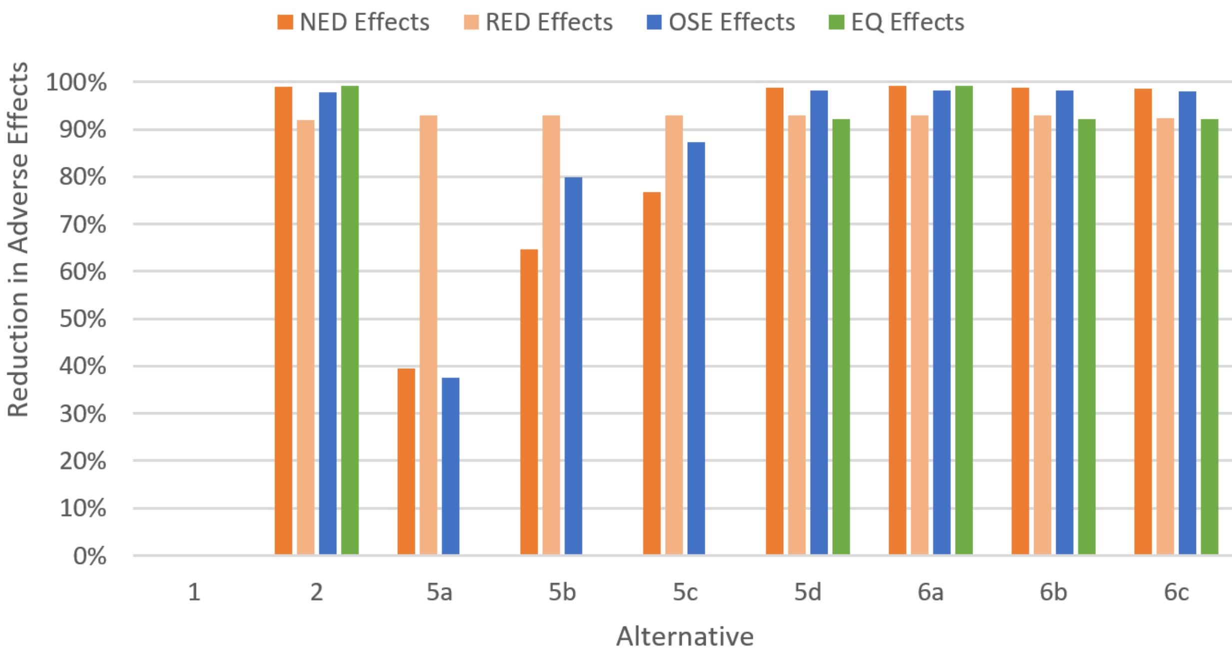

Figure 21 – Tradeoffs of Effects by Plan Evaluation Account

12.0 IDENTIFYING THE TENTATIVELY SELECTED PLAN

PDT review of the CE/ICA outputs found the results to be generally consistent with expectations based upon design of the final array of alternatives. The alternatives which were not cost effective (5D, 6B, and 6C) share the inclusion of substantial areas of beach nourishment. The cost to source and transport material for nourishment to a remote location such as Barrow is a significant cost driver. Nourishment was also identified as the driver of the higher cost for the most expensive best buy, alternative 6A, which includes nourishment at Tasigrook Lagoon. Alternatives 5A, 5B, and 5C were cost effective but not best buys. They also did not provide protection of the South and Middle Salt lagoon reach.

Alternative 2 has been identified by the PDT as the Tentatively Selected Plan (TSP). Alternative 2 would provide protection for the lineal extent of the study area and address all three components of the community resilience triple bottom line by addressing short and long term coastal erosion and coastal storm flood risk.

Alternative 2 will include erosion protection for the bluffs in front of Barrow starting in front of Wiley-Post Will Rogers airport and heading north until the bluffs start to decrease in height from +19ft MLLW to +15 ft MLLW. A +14.5 ft MLLW berm will tie into the rock revetment and follow the shoreline north to where Tahak Street intersects Stevenson Street. Stevenson Street will be raised to a height of +14.5ft MLLW with the seaward side revetted starting at this intersection and heading north to Dewline Road, just past NARL. Beach access points within the project area will be established during the PED phase and will account for spring break-up, drainage, and public access. Design of the beach access points will be based on community feedback and modeling. Reaches within this alternative will be further refined during PED.

The Section 116 authority affords the Corps an opportunity to develop and implement a project which both embraces the community resilience paradigm and is consistent with the planning principles and procedures which govern Civil Works investigations. In the discussion of a resilience framework, the Corps highlights the importance of resilience at the local level, contributing to greater community resilience. The way that the Corps can contribute to community resilience in Barrow is through delivery of a resilient coastal storm protection project. The TSP presents a robust Corps coastal protection project would be resilient at the project level to flooding and erosion forces, in turn improving resilience of economic, social/cultural, and environmental systems at the community level.

Recurring recent federal disaster declarations in 2015 and 2017 highlight the need for improved resilience for the Barrow community. In the October 2015 storm, Barrow suffered damage during a relatively moderate fall storm. FEMA declared a disaster for the Borough and committed to provide disaster assistance "for emergency work and the repair or replacement of disaster-damaged facilities" in Barrow. Total costs associated with the 2015 storm reached over $7.2 million. Another 1-2 feet of storm surge would have flooded Barrow's Utilidor, disrupting water and sewer service for the entire city of Barrow. With an additional 18 inches of storm surge, sea water would have breached Barrow's fresh water lagoon, and the entire community would have been left without potable water. The September 2017 storm resulted in over $10 million in damages. This included flooding to approximately elevation +10 feet, MLLW, and borough man-power and equipment were mobilized to protect the community and critical infrastructure such as Pump Station 4 and sections of the Utilidor. Large sections of the bluff were eroded and collapsed from wave erosion, threatening the adjacent buildings. Many sections of the near-shoreline road system required immediate maintenance to provide emergency vehicle egress and access for the community. Large sections of Stevenson Street were closed. See Section 3.8 in the 2008 Economics Appendix enclosed as Attachment A for documentation of other previous coastal storm damages in Barrow. The TSP identified in this current study would have precluded these previous damages.

Regarding the assessment of resilience over time as presented in **Figure 5**, the TSP would move Barrow from a state of High Risk with Low Resilience to one of much Lower Risk with Much Greater Resilience. Regarding the four resilience principles presented in **Figure 7**, implementation of the plan would drastically improve the community's capacity to absorb expected coastal storms and greatly decrease the community's and nation's recovery time and costs after storms hit. The PDT and the NSB judge the reductions in risk and associated increase in community resilience and the significance of effects of the TSP to be worth the plan's implementation, operation, and maintenance costs.

The TSP would provide benefits across all four accounts. The plan would achieve NED benefits by the reduced risk of direct dollar damages to private and public property and infrastructure in the study area. RED benefits would be achieved by the reduced risk of business disruption and adverse employment and income effects that would occur following a major coastal storm and erosion damaging event. The plan would achieve OSE benefits by the reduction in risk to human health and safety, both within Barrow and within other borough communities reliant upon Barrow's regional services. The plan would also support protection of cultural resources and improve the long-term viability of the Barrow community in its historical location, supporting the preservation of Barrow's unique sense of place. Taken together, the TSP would provide benefits across the four accounts, and would achieve significant increase in community resilience at Barrow by adapting to a changing coastal storm regime and better positioning the community to absorb the impacts of storm events. Table 28 provides a summary of the significance of the contributions of the TSP towards community resilience to erosion and flooding risk for Barrow and the surrounding communities in the region which are dependent on Barrow.

Table 29 – Significance of TSP Effects

Technical Significance

Coastal Storm Damage Reduction

Existing technical studies and resulting information have demonstrated that under without project conditions, coastal storm driven flood risk is expected to result in adverse consequences for the community of Barrow. Such consequences can be categorized as Economic, Social/Cultural, and Environmental risks.

<u>Without Project Economic Coastal Storm Risks include:</u>

Direct Damages

- $51K DDD to structures and contents
- $107K DDD for recovery costs associated with landfill and sewage lagoon breaches
- $182K DDD for utility and water supply impacts for Isatkoak Lagoon
- $146 DDD in flood damages to Utilidor based on current Pump Station #4 elevation
- $145K DDD for flood damage to Stevenson Street
- $785K DDD for annual flood fighting costs

Adverse Employment and Income Effects

- Loss of up to ~400 FTEs if community gas line were lost
- Loss of up to ~120 FTEs if utility service in Utilidor were flooded

<u>Without Project Social/Cultural Coastal Storm Risks include:</u>

Barrow population (~4,320) without water supply estimated at ~60 days until new system online if fresh water supply is breached by flooding.
Affected Barrow population (~1,270) without utilities estimated at ~40 days until normal service restoration if Utilidor is flooded.
Emergency crews at health and safety risk when actively building protective berms in the surf under storm conditions.

<u>Without Project Environmental Coastal Storm Risks include:</u>

Contaminated site (old U.S. Navy Landfill) and active sewage lagoons at risk of release of materials into environment under flooding conditions.

<u>With Project Effects of the TSP significantly reduce all identified adverse economic, social/cultural, and environmental consequences of flooding:</u>

- Reduces initiation of flooding of structures/contents changes from current (~10-yr event) to over ~80-yr event
- Effectively eliminates risk of flooding and breach of Sewage Lagoon and Old Navy Landfill
- Increases level of protection for flooding damage to Utilidor from current (~40-yr event) to over the ~90-yr event
- Effectively eliminates risk of loss of Stevenson Street under with project conditions
- Effectively precludes the need for active flood fighting and emergency berm maintenance

Based on these technical findings, the TSP is expected to result in a significant increase in the resilience of economic, social, and environmental systems of Barrow to coastal storms.

Technical Significance	***Erosion Risk Reduction*** Existing technical studies and resulting information have demonstrated that under without project conditions, coastal erosion risk is expected to result in adverse consequences for the community of Barrow. Such consequences can be categorized as Economic and Social/Cultural risks. <u>Without Project Economic Erosion Risks include:</u> Direct Damages o $349 DDD to structures o $18K DDD for land expected to be lost (7.5 acres) to erosion in Barrow neighborhood o $14K DDD for cultural resources recovery actions expected to be required due to loss of original village site parcels o $166K DDD in erosion damages to Utilidor Pump Station #4 Adverse Employment and Income Effects o Loss of up to ~240 FTEs if utility service in Utilidor was lost due to erosion of Pump Station #4 Potential NSB Facility Relocations o NSB has identified the likely future need for relocation of Publics Works facilities on Stevenson Street at an estimated cost of up to ~$90M (NSB estimate). <u>Without Project Social/Cultural Erosion Risks include:</u> Significant erosion expected to original village site and associated cultural resources (5-acre site that was original village and contains priceless cultural resources). Affected population (~1,270) without utilities after damage to Utilidor estimated at duration of ~80 days until normal service restoration. <u>With Project Effects of the TSP significantly reduce adverse economic and social/cultural consequences from erosion:</u> • Project effectively eliminates erosion advancement over the period of analysis. Based on these technical findings, the TSP is expected to result in a significant increase in the resilience of economic and social/cultural systems of Barrow to coastal erosion.
Public Significance	The community of Barrow and the government of the North Slope Borough have expressed their public support for implementation of a project to provide relief from the continued risk of flooding and erosion damages to their community. Local government representatives have participated in the planning process and development of flood risk reduction measures included in the TSP. Further, the NSB has stressed the unique dependence of other, even more remote, North Slope communities that depend on fully functioning services in Barrow for providing lifeline services and supplies to their communities. Implementation of the TSP would not only improve the community resilience of Barrow to coastal storms but also those other remote communities which depend on Barrow for their livelihood, public health, and safety.
Institutional Significance	Institutional recognition of an effect means its importance is recognized and acknowledged in the laws, plans and policies of government, public agencies and private groups. The TSP-produced project outputs are consistent with codified Corps mission areas of coastal storm risk management including erosion risk management. Evaluation methods are consistent with procedures as identified in Corps Engineering Regulation ER 1105-2-100 Planning Guidance. Additional plan evaluation procedures have been applied as authorized in Section 116 of the Energy and Water Development and Related Agencies Appropriations Act of 2010 (Public Law 111-85) and associated Corps implementation guidance. Resilience principles incorporated into evaluation methodology are consistent with current Corps publications on resilience in civil works projects.

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ATTACHMENT 1 – 2008 ECONOMICS APPENDIX

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Barrow Alaska Coastal Erosion Feasibility Study

Appendix F: Hydraulics and Hydrology

Barrow, Alaska

August 29, 2018

US Army Corps of Engineers
Alaska District

HYDRAULICS AND HYDROLOGY APPENDIX

1.0. INTRODUCTION

This hydraulic design appendix describes the technical aspects of the Barrow Alaska Coastal Erosion Feasibility Study (Feasibility 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 coastal storm risk management 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.

This report is an update to the previous 2010 Barrow, Alaska Coastal Storm Damage Reduction Technical Report that investigated the Federal interest in a design to reduce damage from flooding and coastal erosion in an environmentally and economically sound manner. No National Economic Development (NED) or locally preferred plan was identified in that study.

1.1. Project Purpose

The authorized project purpose is coastal storm risk management. The purpose of the study is to determine whether there is a Federal interest in developing a solution to the flooding and erosion problems being experienced at Barrow.

This Feasibility Study is intended to identify a safe and functional method of coastal storm damage protection with the following objectives:

- Reduce risk to public health, life, and safety
- Reduce damaged caused by flooding and shoreline erosion to residential and commercial structures and critical public infrastructure
- Reduce or mitigate damage to tangible cultural heritage

1.2. Description of Project Area

Barrow, the northernmost community in the United States, is located on the Chukchi Sea coast. It is located 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 and Tasigarook Lagoon separates the community of Barrow from the community of Browerville which are collectively called Barrow. Further 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.

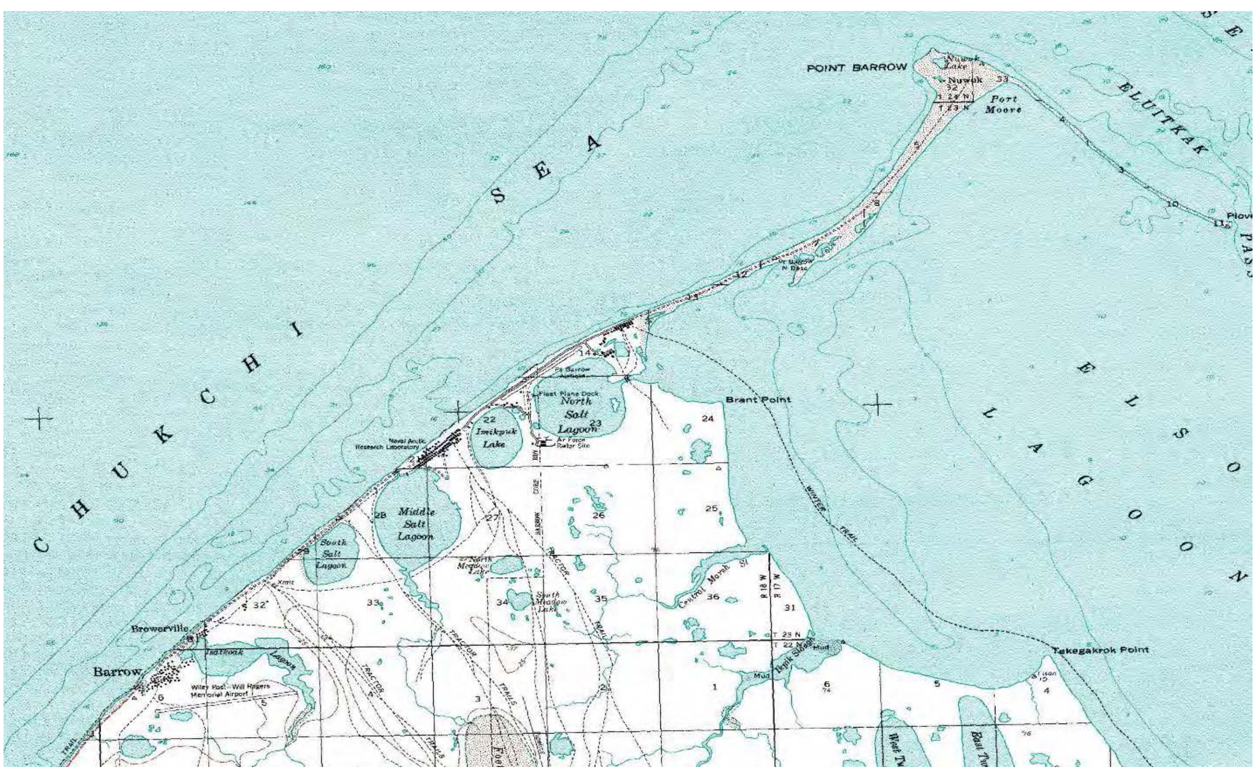

Figure 2. Barrow and Surrounding Area.

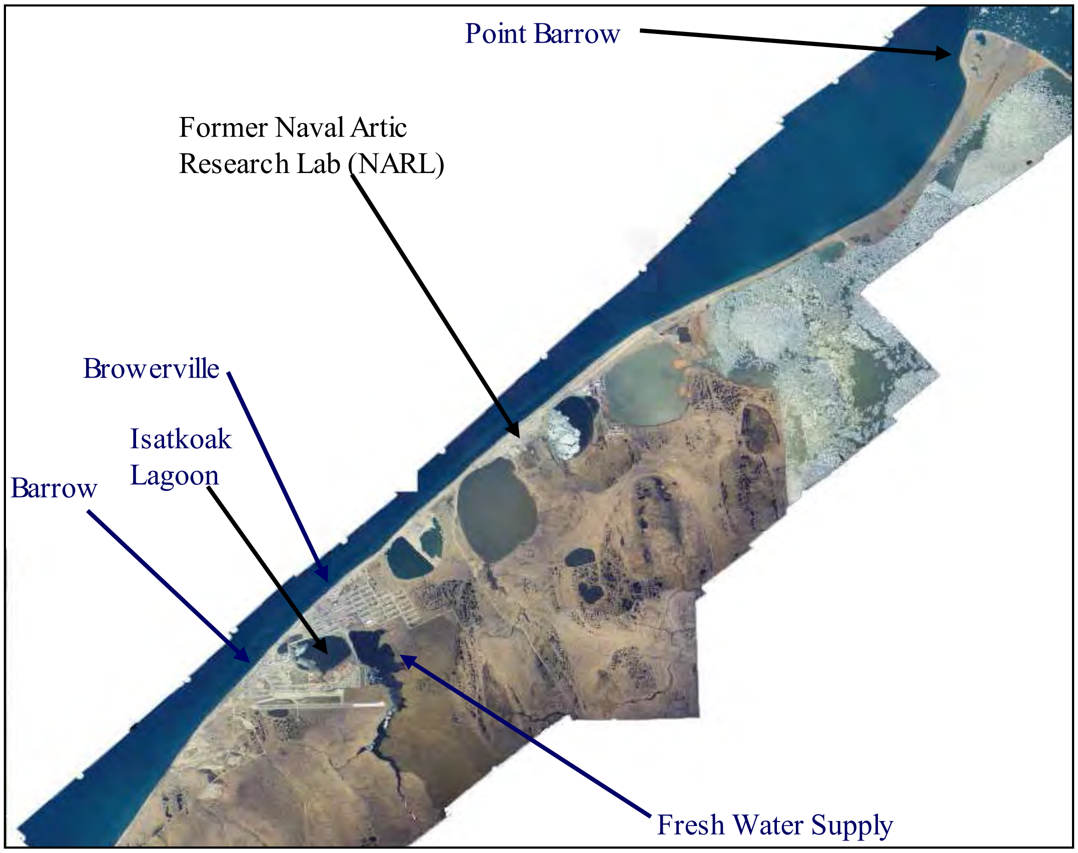

Figure 3. Barrow and Local Features.

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 Tasigarook Lagoon (Figure 5). North of this, the back edge of the beach rises to an elevation of approximately 8 feet, where it grades into 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.

Figure 6. Beach and Level Tundra North of the Community of Browerville.

The beach fronting Barrow and extending out to Point Barrow is comprised 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. Figure 7 shows an example of the beach sediment. 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 situated on a coastline that runs in a northeast and southwest direction. 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 to 12). Figure 13 shows more recent flooding due to a storm event in 2002.

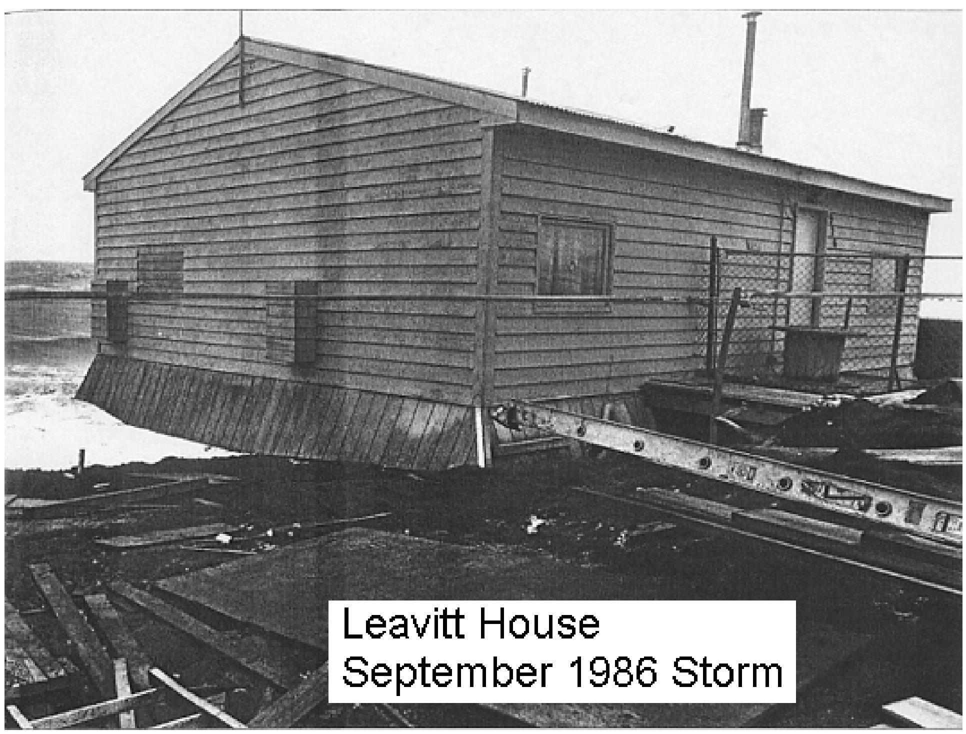

Figure 8. Undermining of Structure From Erosion.

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

Figure 9. Massive Bluff Failure Located Near the Site of a 16th Century House Mound During the 1985 Storm Exposed a Man's Foot. 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 NSB has made numerous attempts to curb the erosion and flooding that impacts the coastline 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.

Figure 16. Sacrificial Berms Placed Along Road.

Figure 17. Remains of Beach Nourishment After Storm. The Dredge 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 0n Beach at an Angle.

Figure 21. Geotextile Tube Protection.

In the summer of 2004, the community installed a seawall type structure using geotextile fabric encased in a wire basket (Figure 22). Since the initial installation of the HESCO baskets, some have experienced damage from cutting and material loss. At three other locations in Alaska, they have failed.

Figure 22. HESCO Baskets.

FEMA and the community plan on installing more supersacks to provide temporary protection after the September 2017 storm.

2.0. STUDY CONSTRAINTS

During the Feasibility Study, a number of study constraints were identified, including:

- Any in water work will need to be coordinated to not interfere with subsistence hunting of marine mammals.
- Work in the beach area is governed by ice formation.
- The coast is the site of numerous archaeological sites.
- Gravel sized material that is locally available for construction is limited.
- 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 4.5 inches. The average annual snowfall is 34 inches. Temperature extremes range from -55 to 79 degrees Fahrenheit, with average summer temperatures ranging around 38 degrees Fahrenheit (Figure 23). The daily minimum temperature is below freezing 300 days of the year. Prevailing winds are easterly and average 12 mph. The Chukchi Sea is typically ice-free from mid-June through October.

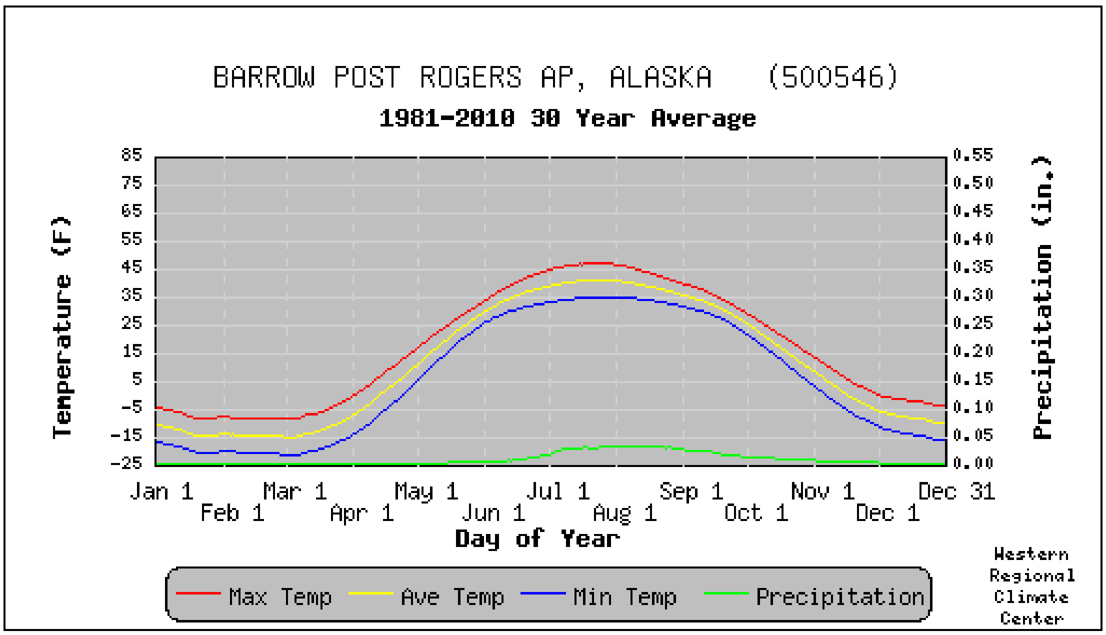

Figure 23. Temperature and Precipitation at Barrow.

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 nearshore 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.

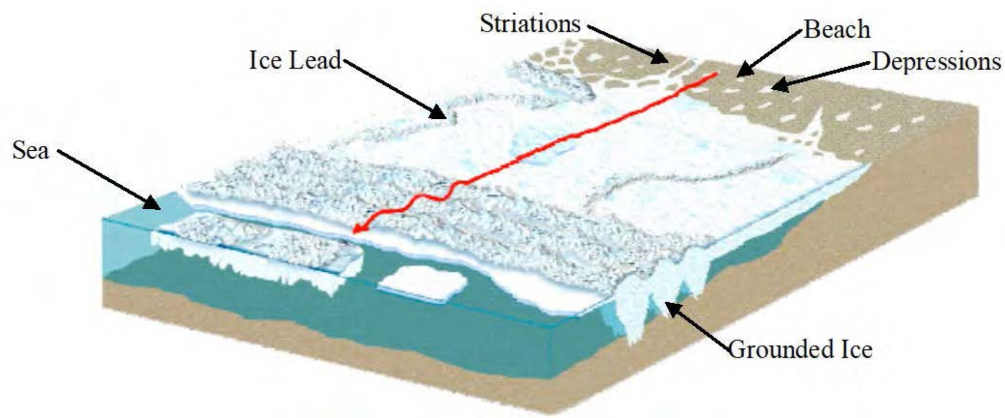

Figure 24. Illustration of Nearshore Ice Processes.

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 very 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 event 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 which was frozen to its base when in shallow water or washed or blown onto its surface. After melting, and ice-push, a mound is left 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-m) 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) in Hanover, New Hampshire, described in Section 8.4.5.

Figure 30. Location of Ice Measurements.

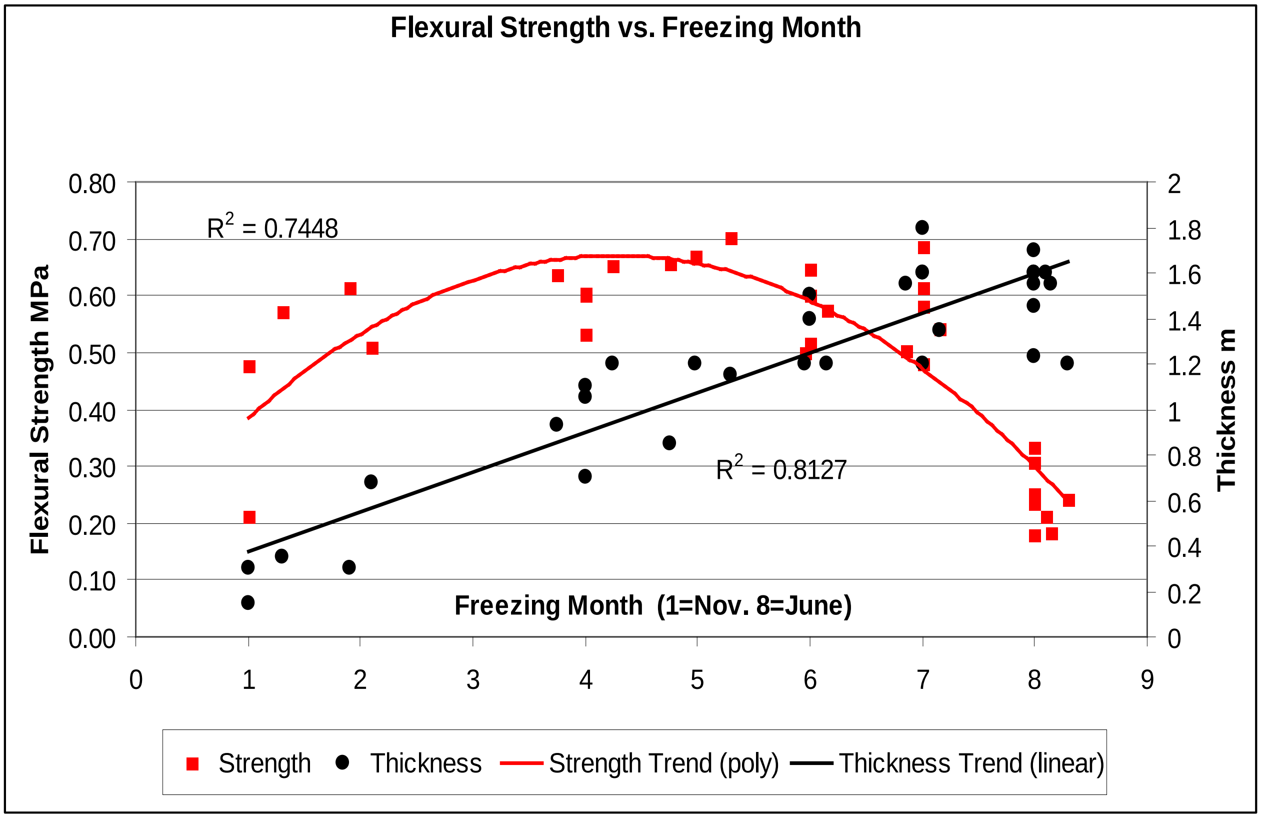

Figure 31. Summary of Ice Measurements.

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 NOAA Tidal Benchmarks at Barrow Offshore. The tidal datum was determined over a 1 year period from September 2008 to August 2009. There is a highest observed water level recorded on December 14, 2008 of 2.92ft and a lowest observed water level recorded on January 29, 2010 of -2.57ft.

Table 1. Tidal Parameters-Point Barrow.

Parameter	Elevation (ft)
Mean Higher High Water (MHHW)	0.66
Mean Sea Level (MSL)	0.31
Mean Lower Low Water (MLLW)	0.00

3.4. Sea Level Rise

Evidence suggests that the arctic environment is experiencing a warming trend. The magnitude, duration, and effect of a warming trend is not known; however a shrinking polar ice pack could result in an extended open water season and an increase in frequency of the large storms that could impact the coastline at Barrow.

The Corps of Engineers requires that planning studies and engineering designs over the project life cycle, for both existing and proposed projects consider alternatives that are formulated and evaluated for the entire range of possible future rates of sea-level change (SLC), represented by three scenarios of "low," "intermediate," and "high" sea-level change. According to Engineering Circular (EC) 1165-2-212, *Sea-Level Change Considerations For Civil Works Programs*, the SLC "low" rate is the historic SLC. The "intermediate" and "high" rates are computed using the following:

- Estimate the "intermediate" rate of local mean sea-level change using the modified National Research Council (NRC) Curve I and the NRC equations. Add those to the local historic rate of vertical land movement.
- Estimate the "high" rate of local mean sea-level change using the modified NRC Curve III and NRC equations. Add those to the local rate of vertical land movement. This "high" rate exceeds the upper bounds of IPCC estimates from both 2001 and 2007 to accommodate potential rapid loss of ice from Antarctica and Greenland.

NRC Equations

The 1987 NRC described these three scenarios using the following 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 change, in meters, as a function of t. The NRC committee recommended "projections be updated approximately every decade to incorporate additional data." At the time the NRC report was prepared, the estimate of global mean sea-level change was approximately 1.2 mm/year. Using the current estimate of 1.7 mm/year for GMSL change, as presented by the IPCC (IPCC 2007), results in this equation being modified to be:

$$E(t) = 0.0017t + bt^2$$

The three scenarios proposed by the NRC result in global eustatic sea-level rise values, by the year 2100, of 0.5 meters, 1.0 meters, and 1.5 meters. Adjusting the equation to include the historic GMSL change rate of 1.7 mm/year and the start date of 1992 (which corresponds to the midpoint of the current National Tidal Datum Epoch of 1983-2001), results in updated values for the variable b being equal to 2.71E-5 for modified NRC Curve I, 7.00E-5 for modified NRC Curve II, and 1.13E-4 for modified NRC Curve III. The three GMSL rise scenarios are depicted in Figure 32.

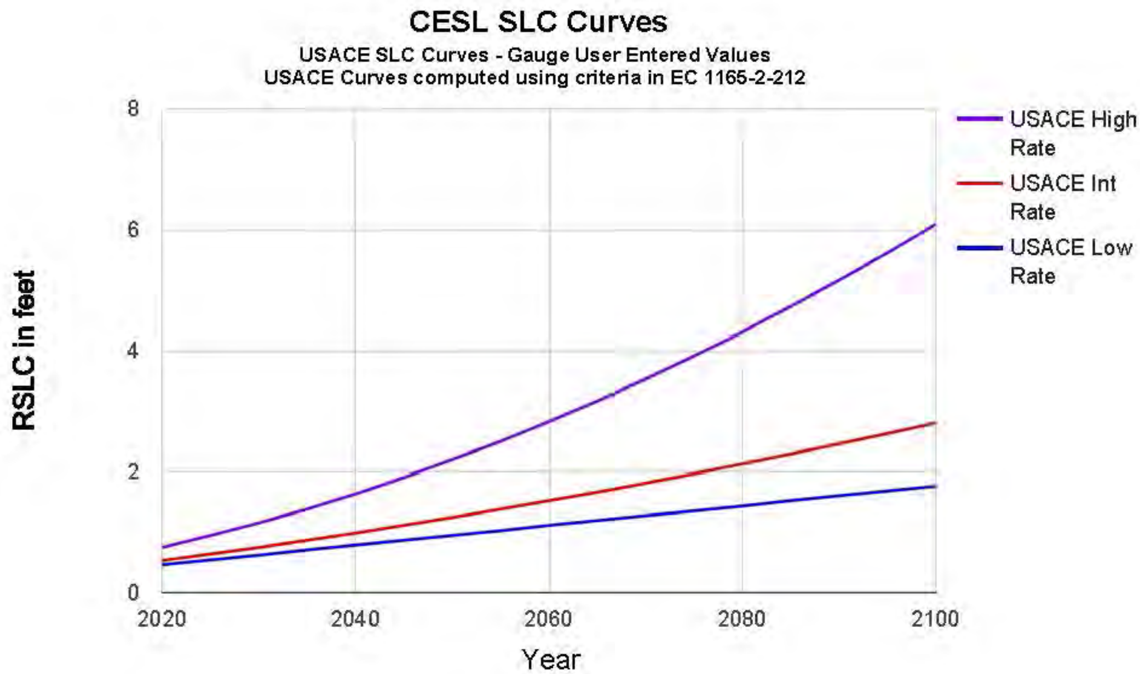

Figure 32. Scenarios for GMSL Rise (based on updates to NRC 1987 equation).

Manipulating the equation to account for the fact that it was developed for eustatic sea level rise starting in 1992, while projects will actually be constructed at some date after 1992, results in the following equation:

$$E(t2)-E(t1) = 0.0017(t_2-t_1) + b(t_2^2-t_1^2)$$

where t_1 is the time between the project's construction date and 1992 and t_2 is the time between a future date at which one wants an estimate for sea-level change and 1992 (or $t_2 = t_1$ + number of years after construction). For the three scenarios proposed by the NRC, b is equal to 2.71E-5 for Curve 1, 7.00E-5 for Curve 2, and 1.13E-4 for Curve 3.

This sea level rise should then be added to a measured sea level trend for the Barrow area. There is no sea level trend data for Barrow or the area around Barrow. Guidance in Appendix B of Engineering Regulation 1100-2-8162, *Incorporating Sea Level Change in Civil Works Programs*, recommends that the next closest long term gage be used. The Permanent Service for Mean Sea Level has sea level trends published for Prudhoe Bay, AK (Figures 33 and 34), which is the closest station to Barrow with a long-term record. The record length for Prudhoe Bay is 29 years, which is less than the recommended two tidal epoch duration of about 40 years, but it is the longest record near Barrow. The published sea level trend for Prudhoe Bay is +0.0870 inches/year. This value was used to determine the possible sea level rise at the end of the project life (Figure 35).

For a 50-year project life, a project in the Barrow area could see sea level rise as much as 2.13 feet (Table 2). The wave height that could impact any coastal protection may increase. By having stockpiles of material to address maintenance due to ice events, any damage due to a larger wave should also be able to be addressed with the stockpiles material.

The map above illustrates relative sea level trends , with arrows representing the direction and magnitude of change. Click on an arrow to access additional information about that station.

Relative Sea Level Trends
mm/yr (feet/century)

Above 9 (Above 3)	6 to 9 (2 to 3)	3 to 6 (1 to 2)	>0 to 3 (0 to 1)	-3 to 0 (-1 to 0)	-6 to -3 (-2 to -1)	-9 to -6 (-3 to -2)	Below -9 (Below -3)

The Center for Operational Oceanographic Products and Services has been measuring sea level for over 150 years, with tide stations of the National Water Level Observation Network operating on all U.S. coasts. Changes in RSL, either a rise or fall, have been computed at 142 long-term water level stations using a minimum span of 30 years of observations at each location. These measurements have been averaged by month which removes the effect of higher frequency phenomena in order to compute an accurate linear sea level trend. The trend analysis has also been extended to 240 global tide stations using data from the Permanent Service for Mean Sea Level (PSMSL). This work is funded in partnership with the NOAA OAR Climate Observation Division.

Figure 33. Location of Prudhoe Bay, AK.

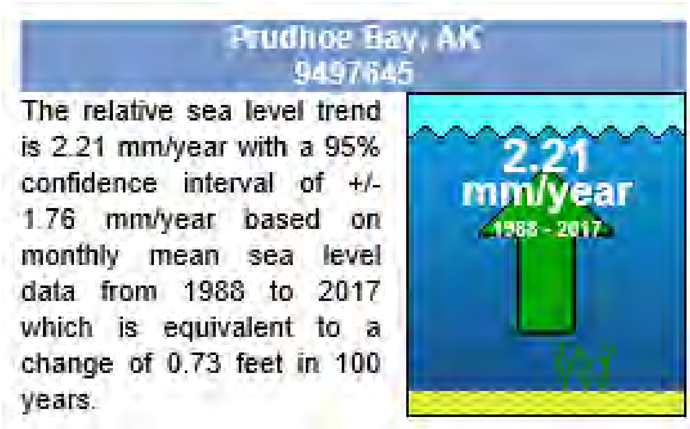

Figure 34. Sea Level Trend in Prudhoe Bay, AK.

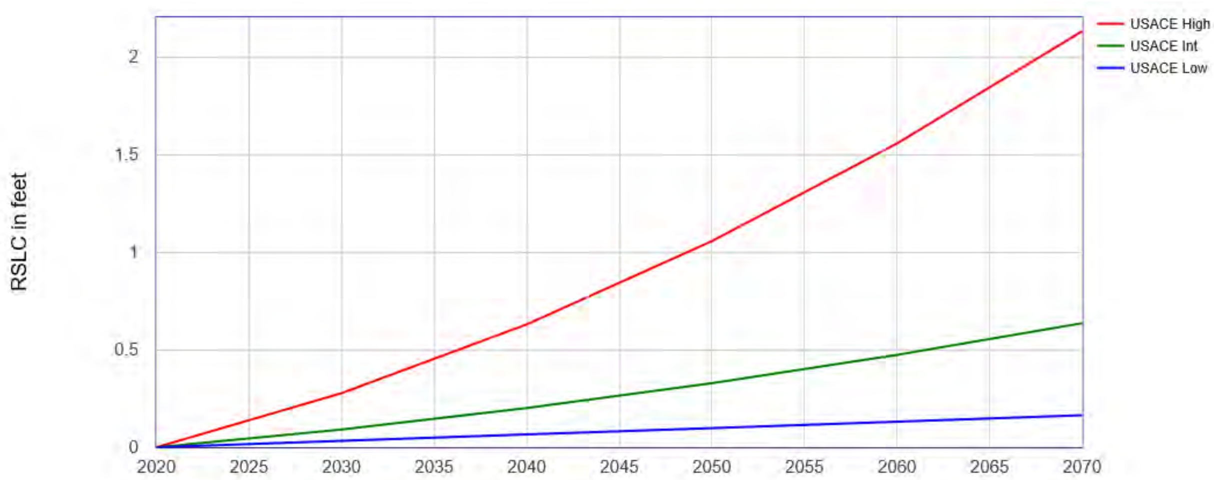

Figure 35. Plot of Sea Level Rise.

Table 2. Sea Level Rise Prediction for a 50-year Project Life Assuming Project Start in 2020.

User Defined Rate: 0.00328 feet/yr
All values are expressed in feet

Year	USACE Low	USACE Int	USACE High
2020	0.00	0.00	0.00
2030	0.03	0.09	0.28
2040	0.07	0.20	0.63
2050	0.10	0.33	1.06
2060	0.13	0.47	1.56
2070	0.16	0.64	2.13

3.5. 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 mph (Figure 36). The predominant wind direction is out of the east and north east with the majority of the wind coming out of the east northeast (Table 3).

Barrow, AK

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

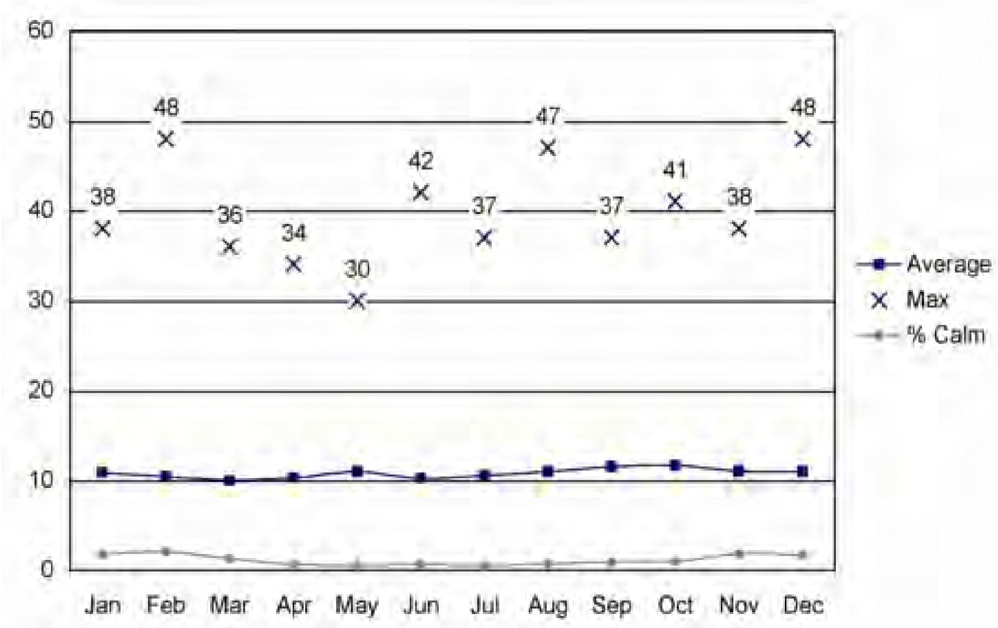

Figure 36. Mean and Maximum Monthly Wind Speed (mph) and Percent of Calm Observations.

Table 3. 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 deepwater 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 deepwater wave hindcast boundary output point to the nearshore at Barrow.

4.1. Wind Hindcast

The specification of the wind fields is critical to the generation of an accurate wave climate. A 10 percent uncertainty in the wind speed estimate will lead to an approximate 20 percent uncertainty in the wave height. To accurately characterize the forcing mechanisms for the wave and current modeling, a hindcast was performed for the years 1982-2003 by Oceanweather Inc. (OWI), under contract to the 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 37. 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 which 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 assures 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°, 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.

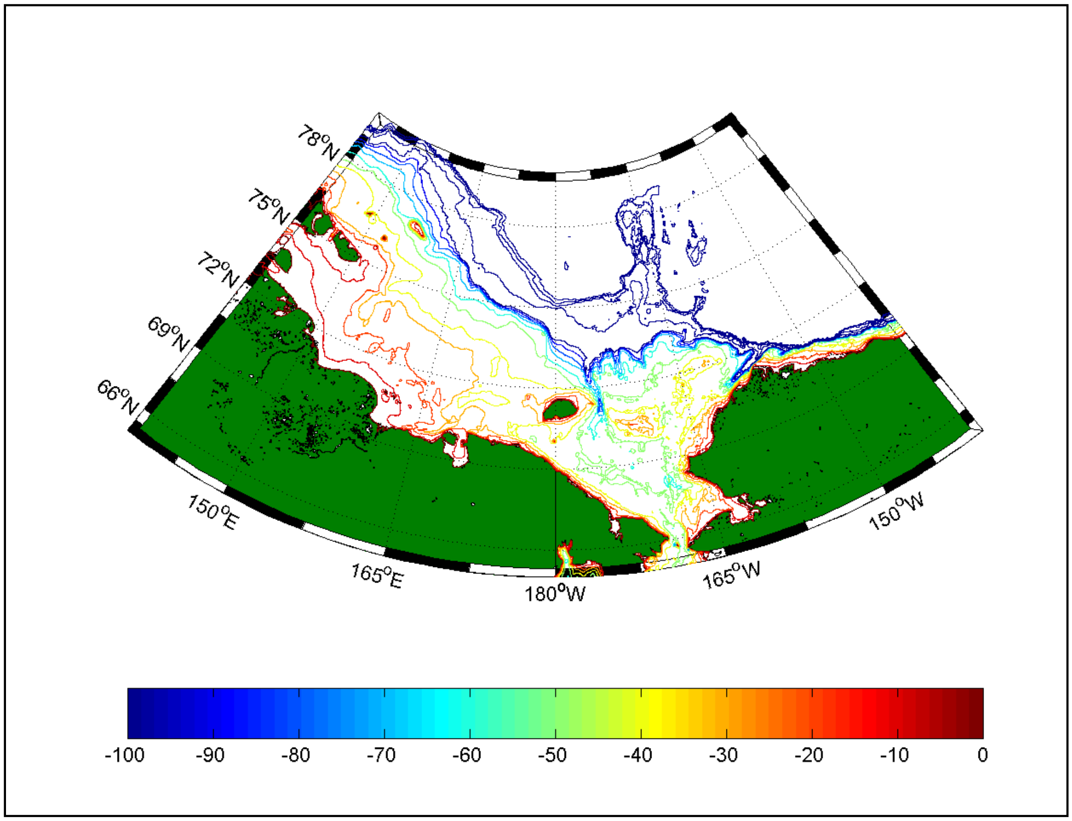

Figure 37. The Barrow Deep Water Wind, Ice and Wave Model Target Domain Water depths are contoured in meters (1 meter = 3.3 feet).

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 38. 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 the 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). Ice maps for selected storm events prior to the 1972 digital database were constructed by OWI.

The 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 assuring consistency across the land/water boundary. The fine scale ice field replaced the area in close proximity to the Barrow site. The concentration level (from 0 to 100 percent where the higher levels of concentration indicate increased ice compared to 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 39 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).

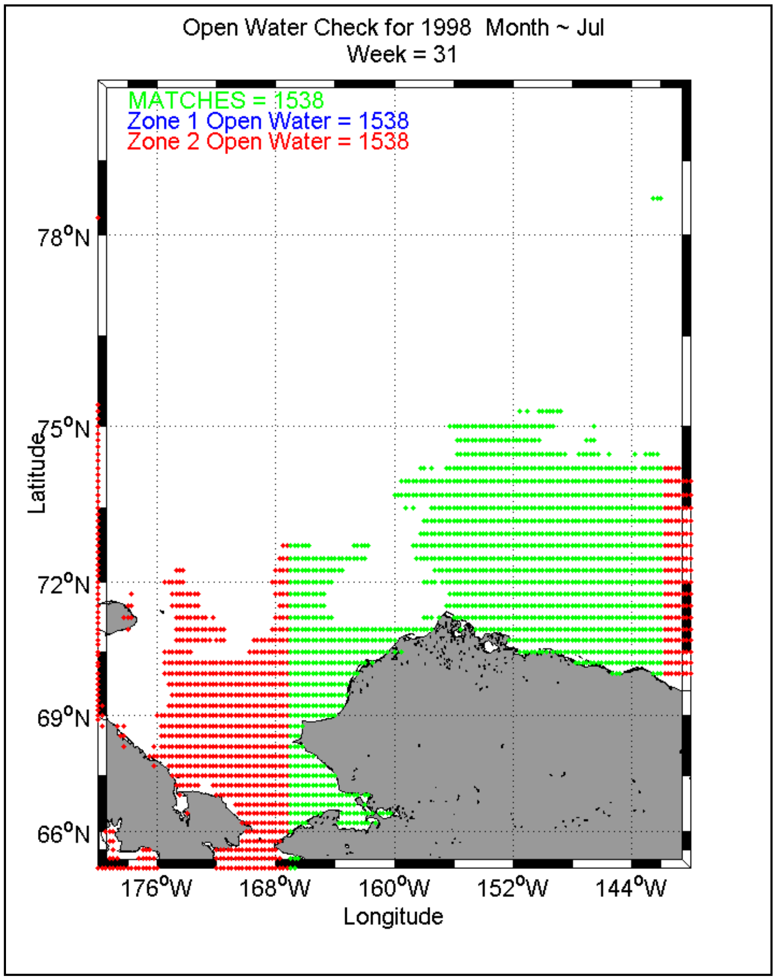

Figure 38. Example of the Final Ice Map Used in Wave Model Simulation
Note the symbols identify the open water area.

5 - 6 tenths "open drift"

7 - 8 tenths "close pack"

Figure 39. Examples of Sea Ice Concentration
Left 50 to 60 percent, right panel 70 to 80 percent concentration.

4.3. Deepwater Hindcast

The deepwater waves were analyzed using the **WA**ve prediction **M**odel (WAM). WAM is a third generation wave model which 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, whitecapping, 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.
- Free form of spectral shape.
- High dissipation rate to short waves.

The domains describing the wind, ice and wave model are found in Table 4 and were shown in Figure 37. 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 4. 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

Verification of Deepwater Wave Model. There is not a 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 40 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).

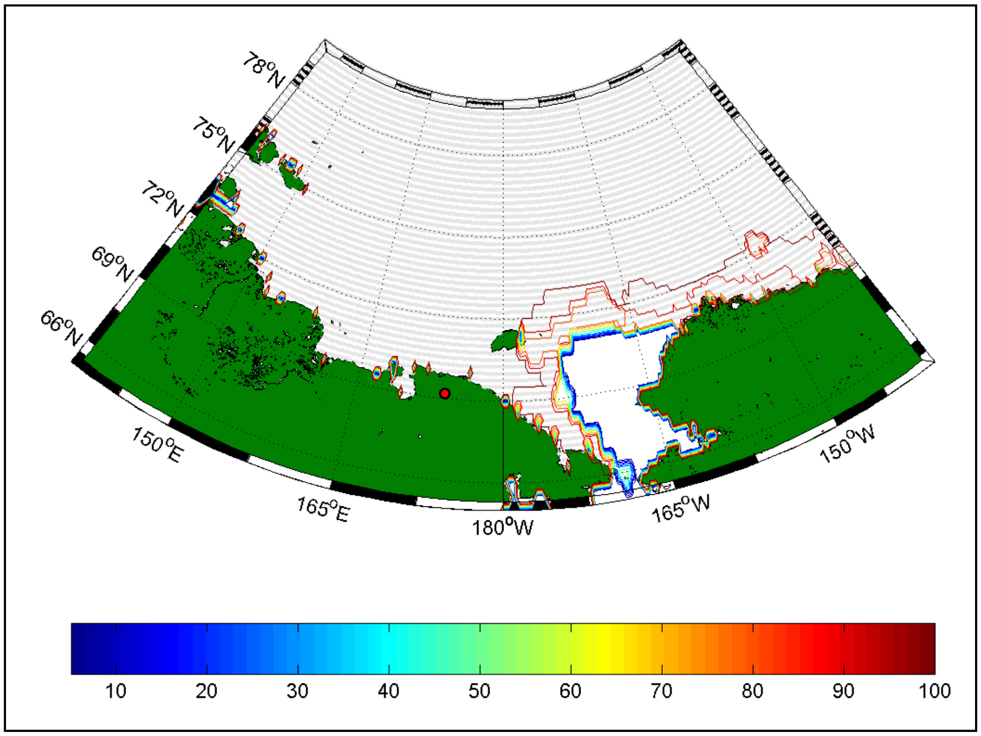

Figure 40. Location (red symbol) of the Shell Oil Wave Measurements for Stations A and B During Two Deployment Cycles of 1983 and 1984.

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 (H_{mo}), and mean wave period, (T_m) for 1983 are presented in Figures 41 and 42 for Site A and B. The WAM H_{mo}, and T_m estimates for the first deployment period shows 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 on the order of 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.

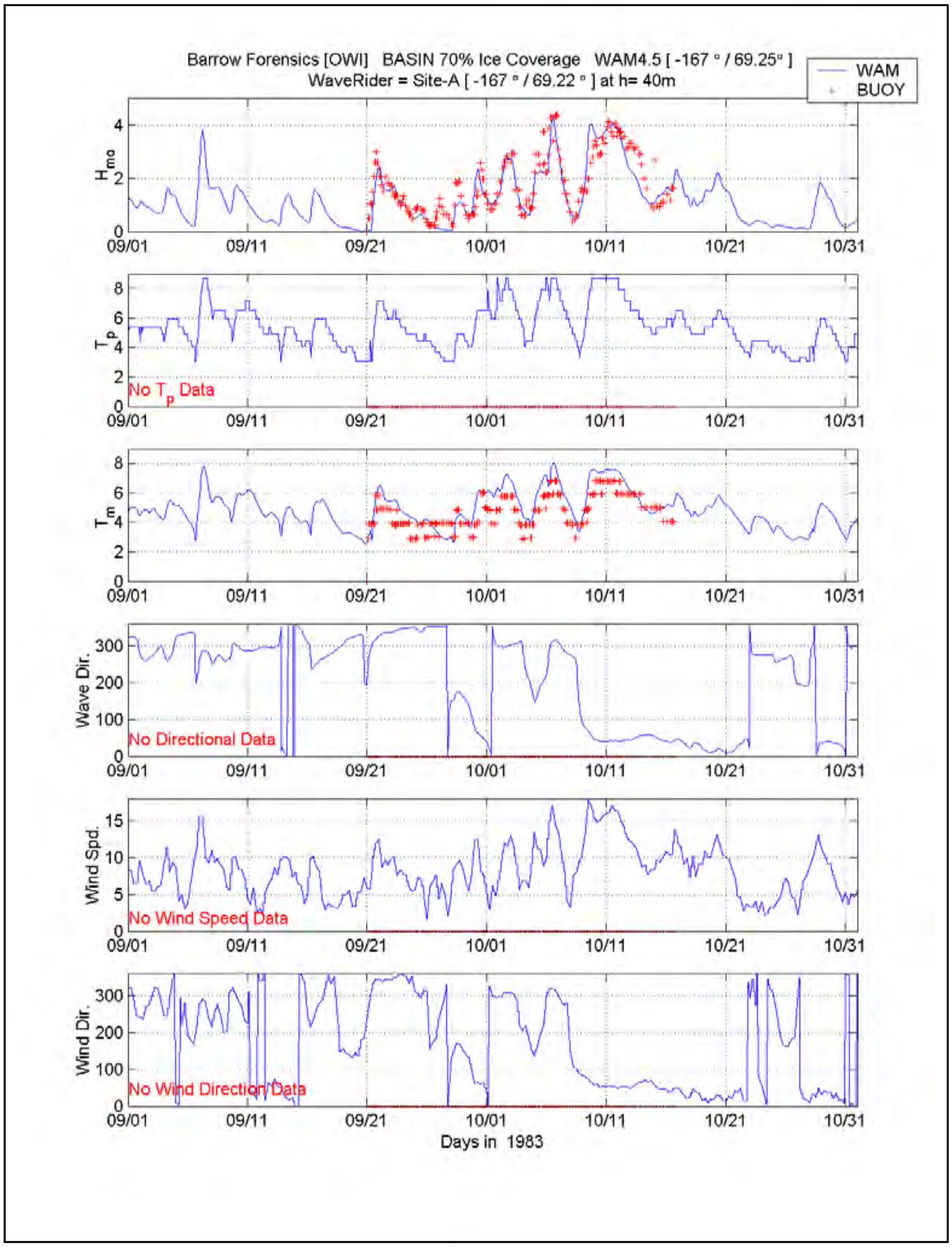

Figure 41. Comparison of WAM Cycle 4.5 (solid blue line) to Shell Oil Co. Buoy Data During Deployment 1, at Site A.

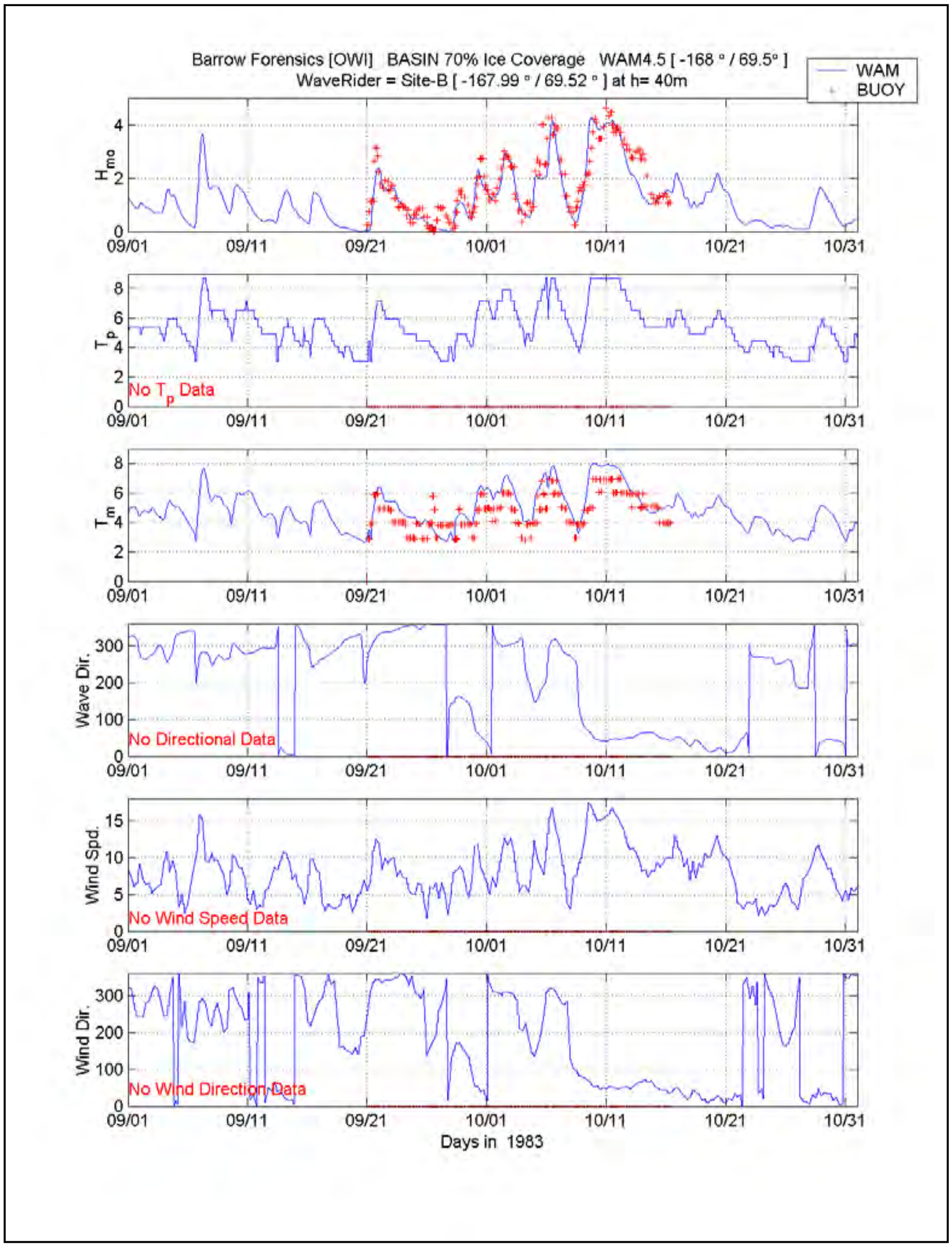

Figure 42. Comparison of WAM Cycle 4.5 (solid blue line) to Shell Oil Co. Buoy Data During Deployment 1, at Site B.

The results of WAM during the second deployment (found in Figures 43 and 44 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 are maintained. For the decay cycles, either rapid in the case of 21 September at Site A, or much slower cycle 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%,

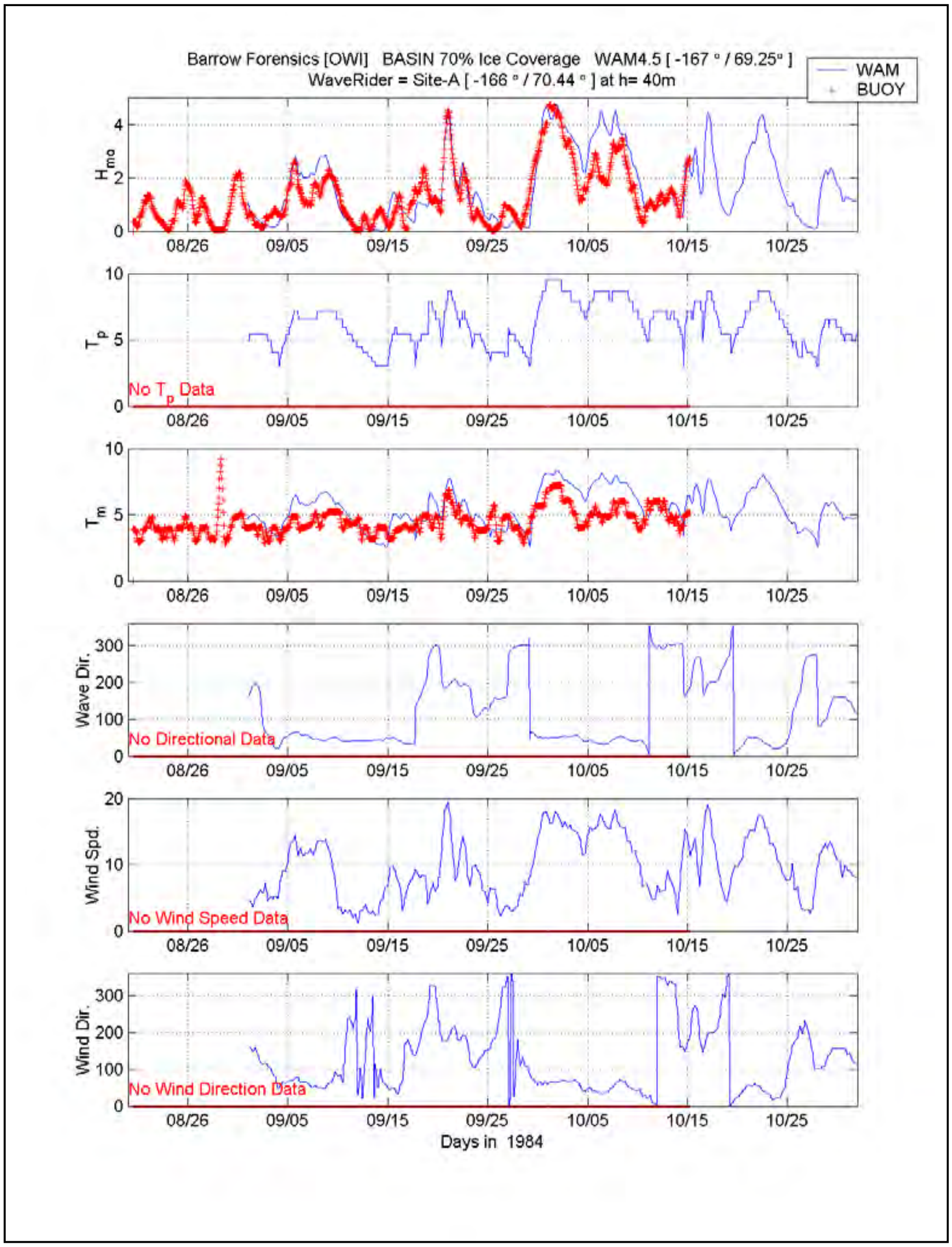

Figure 43. Comparison of WAM Cycle 4.5 (solid blue line) to Shell Oil Co. Buoy Data During Deployment 2, at Site A.

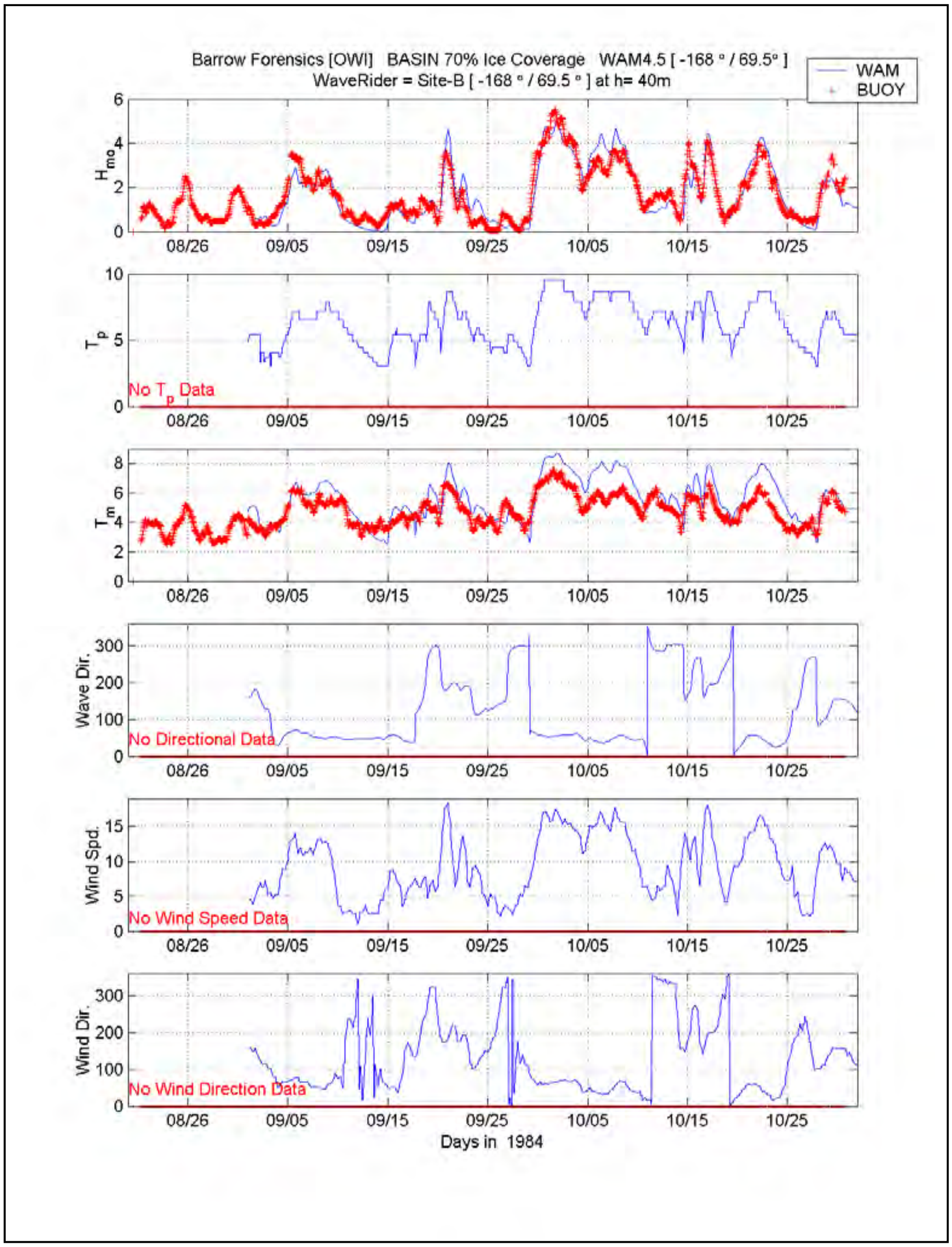

Figure 44. Comparison of WAM Cycle 4.5 (solid blue line) to Shell Oil Co. Buoy Data During Deployment 2, at Site B.

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 through 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 nearshore wave transformation is shown in Figure 45.

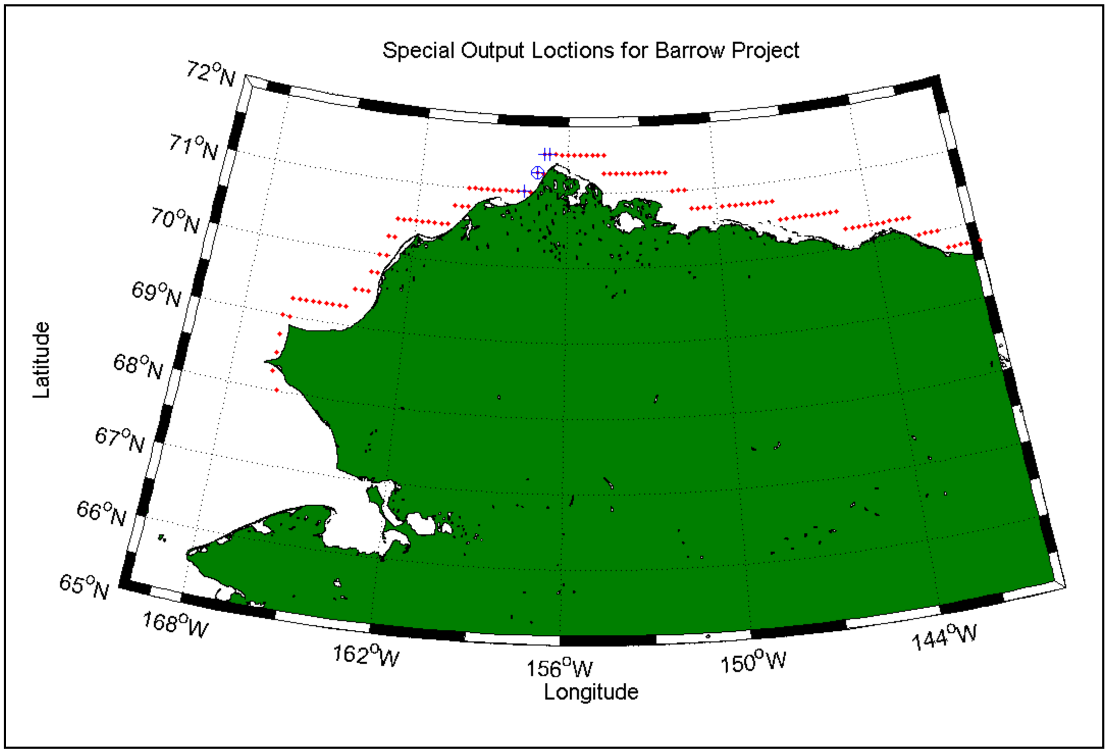

Figure 45. Special Output Locations (red) and Stations 47, 51, 52 (blue +) and the STWAVE Input Site Station 49 (blue ⊕).

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 US Army Corps Alaska District provided a selected number. The last set was derived from storm analysis procedures used by OWI. The 27 storms are summarized in Table 5. 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 for reducing any added false discontinuity.

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 45, 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 Nearshore Wave Simulations. Figure 46 shows Station 49 and its associated bathymetry. Figure 47 presents the integral wave parameters in height, peak spectral wave period, and vector mean wave direction.

Table 5. 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

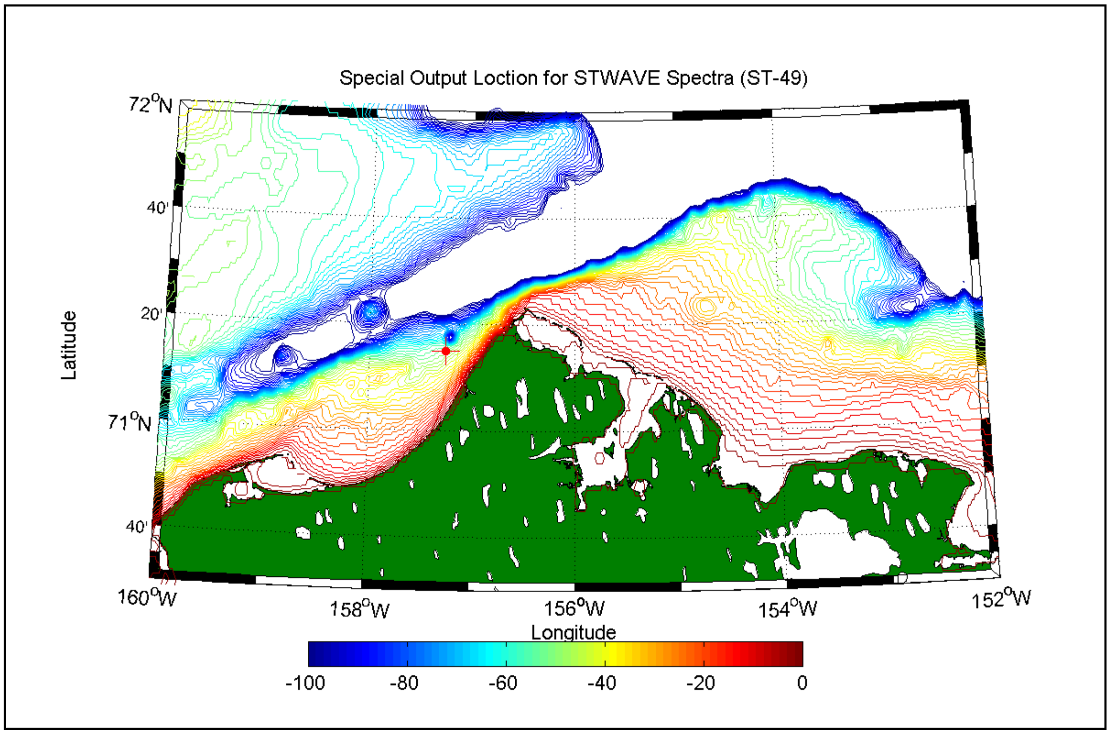

Figure 46. Zoomed View of the Barrow Site and Station 49 (red cross).

Note that only water depths less than 100-m are color contoured to emphasize the local bathymetry. Water depths greater than 100-m exist and are identified by the white area outside the blue 100-m contour interval.

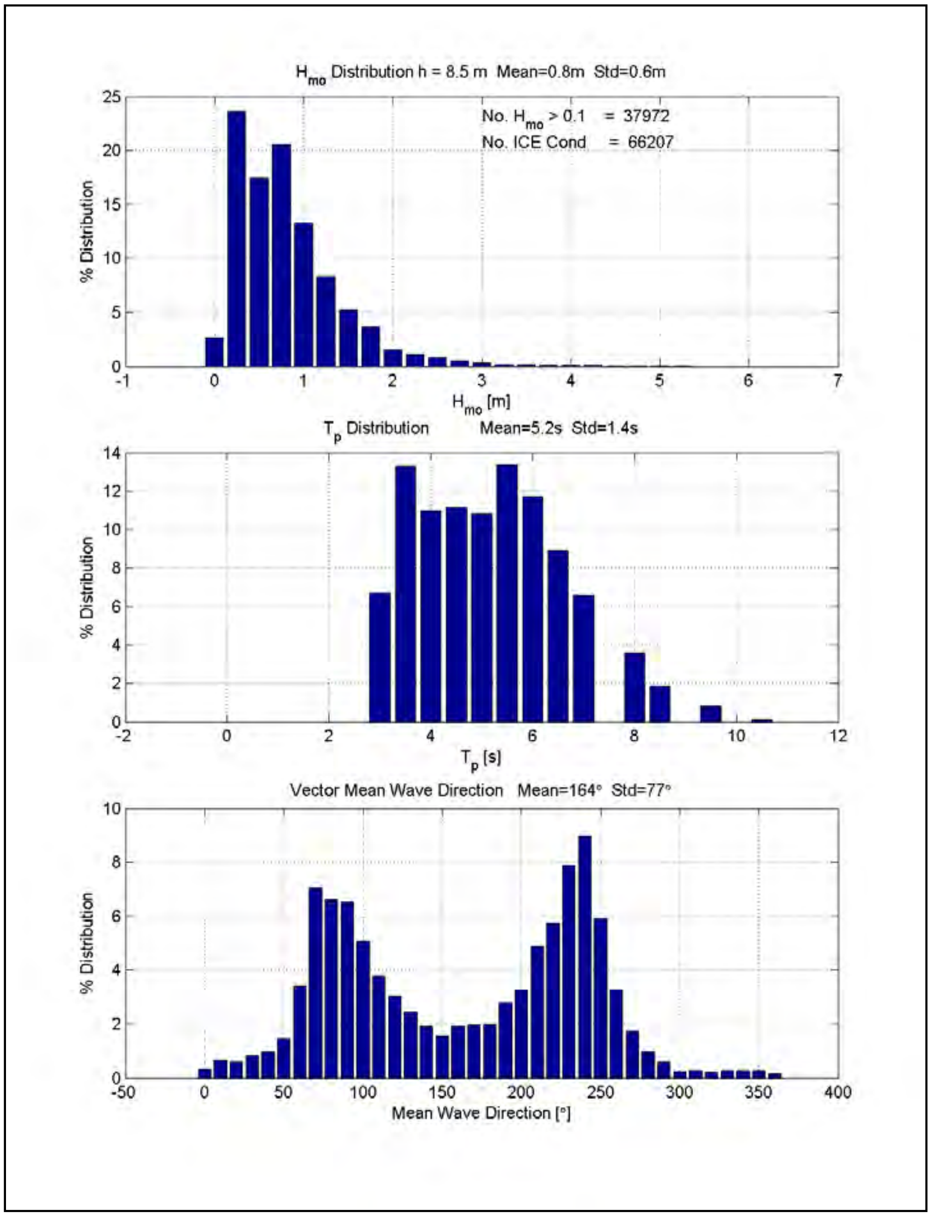

Figure 47. Height, Peak Wave Period and Vector Mean Wave Direction Distributions for the 1982-2003 (June through November) At Station 49.

The H_{mo} and T_p 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-s. What is interesting to note is the mean wave directional distribution. Noting the direction convention is waves propagating towards shore normal at about 135° and waves going towards the east at 90°. 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°, cause the rapid drop in the occurrences.

The wind speed and directional distributions are provided in Figure 48. 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%. 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 to the wave direction are quite different, where there is clearly visible persistence for east-northeasterly directions.

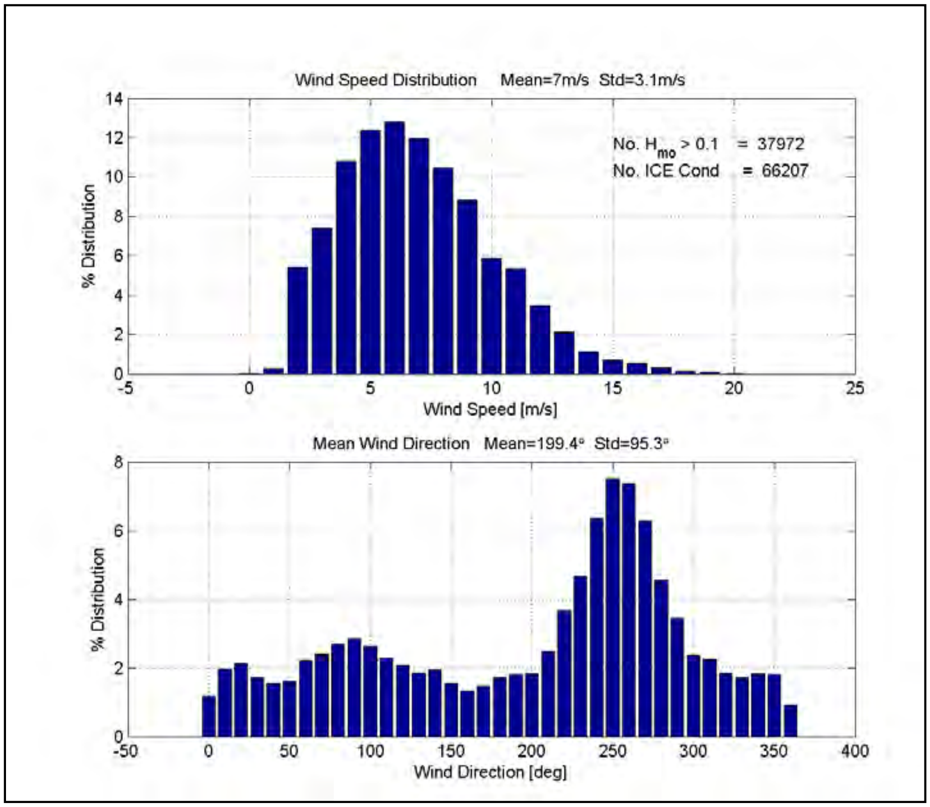

Figure 48. Wind Speed and Direction Distributions for the 1982-2003 (June through November) at Station 49.

The analysis thus far removes the time domain focusing on only the distribution of wind and wave characteristics for the entire climate simulation. Found in Figure 49 are bar plots of the number of observations, the mean and maximum conditions occurring for the June through December months from 1983 through 2003. The values used for plotting purposes are also summarized in Table 6. There are variations from year to year, increasing in the latter 1990s through the end of the simulation period.

There are three dependent variables dictating the wave height maximums. First, meteorological systems with winds in excess of 22 mph (10 m/s) are needed; secondly these winds need to be directed toward the Barrow Project Site; third, the amount of open water is sufficiently large to build the waves. It is interesting to note the large variation in maximum H_{mo}. There is a clearly defined long-term oscillation in the H_{mo} 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 were 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 H_{mo} maxima are over a 22 mph (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 H_{mo} maximums, indicating a dominant local wind-sea environment, which is further supported by the T_p results in the range of 8- to over 10-s during the maximum wave height events. The shore normal direction is at approximately 135°, with a landward attack angles between 45°and 225°. The predominant storm generated waves come from the north, to northeasterly directions. These would be very 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.

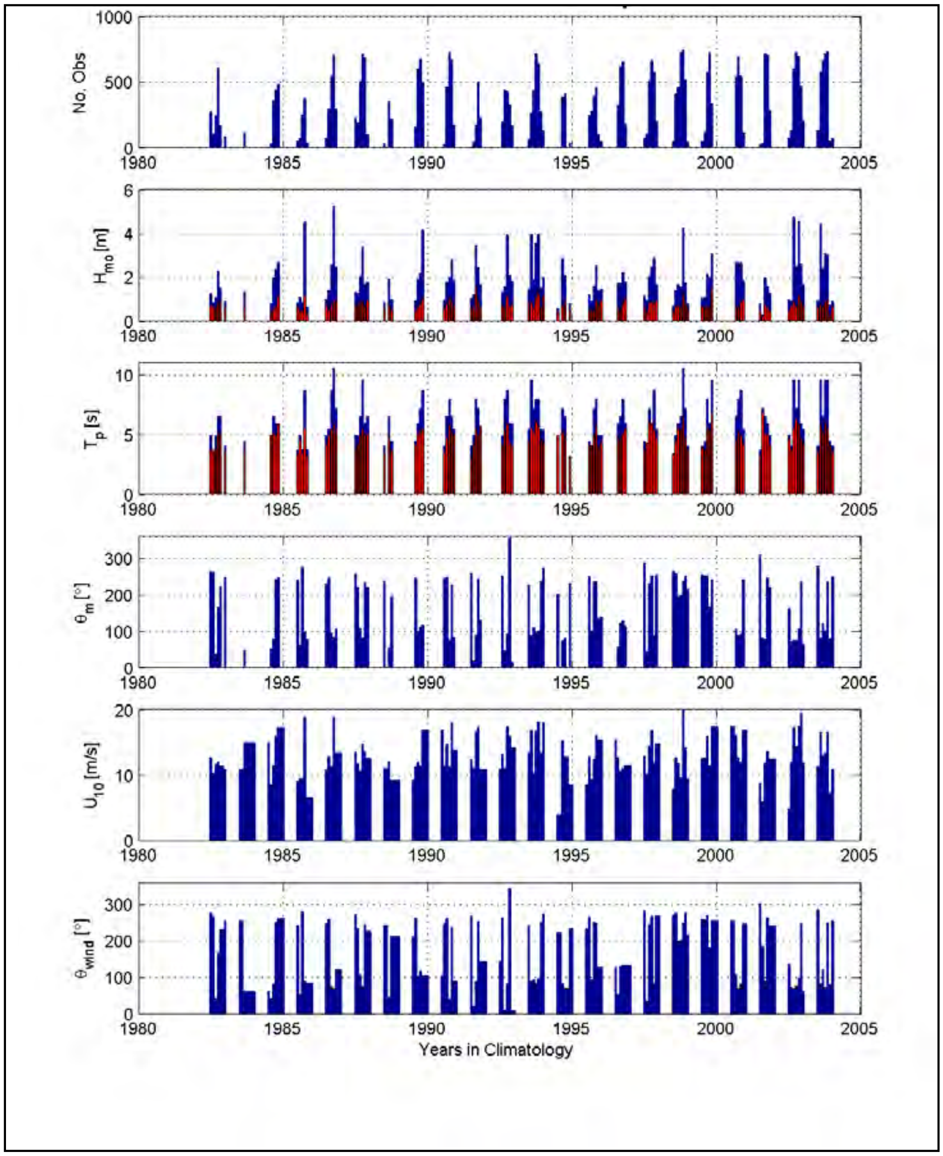

Figure 49. Climate Summary at Station 49 Where Various Panels Define the Variation of Parameter Over Time (Monthly Information); Red Indicates the Mean, Blue the Maximum.

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 H_{mo} 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 of 2003 and 2004. Figure 50 shows the Barrow shoreline for reference.

Table 6. 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 Speed	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

Table 6. 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 Speed	Wind Dir
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
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

Table 6. 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 Speed	Wind Dir
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
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

Table 6. 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 Speed	Wind Dir
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 50. Barrow Shoreline for Reference.

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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 coastal storm risk management project.

The percent of occurrence for the range of wave heights and periods are shown in Table 7. 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 51. Significant wave heights for the selected storms from 1954 to 2003 are shown in Table 8 along with their rankings.

Table 7. 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**	

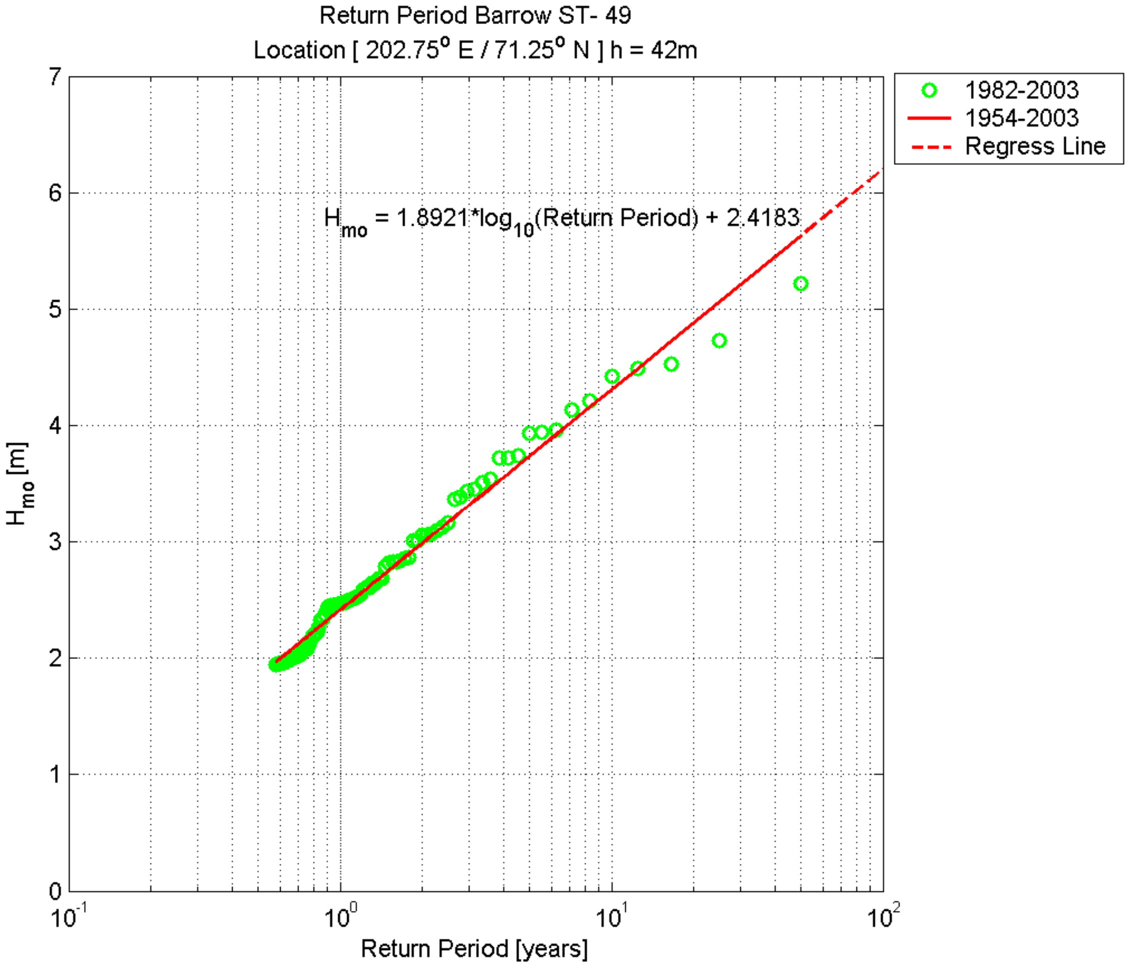

Figure 51. Deep Water Wave Height Return Period.

Table 8. 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
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

Table 8. Storm Ranking.

Rank	Return Interval	Year	Month	Date	Time	Hmo [m]	Hmo [ft]	Tp	DIR (TWD WCH)	Wsp [m/s]	Wdir
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
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

Table 8. Storm Ranking.

Rank	Return Interval	Year	Month	Date	Time	Hmo [m]	Hmo [ft]	Tp	DIR (TWD WCH)	Wsp [m/s]	Wdir
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 nearshore 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 that were 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.

4.5.1. Bathymetry. Figure 52 shows a contour plot of the bathymetry for the Barrow STWAVE grid. The grid was developed by merging digit bathymetry from NSIDC (Lestak et.al. 2003) and beach profiles provide by the Alaska District. The grid origin is x = 1,740,000 ft and y = 6,310,000 ft (Alaska State Plane, Zone 6). The grid has 280 rows (south to north, alongshore) and 94 columns (cross-shore), and grid spacing is 300 ft. The grid orientation is 315 deg 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 ft.

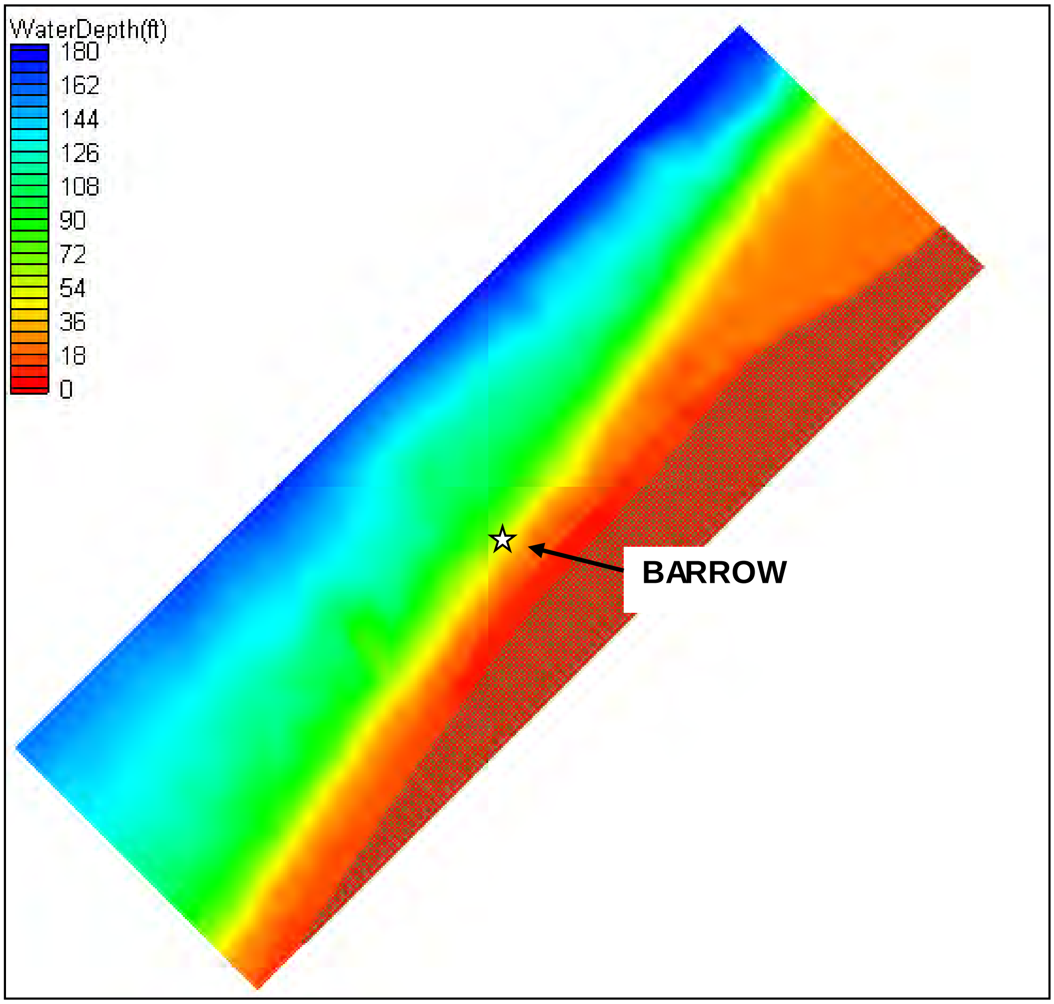

Figure 52. STWAVE Bathymetry Grid for Barrow, AK (depths in feet) Land area is shown in brown.

4.5.2. Water Level and Wind. Water level variations are a combination of tide and storm surge. Water level is applied in STWAVE as 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 deg N and 157.25 deg W and applied to the entire STWAVE grid.

4.5.3. Sample Output. Figure 53 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 nearshore 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 ft, peak period of 8.7 sec, and a direction of 275 deg.

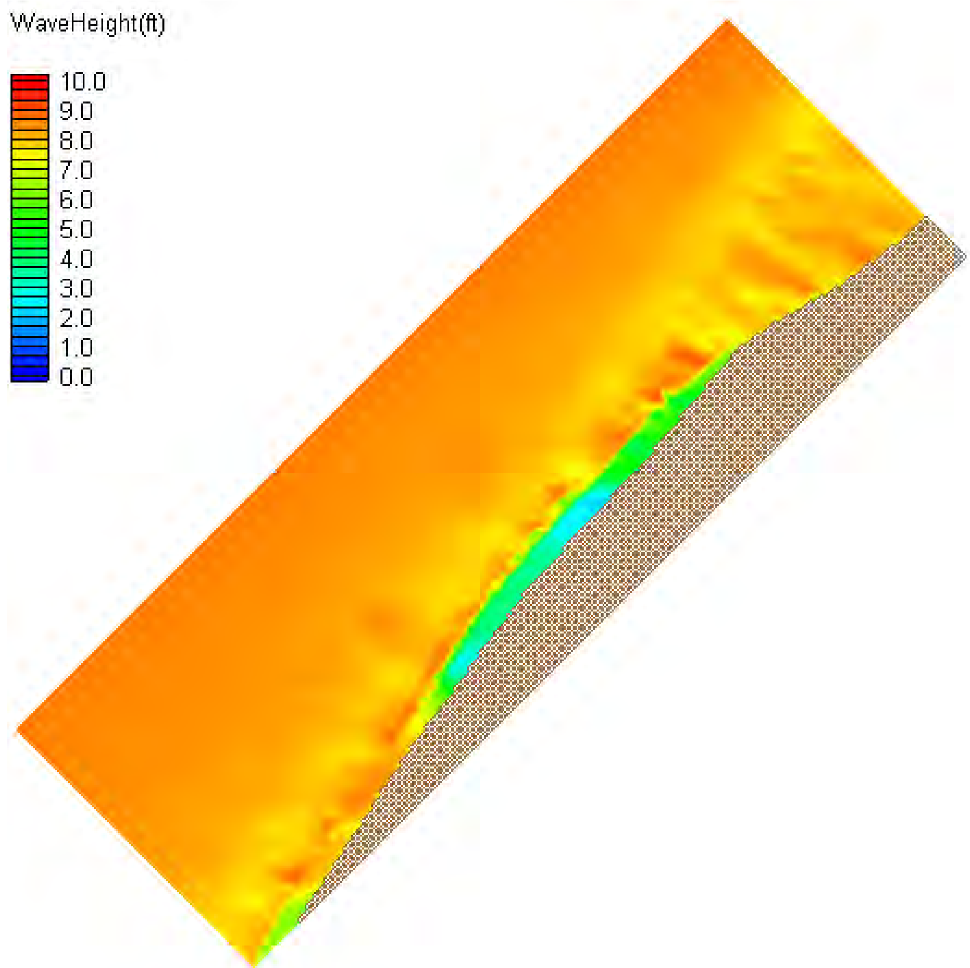

Figure 53. Sample STWAVE Transformed Wave Height Field.

4.5.4. Field Data. The model was validated using nearshore wave measurements acquired during the summer and fall of 2003 at depths of 33 and 16 ft. The wave gages used for this study were RD Instruments Sentinel 1200 kHz Acoustic Doppler Current Profilers (ADCP).The gages were deployed 12 September-4 November 2003, with a short gap for servicing on 1-2 October 2003. The gages were deployed at 71.296341 deg N, 156.812040 deg W in a depth of approximately 33 ft and at 71.294176 deg N, 156.799910 deg W in a depth of approximately 16 ft (Figure 54). Data recovery included a storm event occurring 8-12 September 2003. The peak wave height during the storm was 10 ft with a peak period of 10 sec. Figures 55 through 57 show the wave height, period, and direction, respectively, for both gages throughout the deployment period.

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

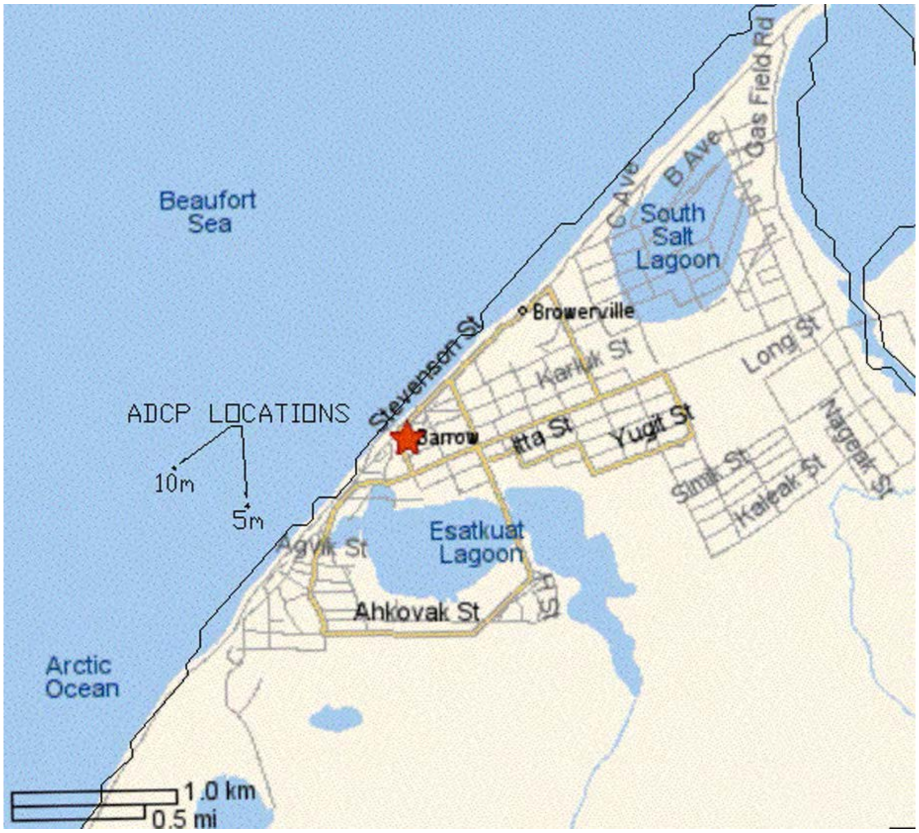

Figure 54. Location of ADCP Instruments.

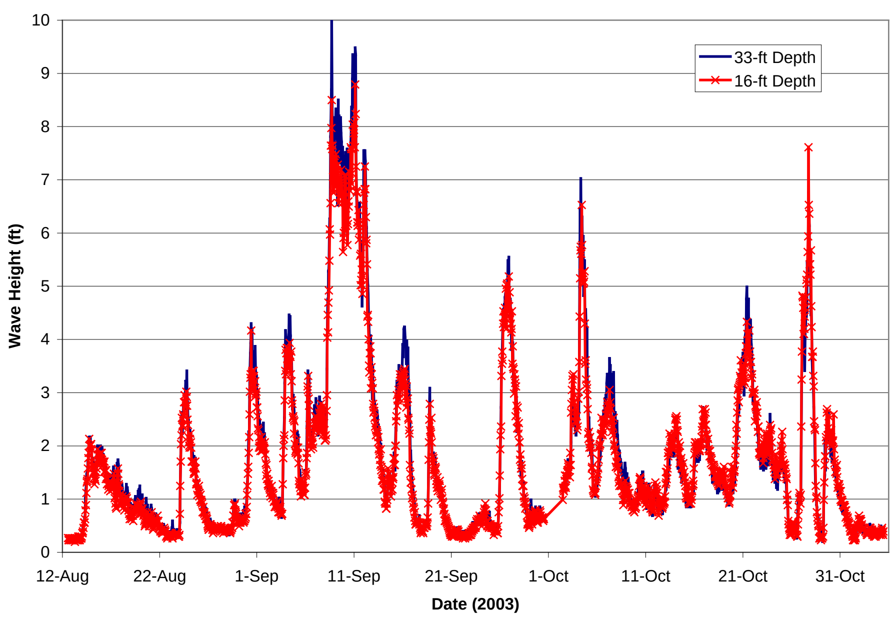

Figure 55. Measured Wave Height at 33- and 16-ft Depths.

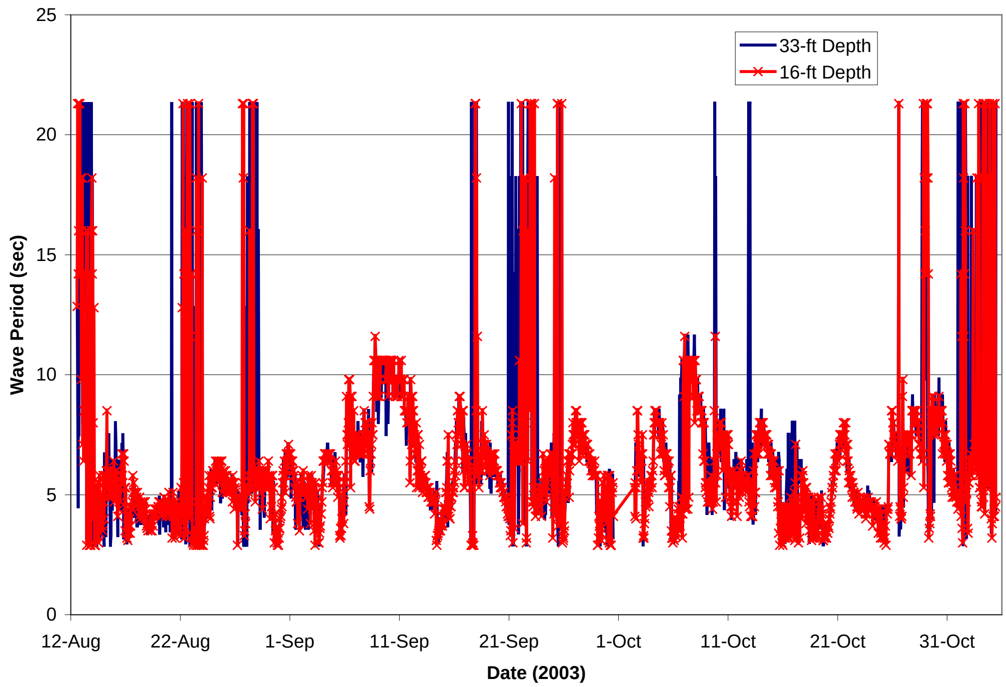

Figure 56. Measured Peak Wave Period at 33- and 16-ft Depths.

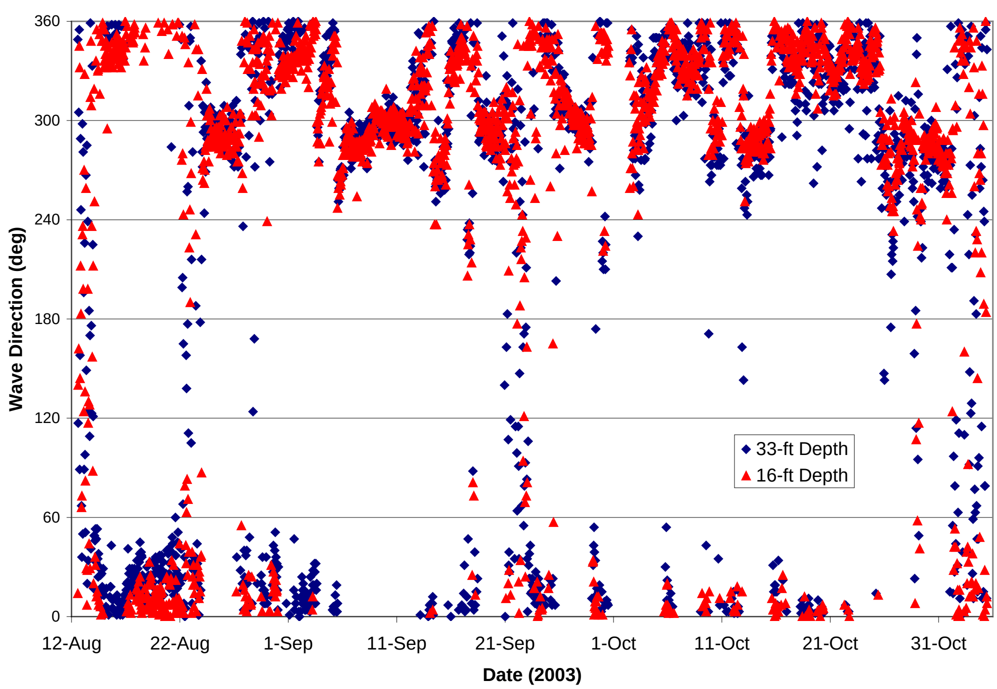

Figure 57. Measured Wave Direction at 33- and 16-ft Depths.

4.5.5. Model Validation. STWAVE was validated for Barrow using the wave data collected at water depths of 33 and 16 ft. Within the August through November 2003 wave record, the largest waves occurred during the period 28 August-17 September 2003. The measurements include wave height, peak period, and mean wave direction. Figure 58 presents simulated wave heights and periods compared with the data at the 33-ft gage, and Figure 59 shows the mean direction comparisons. The wave heights show good agreement with a mean error of 0.07 ft and a root-mean-square error of 0.69 ft. 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 sec and the root-mean-square error is 2.4 sec. The mean error in direction is 8.3 deg and the root-mean-square error is 31 deg. 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 gage in a depth of 16 ft, the wave height error increases slightly, as the period and directional errors decrease. Comparisons with measurements at the 16-ft depth are shown in Figure 60 for wave height and peak period and Figure 61 for mean direction. The mean wave height error is -0.23 ft and the root-mean-square error is 0.75 ft. The measured periods again jump between sea and swell, but less than at the deeper gage. The mean error in peak period is 0.3 sec and the root-mean-square error is 2.1 sec. The mean error in mean direction is 0.6 deg and the root-mean-square error is 26 deg. The validation shows good agreement between the modeling methodology and the measurements.

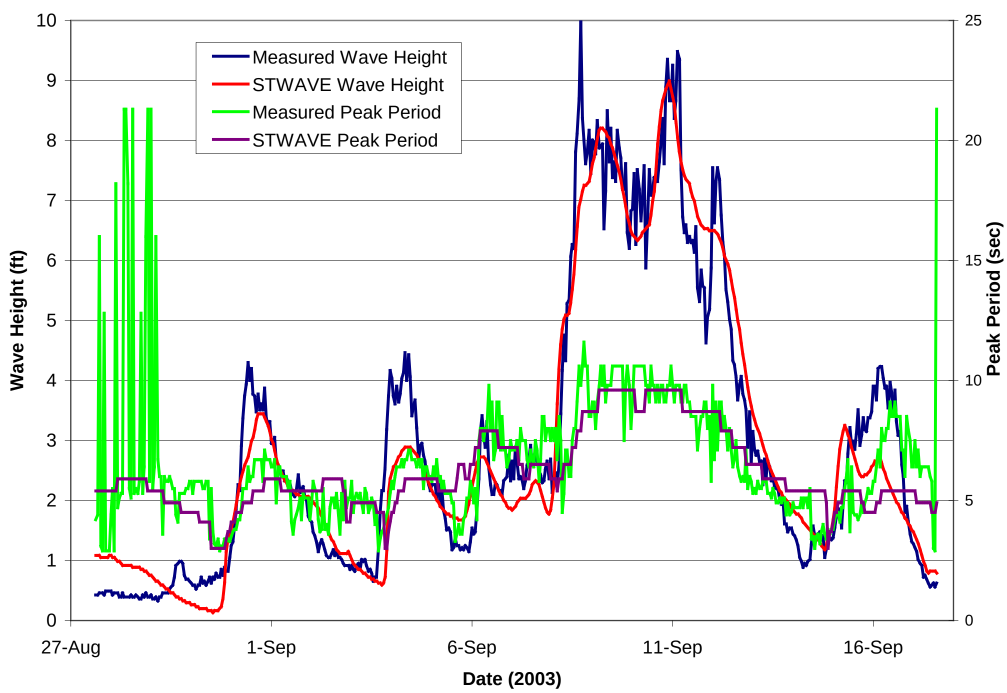

Figure 58. STWAVE Validation of Wave Height and Peak Period with Measurements at 33-Ft Depth for 27 August-17 September.

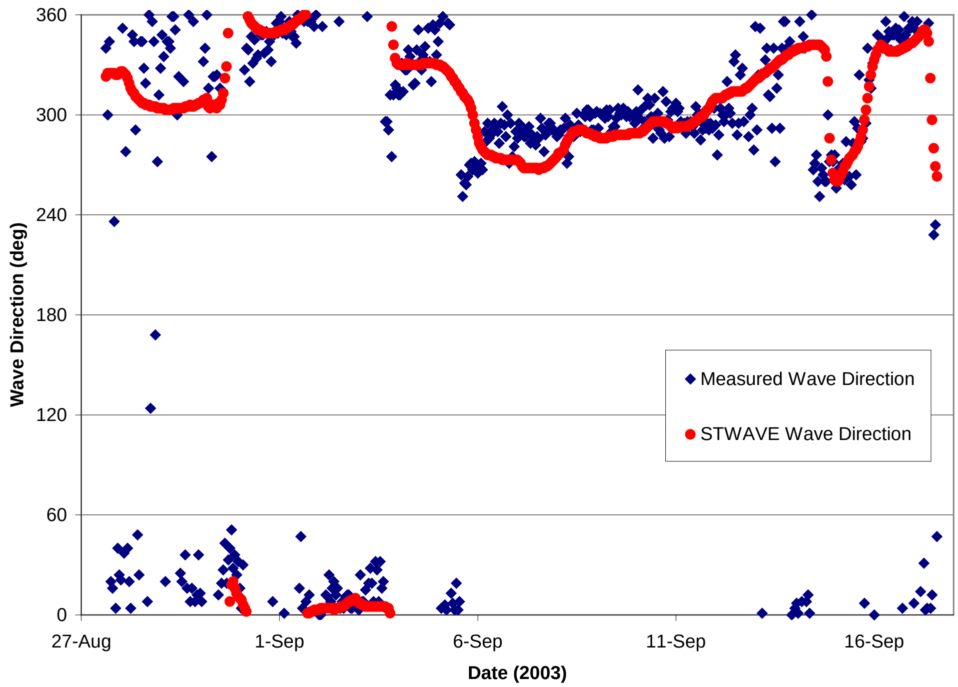

Figure 59. STWAVE Validation of Mean Wave Direction with Measurements at 33-ft Depth for 27 August-17 September.

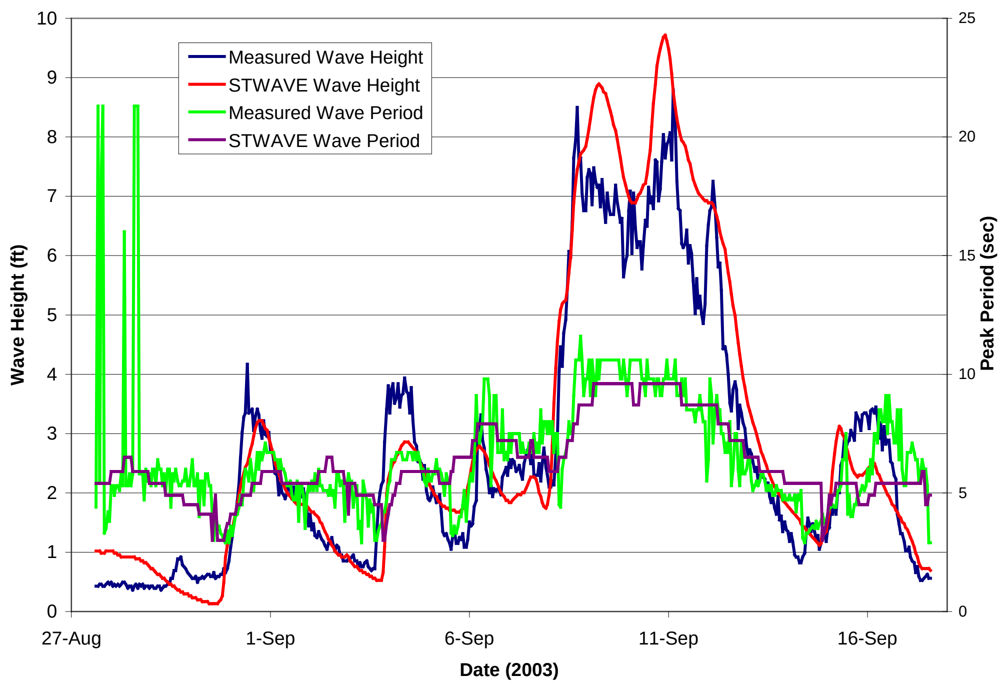

Figure 60. STWAVE Validation of Wave Height and Peak Period with Measurements at 16-ft Depth for Julian Day 240-260, 2003 (28 August-17 September).

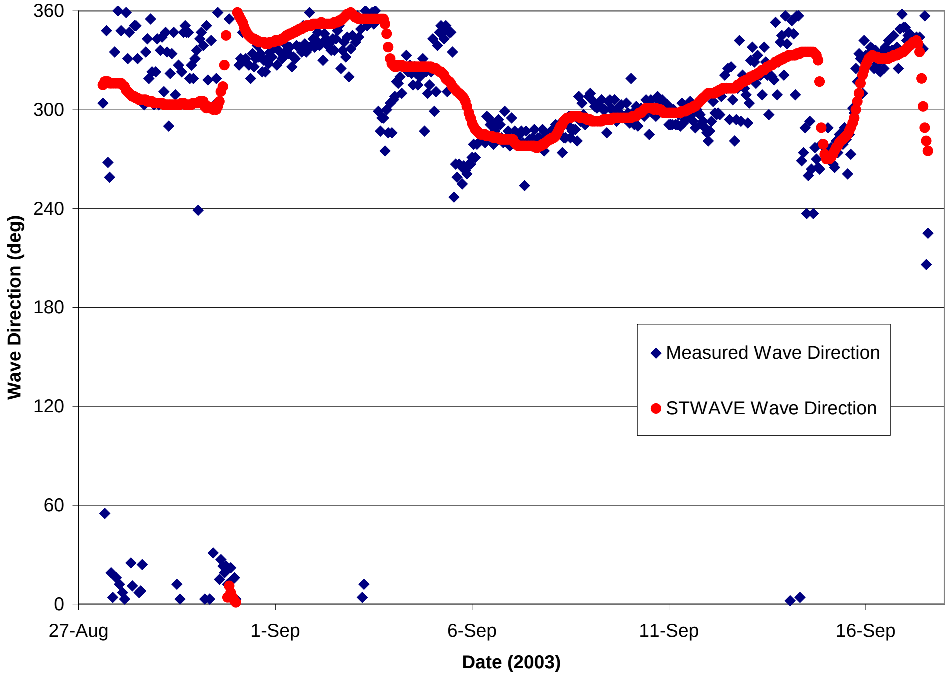

Figure 61. STWAVE Validation of Mean Wave Direction with Measurements at 16-ft depth for Julian Day 240-260, 2003 (28 August-17 September).

4.5.6. Summary of Results. The wave transformation model STWAVE was used to transform waves from the deepwater wave hindcast boundary output point to the nearshore at Barrow. The modeling simulations included 51 typical waves and 28 storm events. The model was validated using nearshore wave measurements acquired during the summer and fall of 2003 at depths of 33 and 16 ft. The validation shows good agreement between the model and measurements, indicating the deepwater hindcast and nearshore transformation model methodologies are sufficiently skilled to provide design input. Figure 62 provides the nearshore wave height (in 28.5 ft water depth, directly offshore of Barrow) as a function of return period based on the storms simulated between 1954 and 2003.

Figure 62. Return Period for Nearshore Storm Wave Heights (1954-2003).

The percent occurrence for wave height and period for the STWAVE boundary location is given in Table 9. The mean wave height is 2.6 ft and the mean peak period is 5.1 sec.

Table 9. 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 in order 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 **AD**vanced **CIRC**ulation (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 is shown in Figure 63. 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.

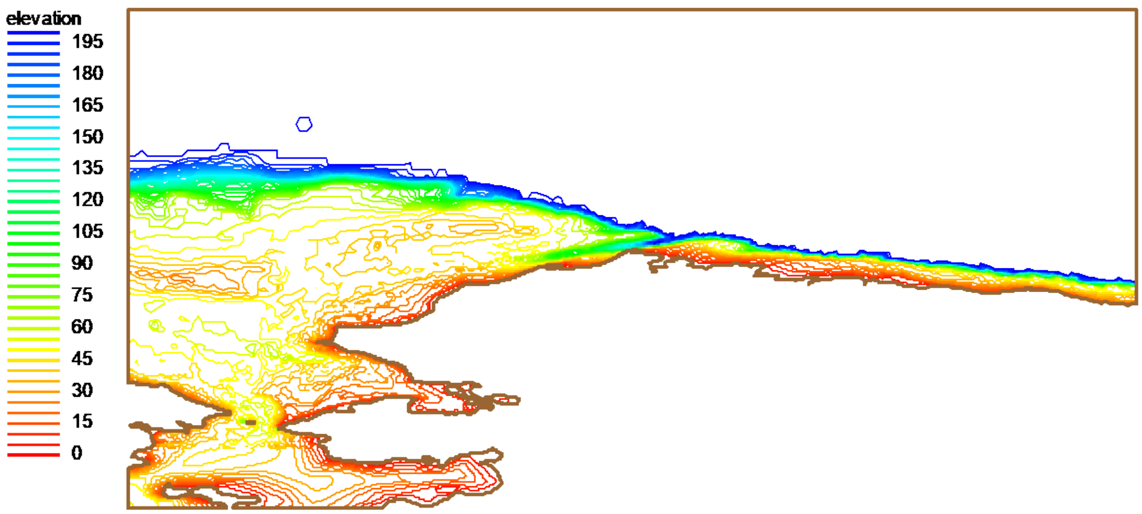

Figure 63. Regional ADCIRC Grid Bathymetry Showing Depths Less Than 200 Meters.

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. The 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 64 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 64 that the corrected peak water surface elevation tracks well within the observed wind set up and tidal range (Days 6-10).

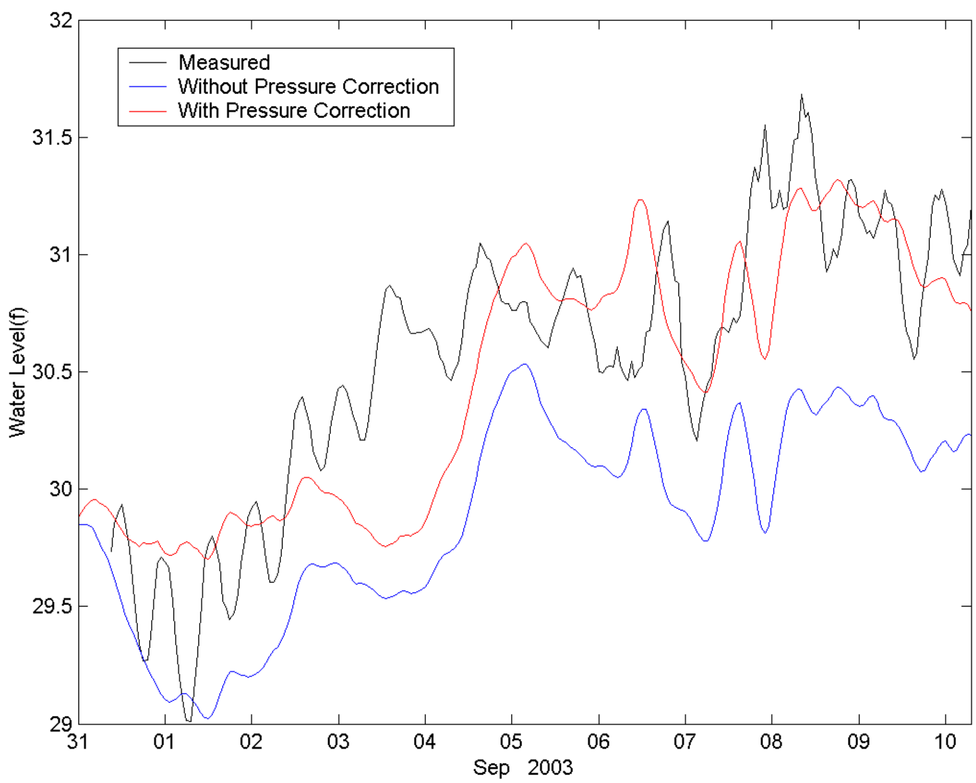

Figure 64. Comparison of Predicted Water Levels with/without the Inverted Barometer Correction and Observations at the Barrow ADCP Instrument Data at the -33 foot Site.

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% ice coverage. Figure 65 shows that the influence of varying degrees of ice coverage.

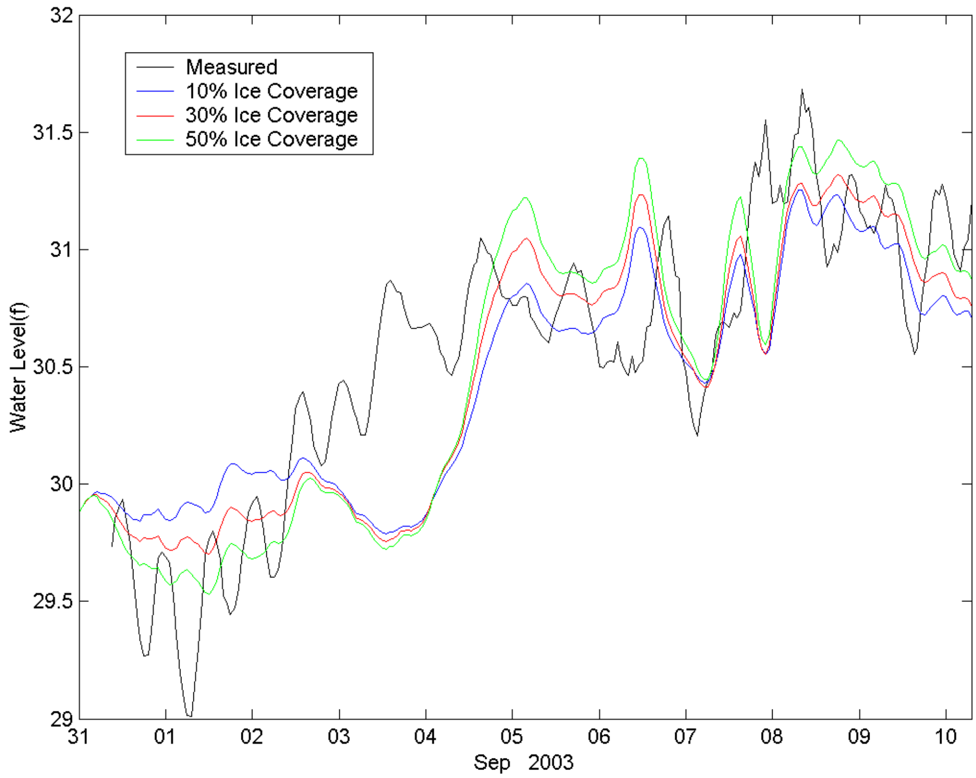

Figure 65. Influence of Varying Degrees of Ice Coverage.

The storm events simulated and the date of occurrence are presented in Table 10. 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 ft 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 10.

Table 10. 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 ft) and inverted barometer correction, which results in the "Total Surge" presented in Table 10. A brief description of EST is presented in Appendix 1. In order 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 11, which presents the stage-frequency distribution and standard deviation for 5 to 100 years.

Table 11. Summary of Frequency-of-Occurrence Relationships with Variable Tide Population.

Return Period Year	Elevation Feet MLLW	Standard Deviation Feet
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.

5.2.1. Calibration and Verification of ADCIRC. Calibration and verification of ADCIRC was performed using the water surface and current measurements collected during the August-November 2003 ADCP deployment (Evans- Hamilton, Inc, 2004). Calibration of the predicted current speed and direction was performed using the August-September field measurements. The calibrated model was then applied to the October 2003 measurement period for purposes of verifying model calibration. Figure 66 presents a comparison of the predicted depth averaged current with surface, mid-depth and near bottoms ADCP current measurements at the 33 foot depth site.

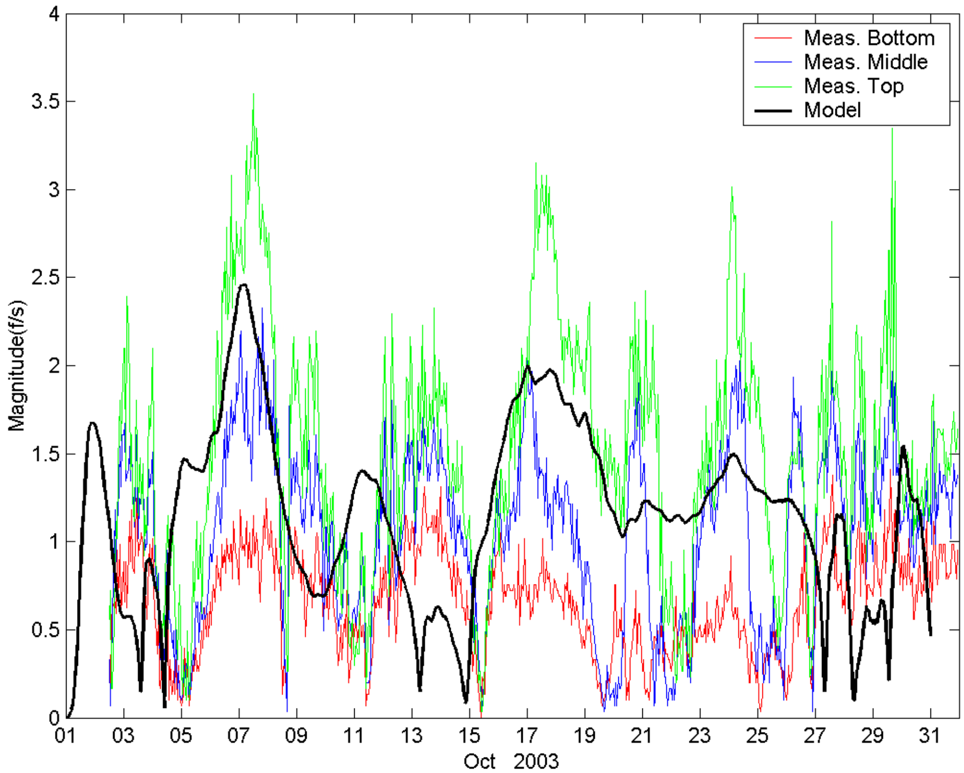

Figure 66. Comparison of Predicted Depth-Averaged Current Speed and Surface, Mid-Depth and Bottom ADCP Current Measurements at the 33 Ft Barrow Site.

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 66 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 67 that the change in current direction from the bottom to the surface exhibits a lag of more than two days during periods where changes in wind direction and strength are significant (Days 5-9, 15-19 and 23-26).

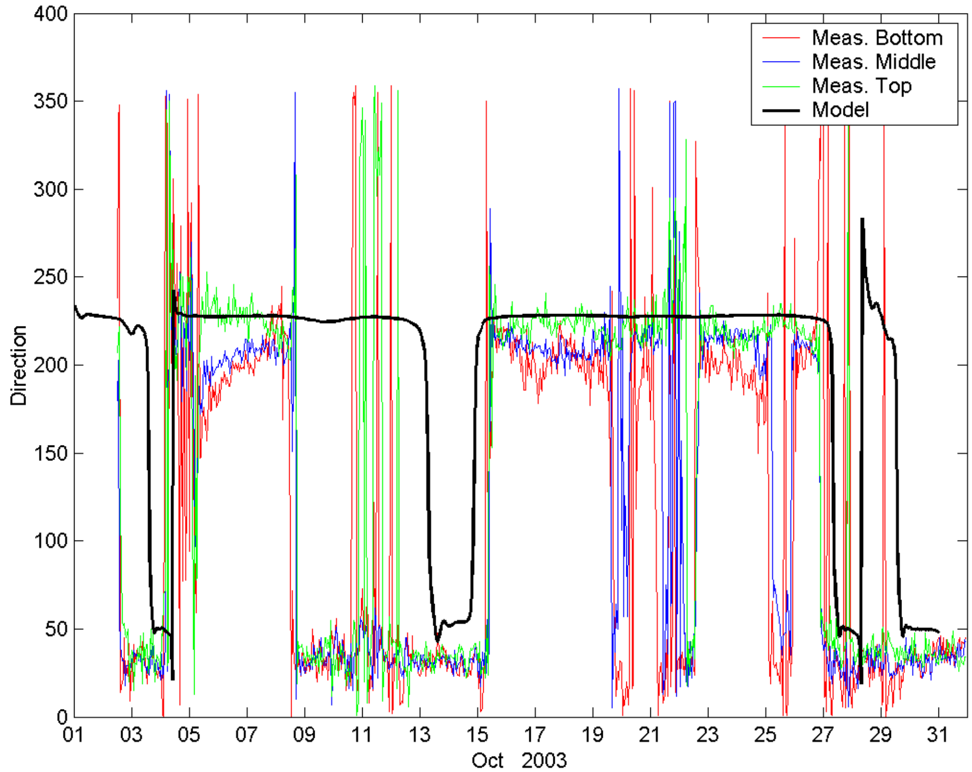

Figure 67. Comparison of Predicted Depth-Averaged Current Direction and Surface, Mid-Depth, and Bottom ADCP Current Direction Measurements at the 33 Ft Barrow Site.

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 in a northeast direction 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 68. 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 69, and a blowup of the active portion of this range line is shown in Figure X-70.

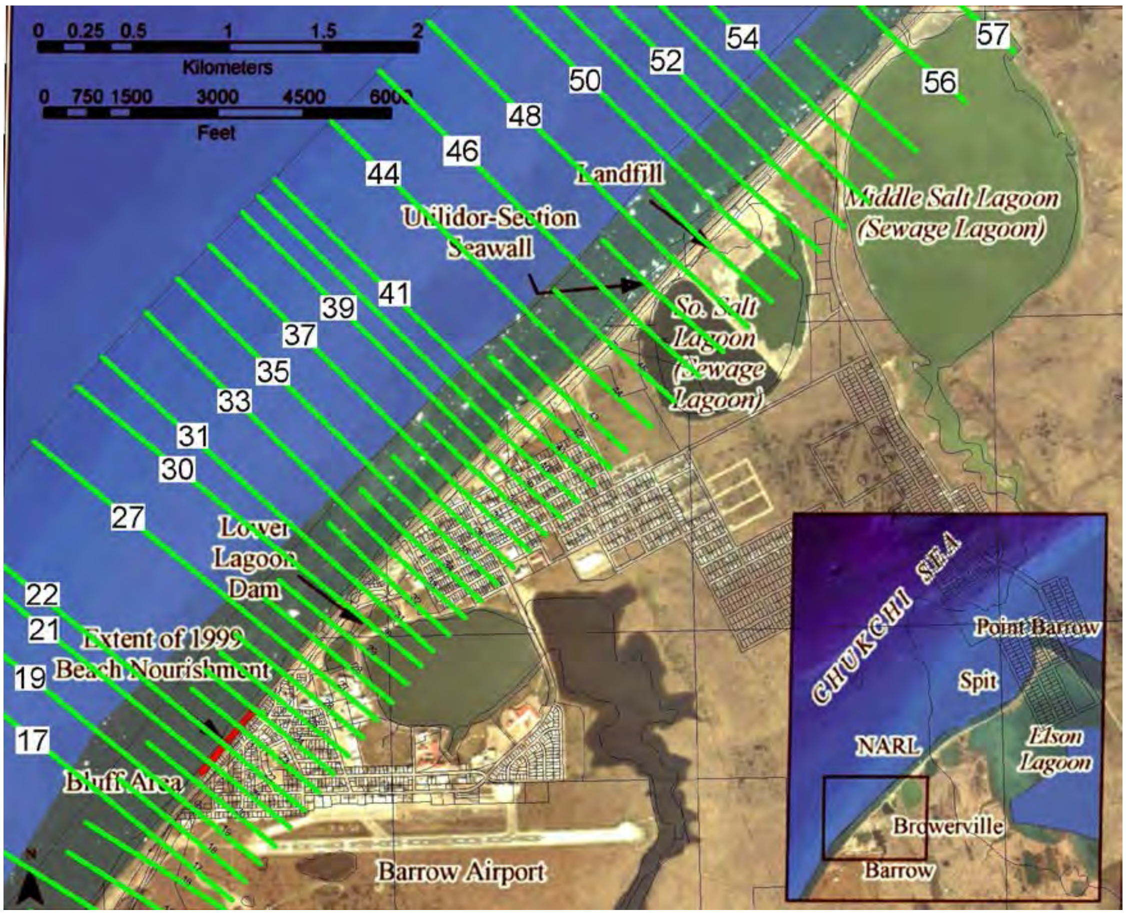

Figure 68. Transect Lines Along the Coast.

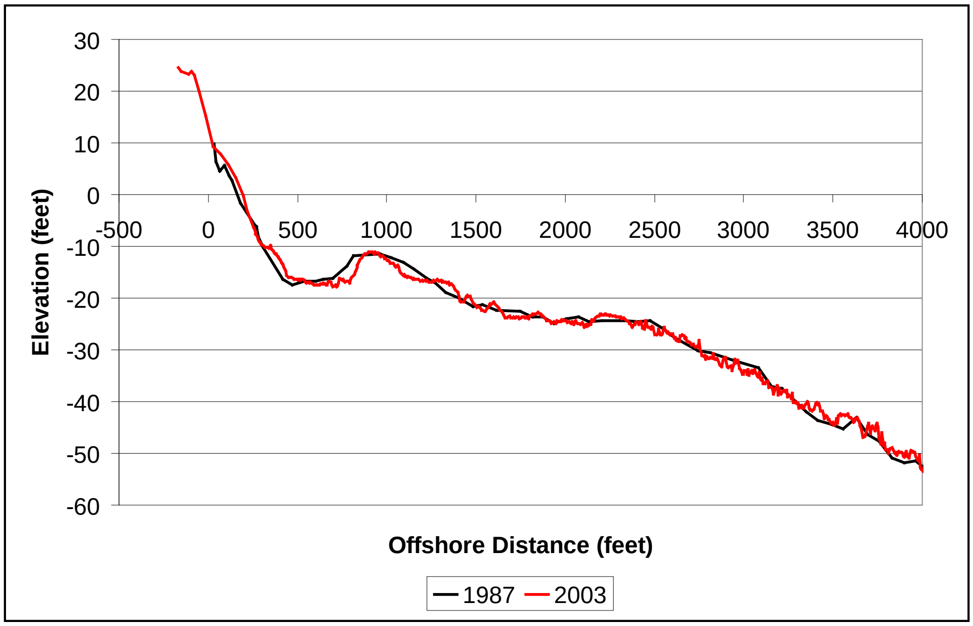

Figure 69. Comparison of 1987 and 2003 Profiles-Transect #22.

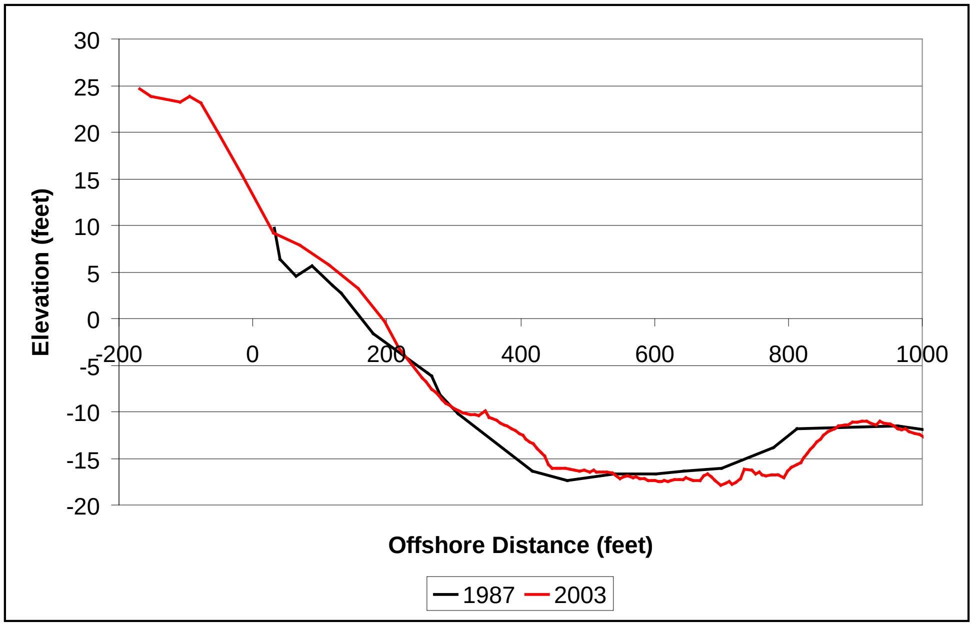

Figure 70. Blowup of Profile 22 Comparison Showing Active Portion of the Profile.

5.3.2. Longshore Transport. Longshore sediment transport at the site was evaluated using the formula of Soulsby (Soulsby, 1997), one of the few which 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 NE. 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 71 and 72. 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 0.05.

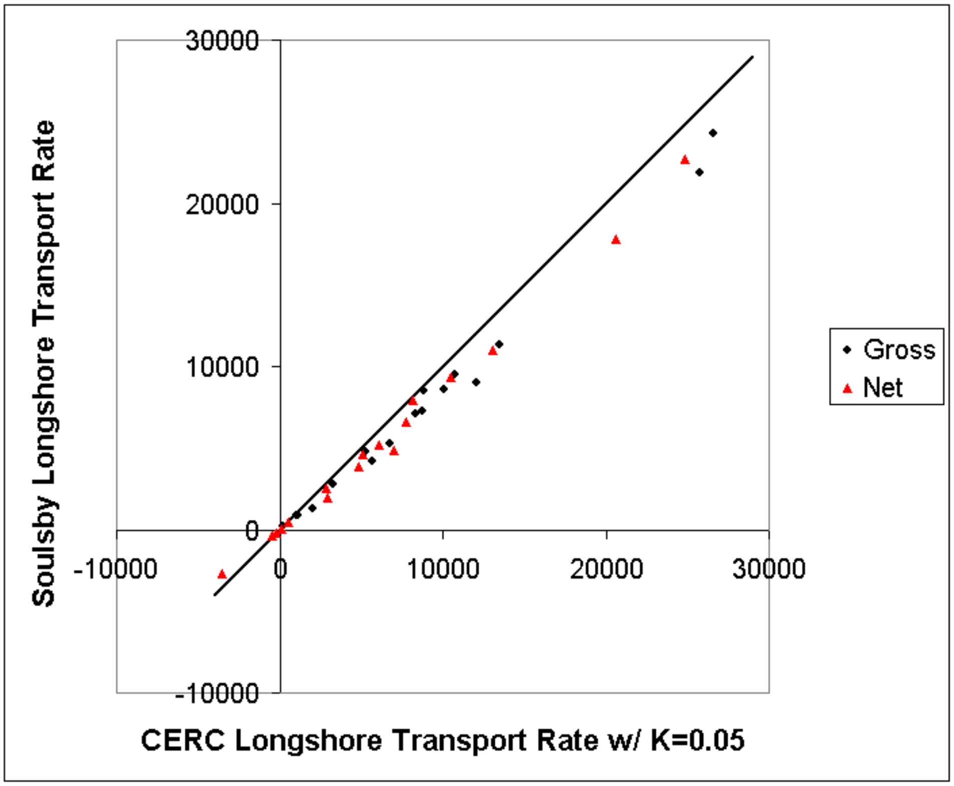

Figure 71. Comparison of Yearly Sediment Transport Rates (in yd^3/yr) Between the Soulsby and CERC Formulas.

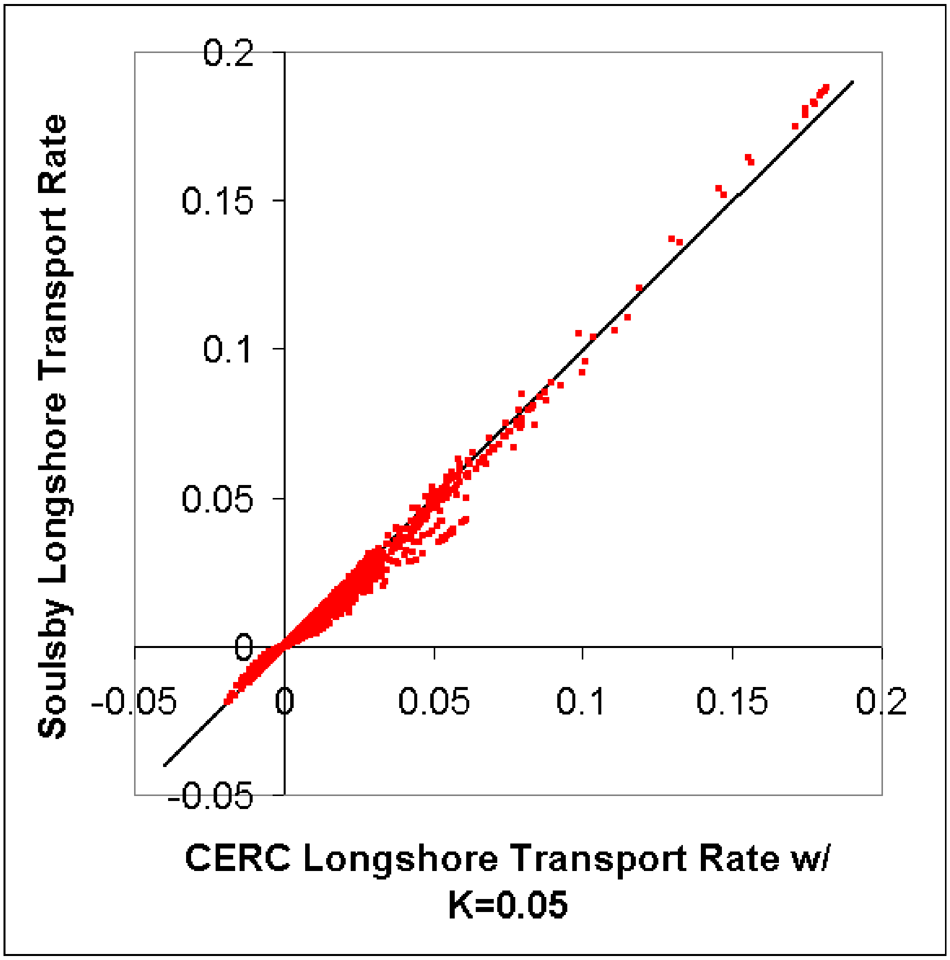

Figure 72. Comparison of Hourly Sediment Transport Rates (in yd^3/hr) Between the Soulsby and CERC Formulas.

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 68. An example of the digitized shore lines and bluff lines is shown in Figure 73. Overall erosion rates based on the aerial photography analysis are listed in Table 12. The location of the bluff line in 50 years based on that erosion rate is shown in Figure 74.

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

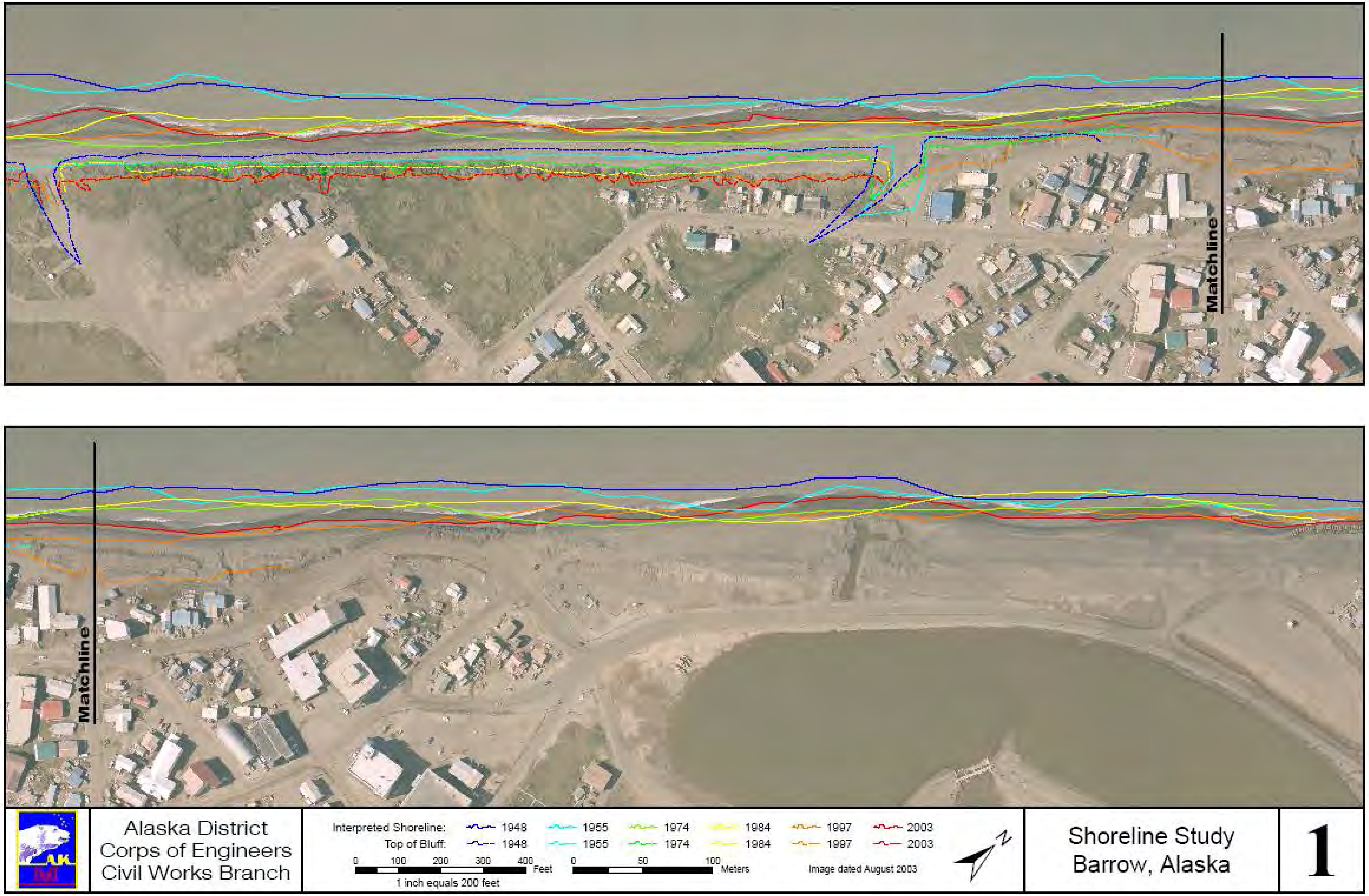

Figure 73. Example of Bluff and Shoreline Analysis.

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Table 12. Average Erosion/Accretion Rates

Reach	Bluff [1] [ft/yr]	Shore [ft/yr]
South of Gravel Pit		-1.04
City of Barrow [2]	-1.08	-1.05
Water Supply	NA	-0.72
Browerville	NA	+1.12
Landfill/Sewage Lagoon	NA	-0.61

[1] 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.

[2] Maximum bluff erosion rate is 1.5 ft/yr and maximum shoreline erosion rate is 1.93 ft/yr

Erosion noted by –

Accretion noted by +

Figure 74. Location of the Bluff Line in 50 Years.

The coastal erosion is well documented with aerial photography. The differences in the shoreline movement were plotted in time increments to determine if the erosion along the coast is episodic or consistent through the years (Figure 75). Between 1948 and 1955 the plots indicate typical shoreline behavior with areas of erosion and accretion occurring. Between 1955 and 1974 there was a large amount of shoreline erosion that 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 time period. The concentration of erosion during one time period indicates that 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 there is a large volume of material is moved. This leaves the coast after the 1955 to 1974 time period 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 when the highest storm water levels occurred and 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 time period saw road, airport, and building construction requiring foundation material. To facilitate the construction associated with this development, there was a great deal of material borrowed from the beach.

6.1. 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 76 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 (Figure 77 and 78). 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 79). It was during this time period that the Wiley Post-Will Rogers Memorial Airport was built, the Samuel Simmonds Memorial Hospital was built. A comparison of aerial photographs from 1962 and 1964 shows the rapid growth that was experienced during that period (Figures 80 and 81).

The head of the Naval Arctic Research Laboratory, Dr. Max Brewer, estimated that, in all, 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 NSB (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.

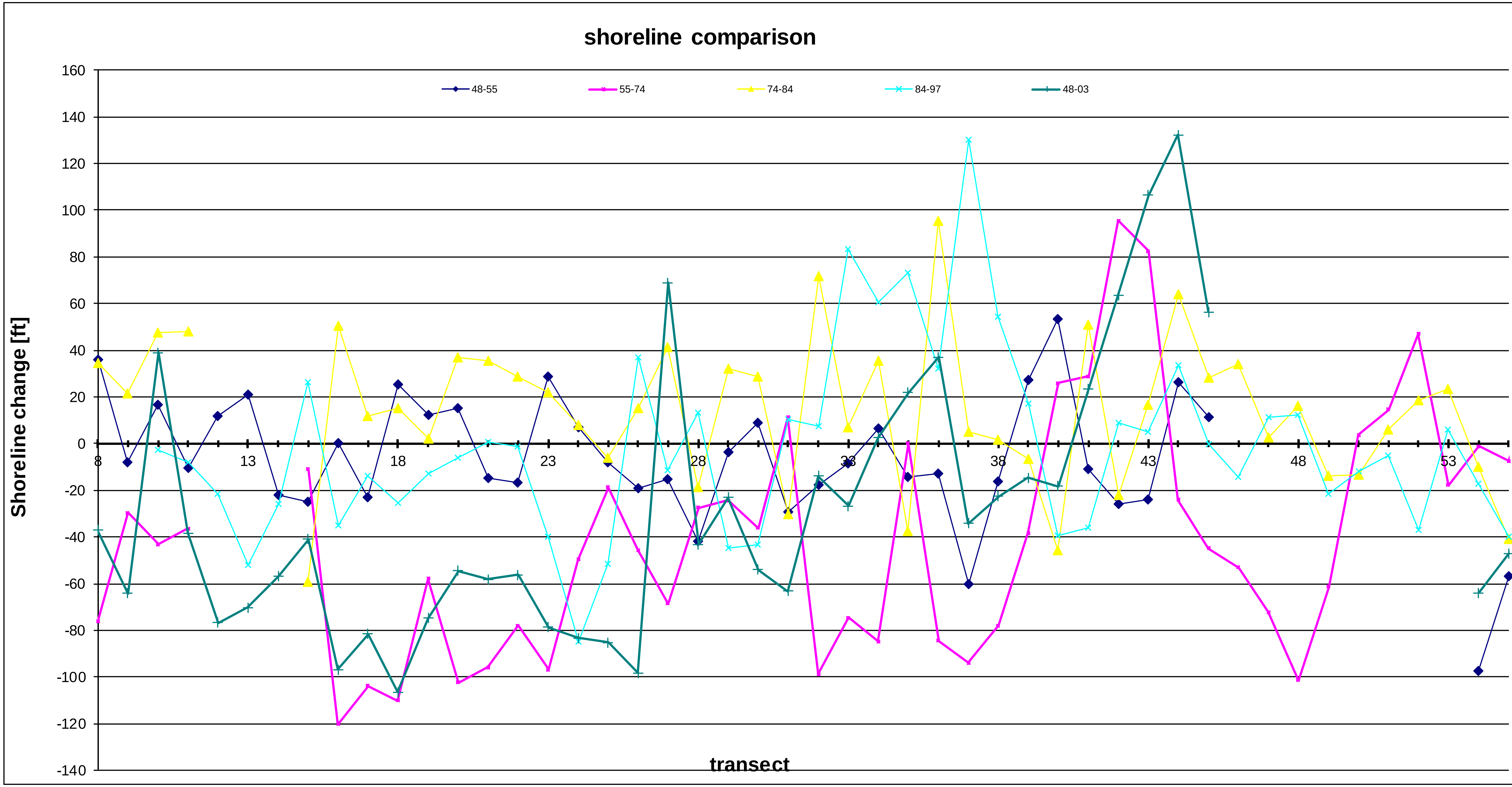

Figure 75. Change in Shoreline.

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Figure 76. Drag Line at NARL.

Figure 77. Haul Road from the Beach Leading to the Airport During Construction.

Figure 78. Close Up of Haul Road.

Figure 79. Scalloped Shoreline Consistent with Beach Borrowing.

Figure 80. 1962 Aerial Photograph.
(National Snow and Ice Data Center photo)

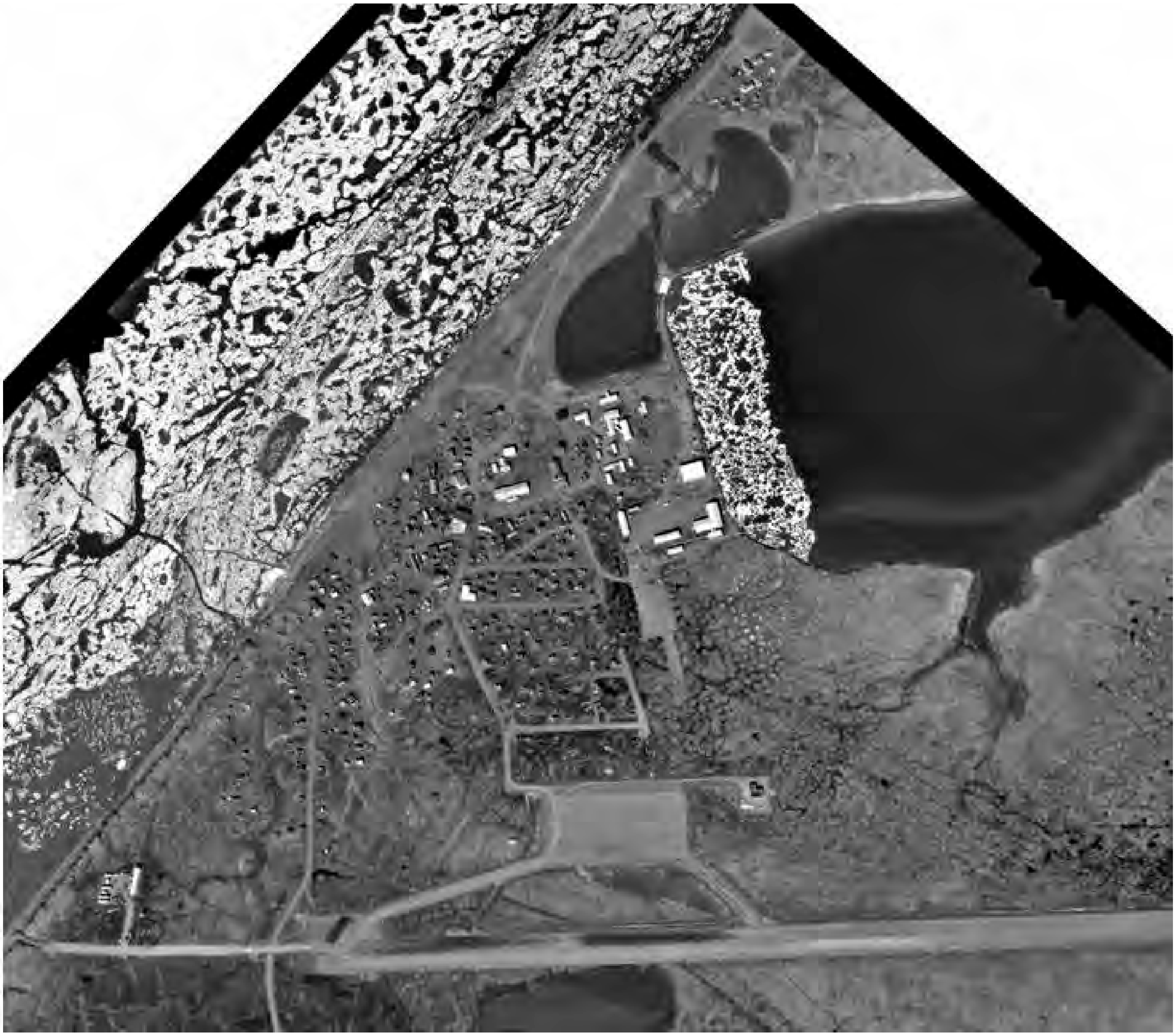

Figure 81. 1964 Aerial Photograph.
(National Snow and Ice Data Center photo)

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 82 and 83). 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 of rate. 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 83 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.

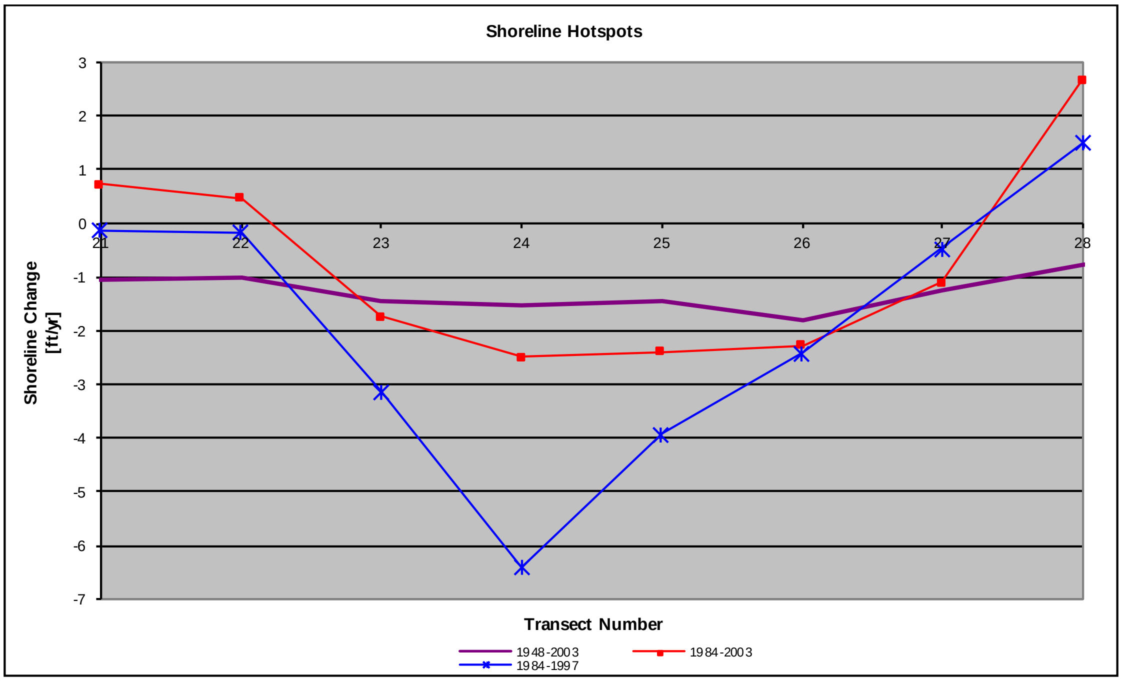

Figure 82. Plot of "Hot Spot" Areas of Persistent Erosion.

Figure 83. Aerial Photograph of "Hot Spots".

7.0 COASTAL FLOODING

Coastal flooding at Barrow results from wave runup 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 84) 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 85 to 88. (Note the variation in berm crest between the various profiles, which influences the volume of water washed over the crest. Because the coastal flooding results from wave runup, it 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, 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.

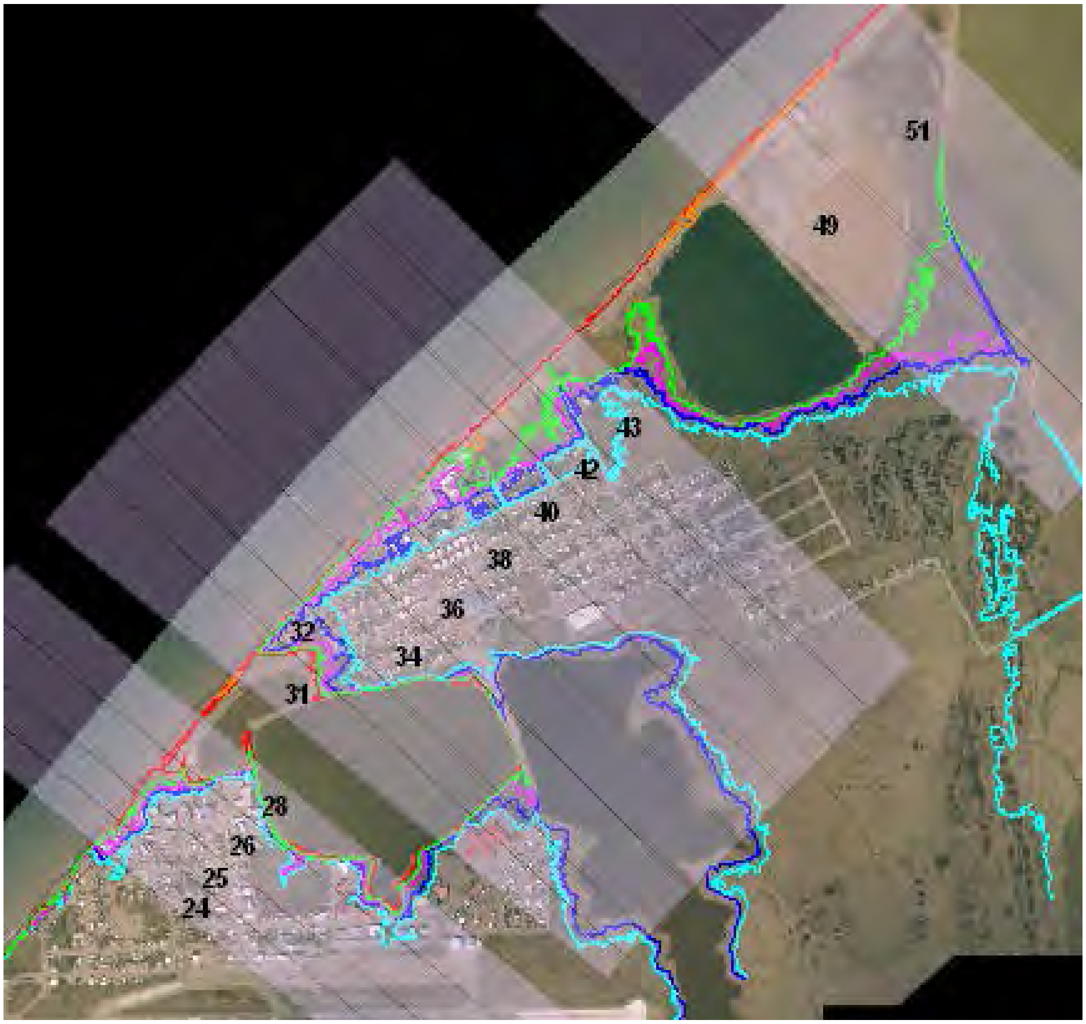

Figure 84. Study Area with Reaches 24-51 Shown Identified and Elevation Contours (red=8ft, green/orange=10ft, pink=12ft, blue=14ft, cyan=16ft).

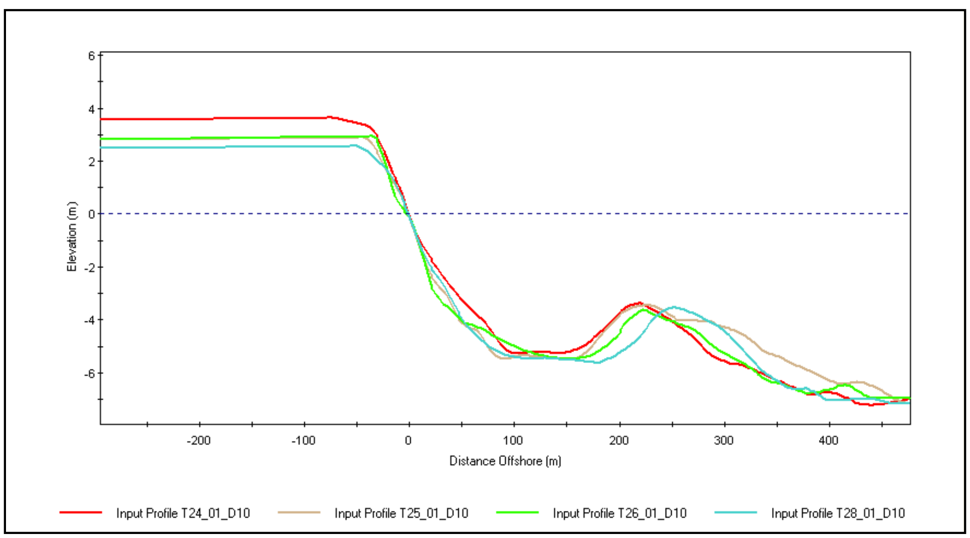

Figure 85. Beach Profiles for Reaches 24, 25, 26, and 28.

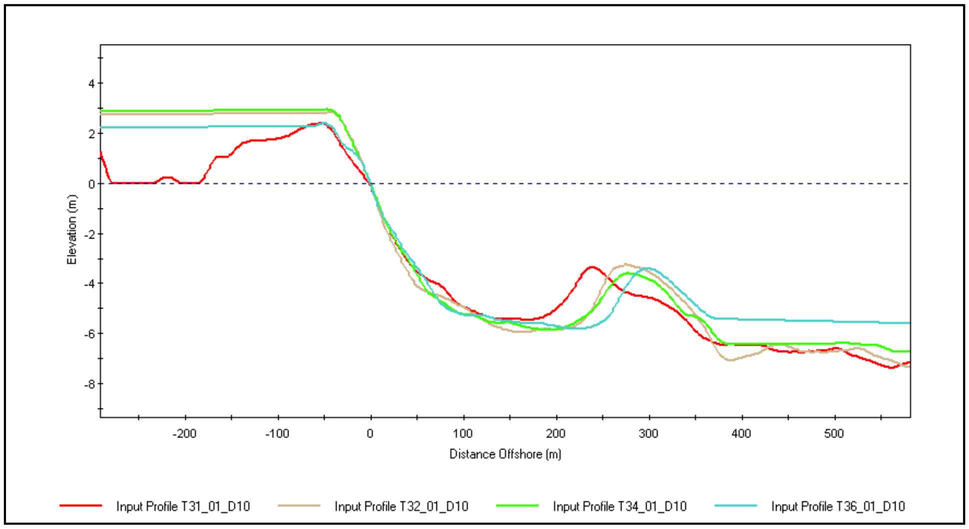

Figure 86. Beach Profiles for Reaches 31, 32, 34, and 36.

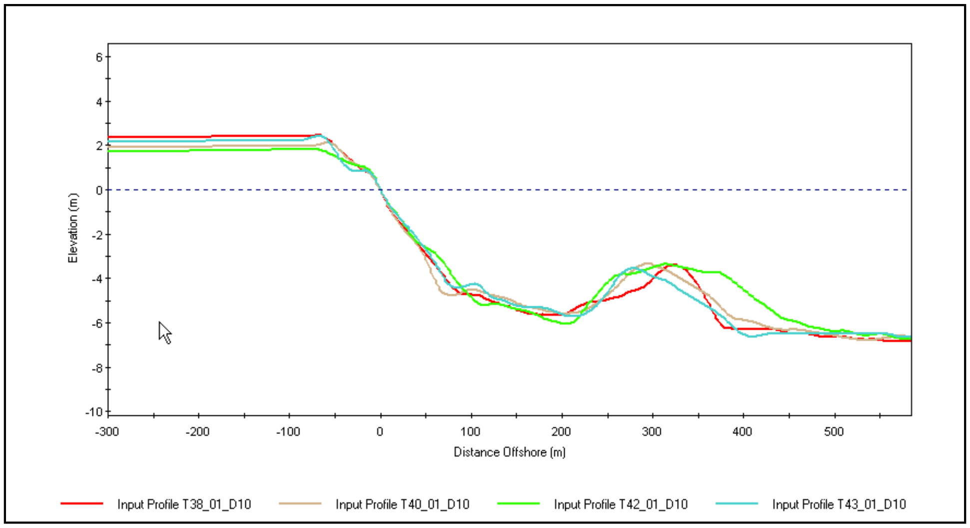

Figure 87. Beach profiles for Reaches 38, 40, 42, and 43.

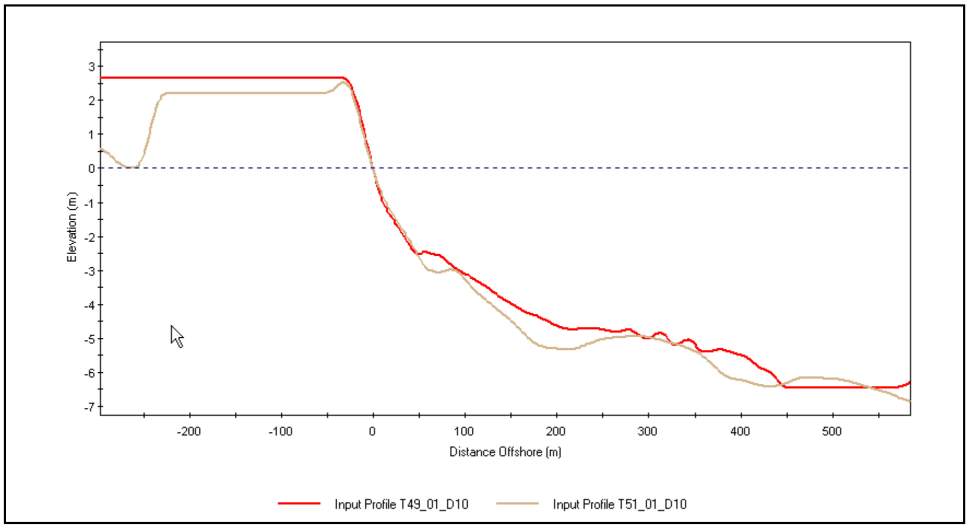

Figure 88. Beach profiles for Reaches 49 and 51.

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. 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 runup that exceeds the dune crest. For the case of overwash, the total water level (tide + surge + wave setup) remains below the dune crest elevation, but wave runup 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 setup 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 of runup calculated by the model. With this approach, the bore depth at the dune crest is zero when the maximum runup elevation is less than or equal to the dune crest, and increases as the calculated runup 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 runup is periodic. However, because rms runup is employed in the model as an estimate the time-averaged runup 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 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 89 shows an example of the calculated and smoothed volume fluxes for the 1986 storm.

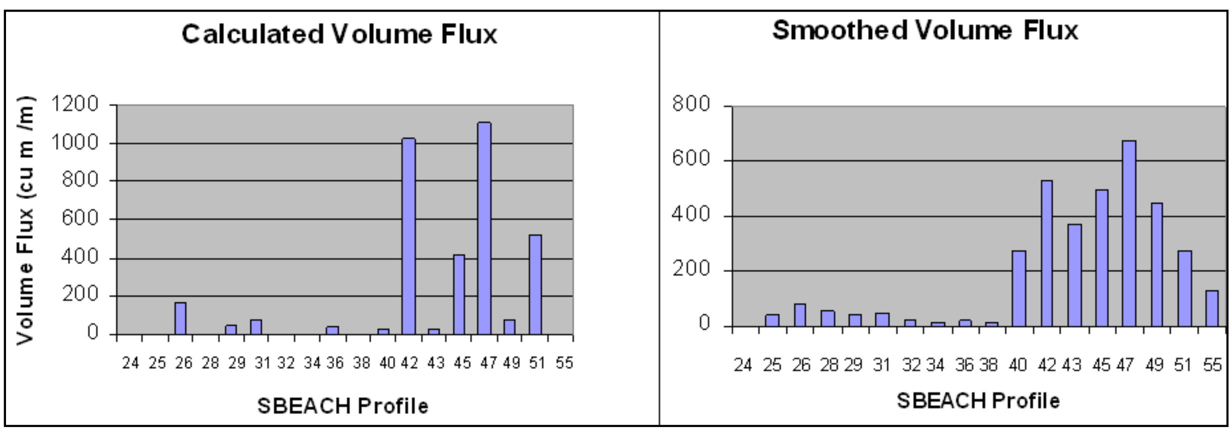

Figure 89. Volume Fluxes for September 19, 1986 Storm.

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 within 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 (i.e. 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 ft above the highest contour in the reach.

The calculated flood exceedance probabilities are presented in Table 13. 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 further 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 the runup flooding is topographically controlled, the stage-frequency curve is reach-dependent. Separate curves were generated for each reach and are given in Figures 90 to 103. 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 13. 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						

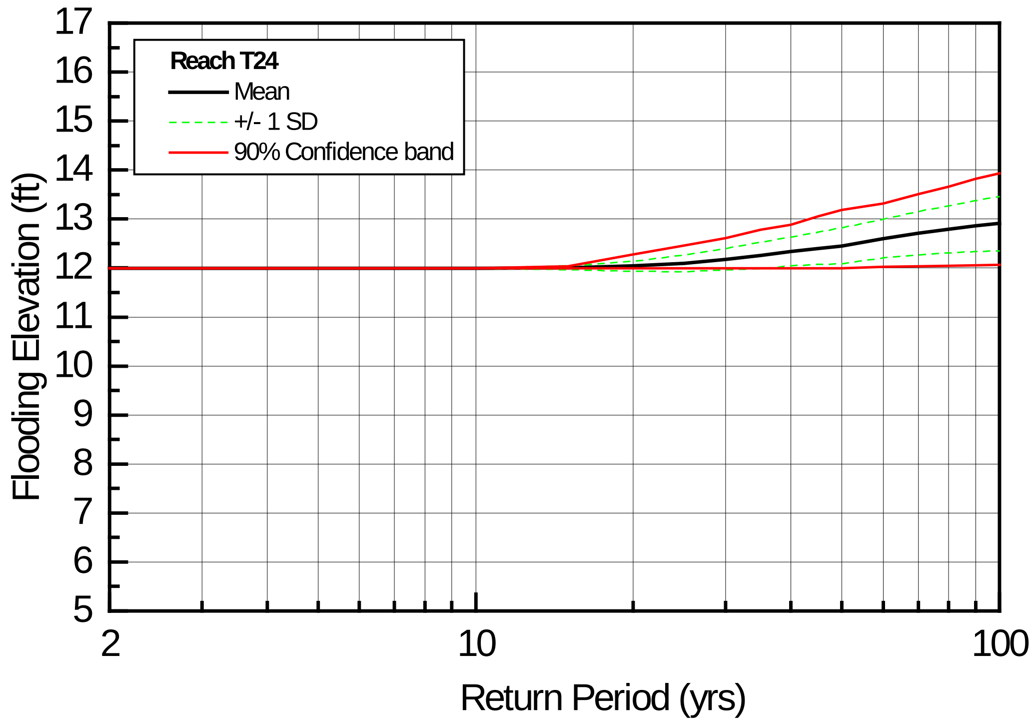

Figure 90. Stage-Frequency Curve for Damage Reach 24.

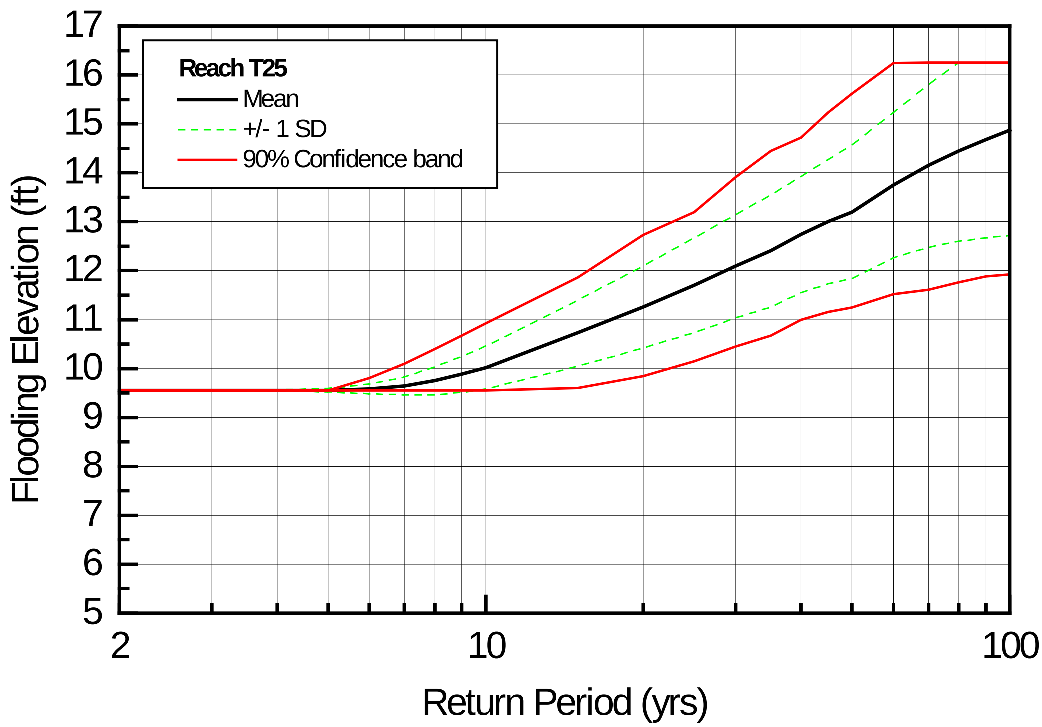

Figure 91. Stage-Frequency Curve for Damage Reach 25.

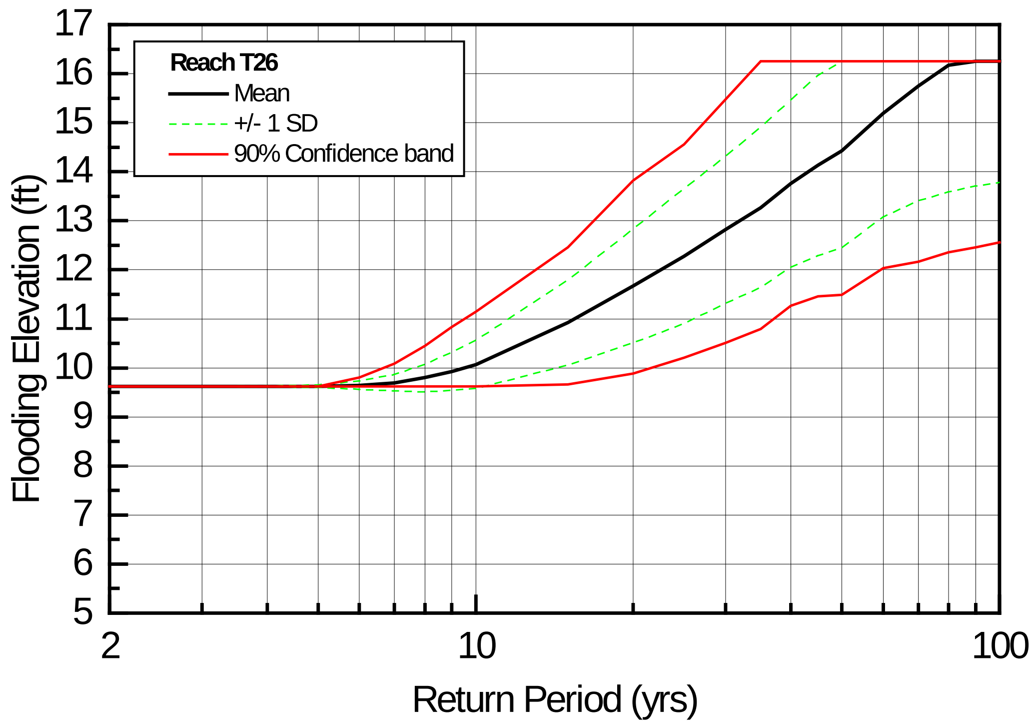

Figure 92. Stage-Frequency Curve for Damage Reach 26.

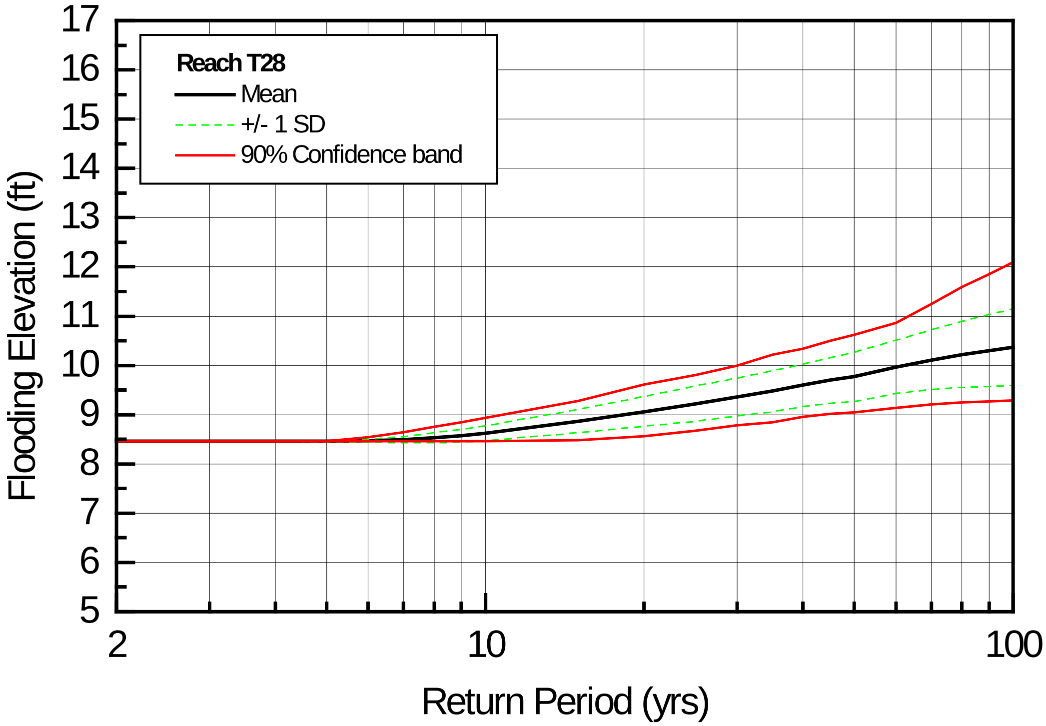

Figure 93. Stage-Frequency Curve for Damage Reach 28.

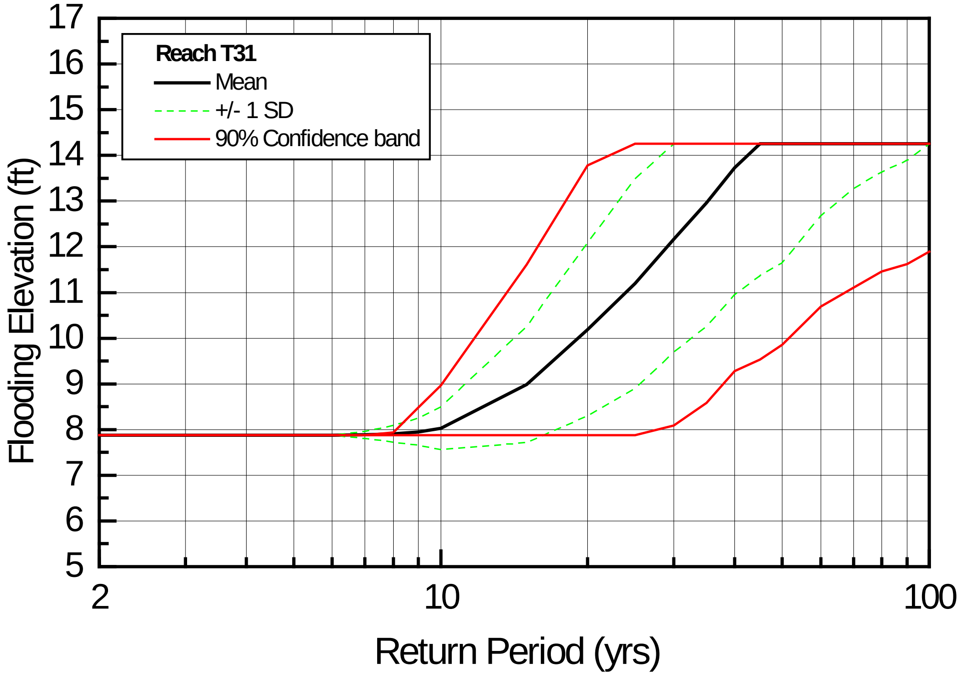

Figure 94. Stage-Frequency Curve for Damage Reach 31.

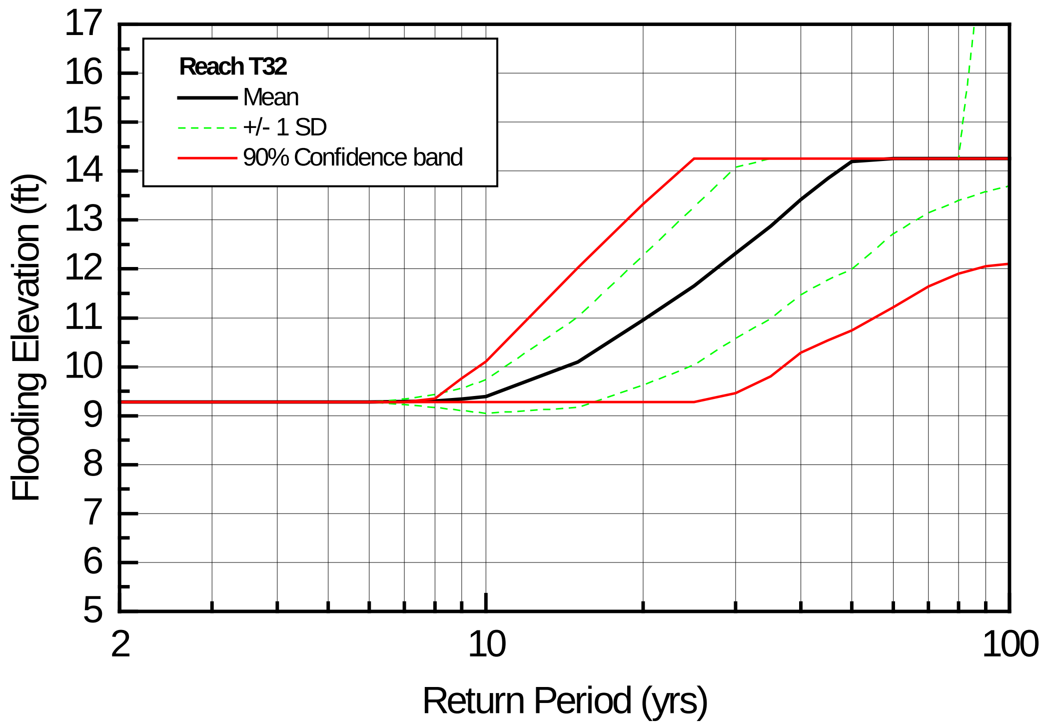

Figure 95. Stage-Frequency Curve for Damage Reach 32.

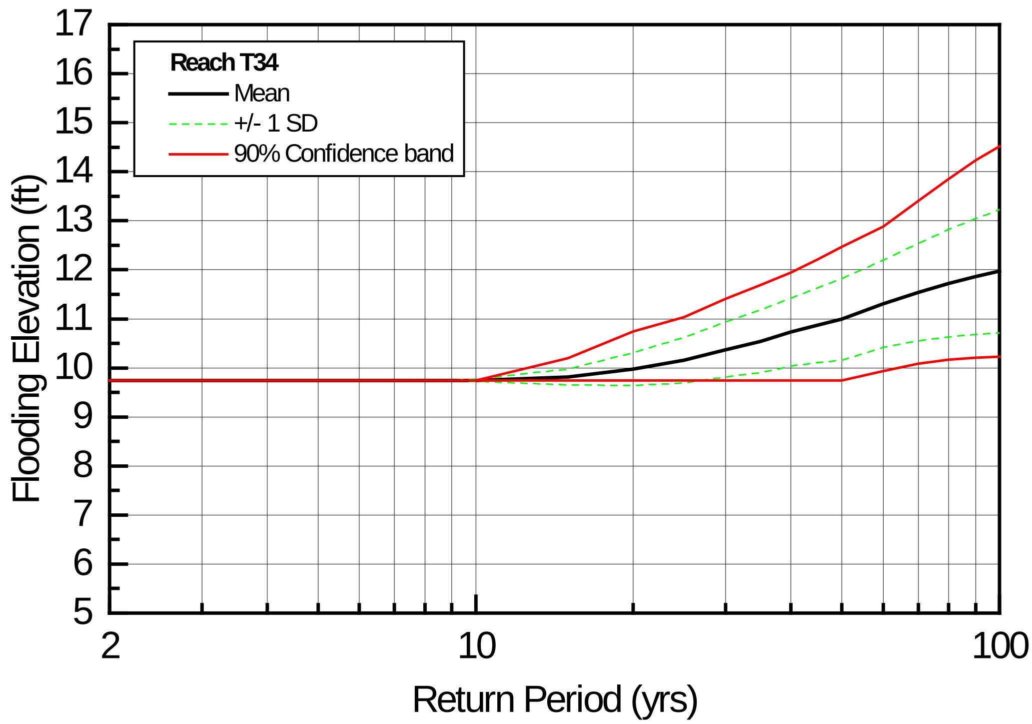

Figure 96. Stage-Frequency Curve for Damage Reach 34.

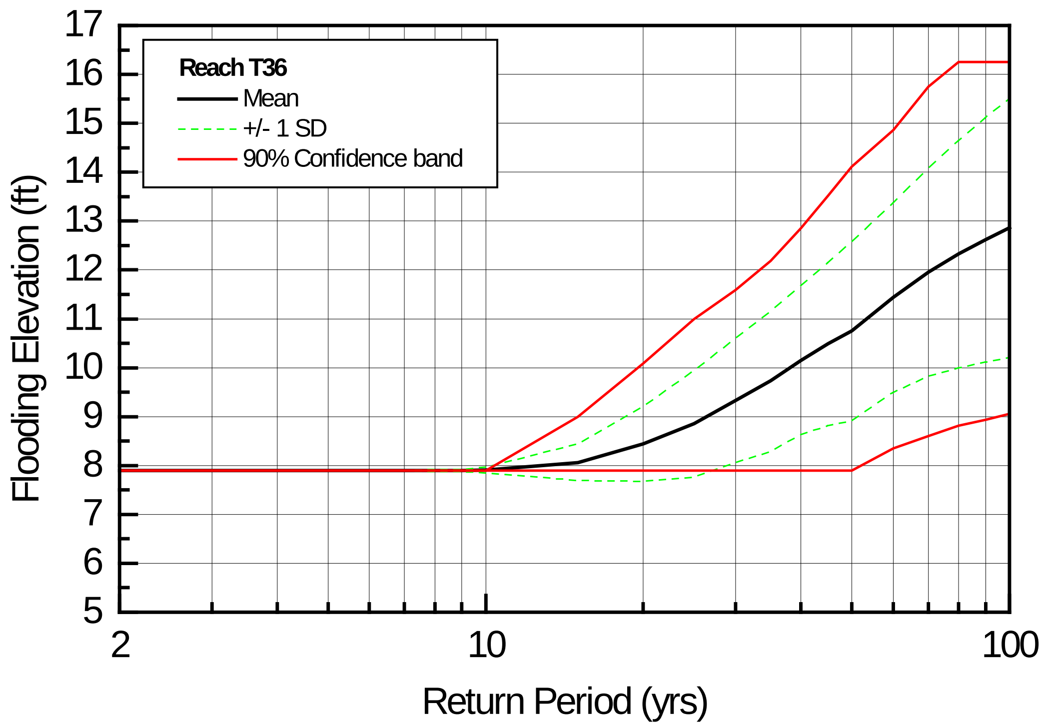

Figure 97. Stage-Frequency Curve for Damage Reach 36.

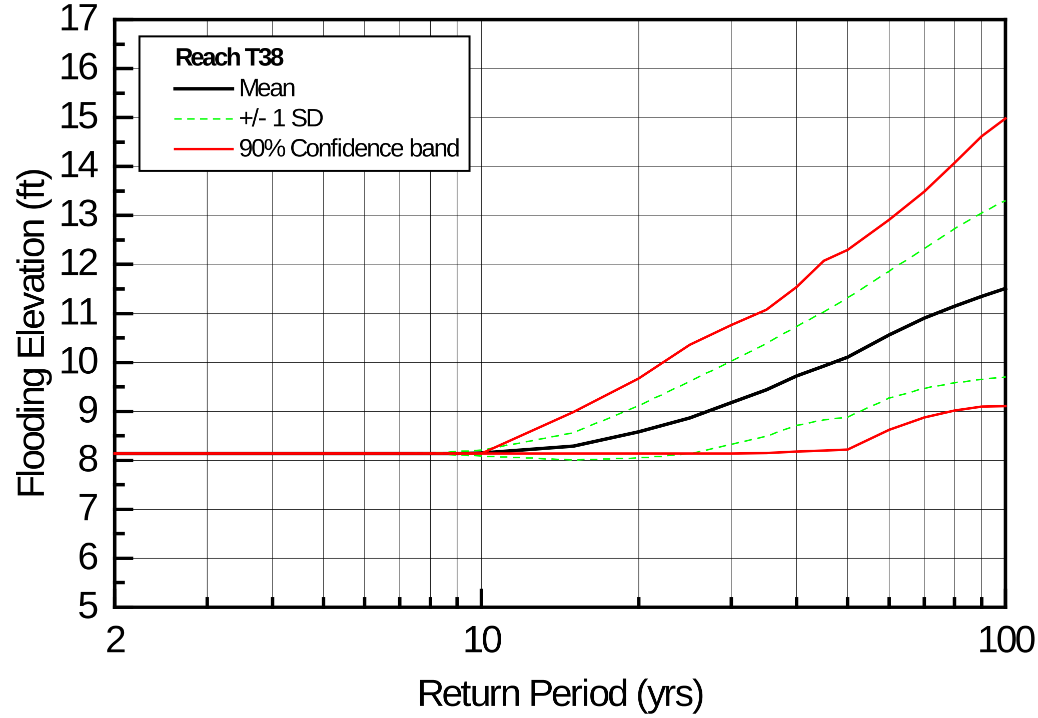

Figure 98. Stage-Frequency Curve for Damage Reach 38.

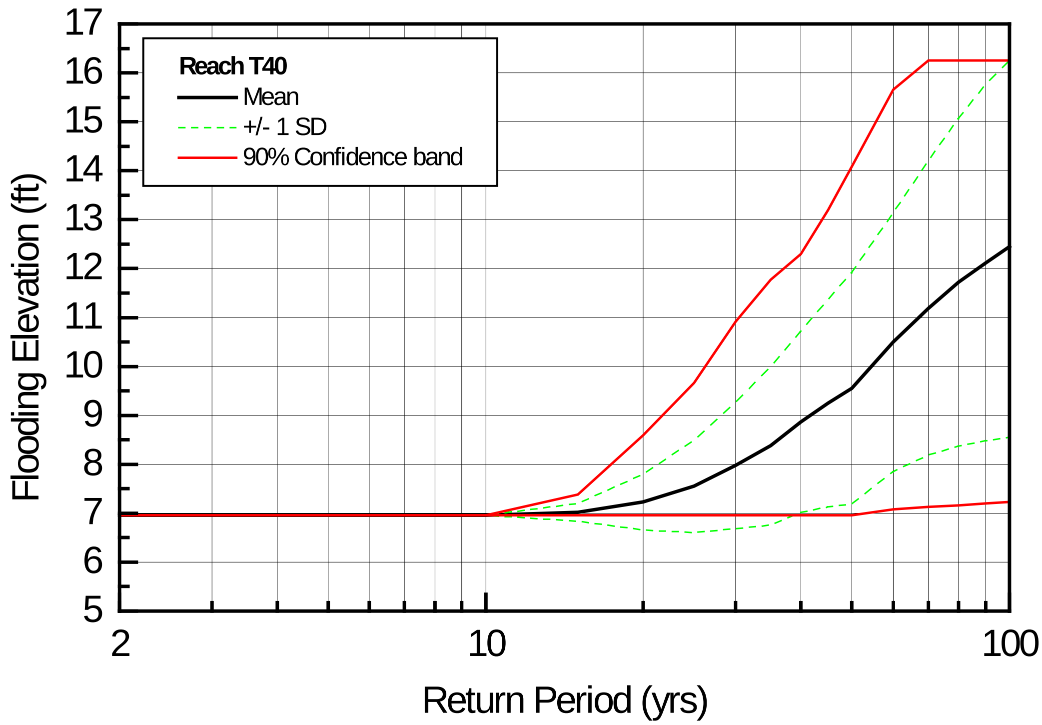

Figure 99. Stage-Frequency Curve for Damage Reach 40.

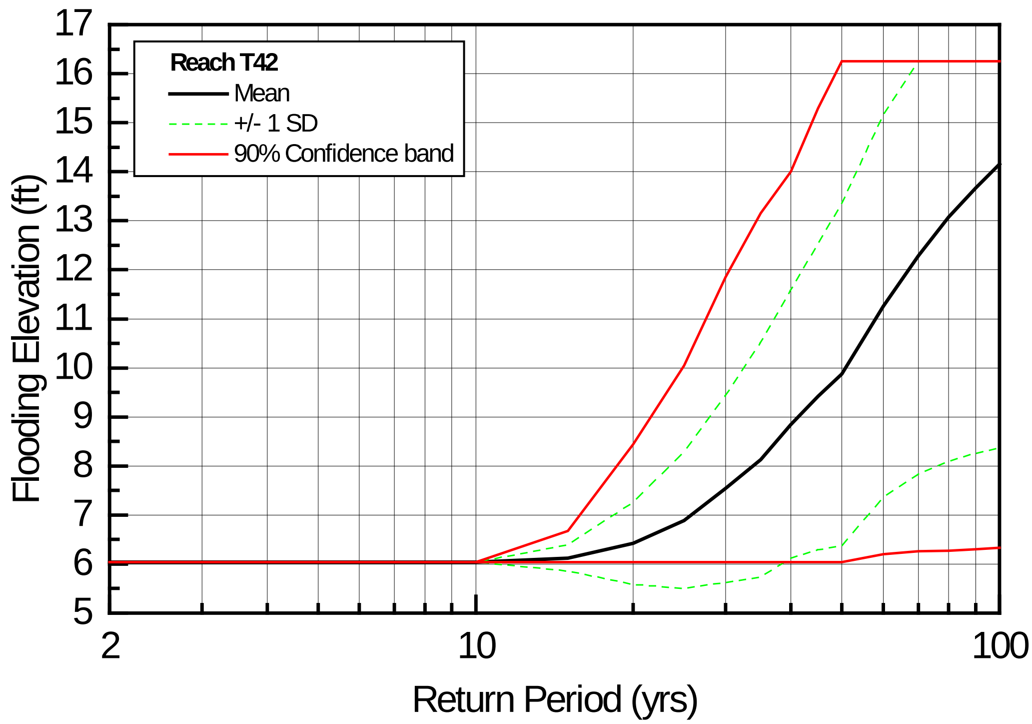

Figure 100. Stage-Frequency Curve for Damage Reach 42.

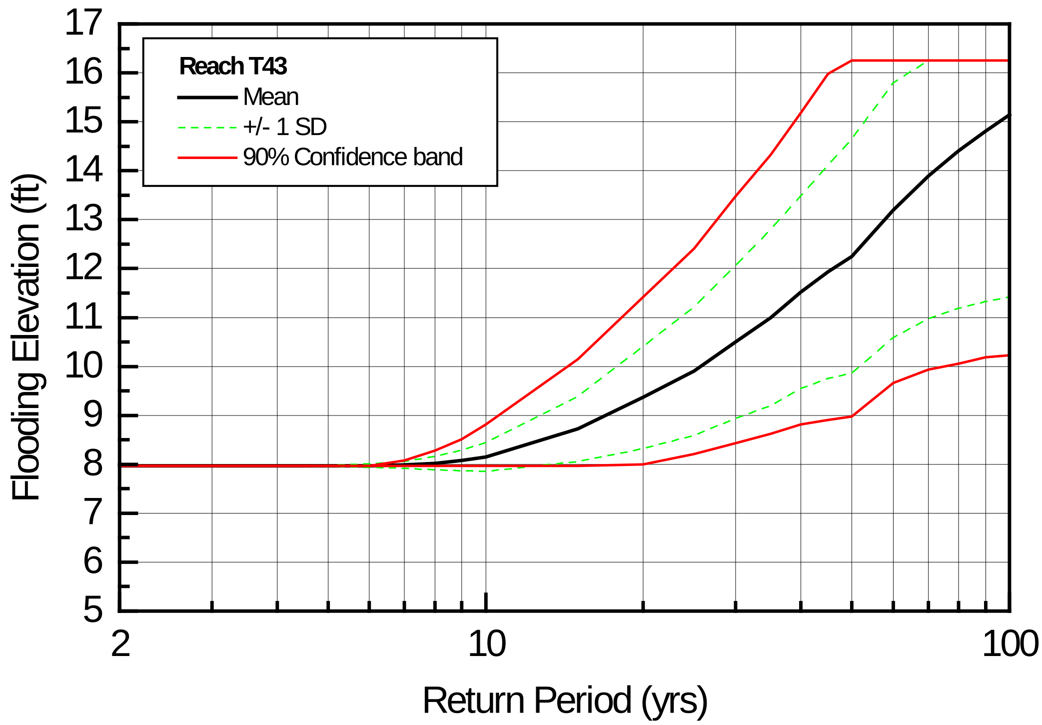

Figure 101. Stage-Frequency Curve for Damage Reach 43.

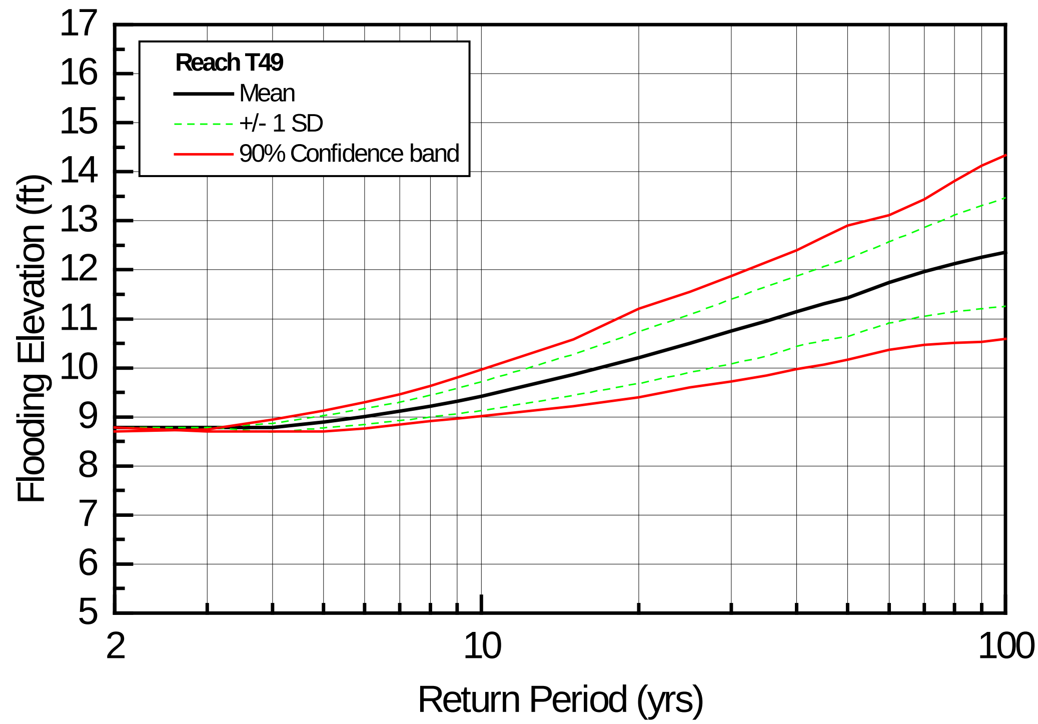

Figure 102. Stage-Frequency Curve for Damage Reach 49.

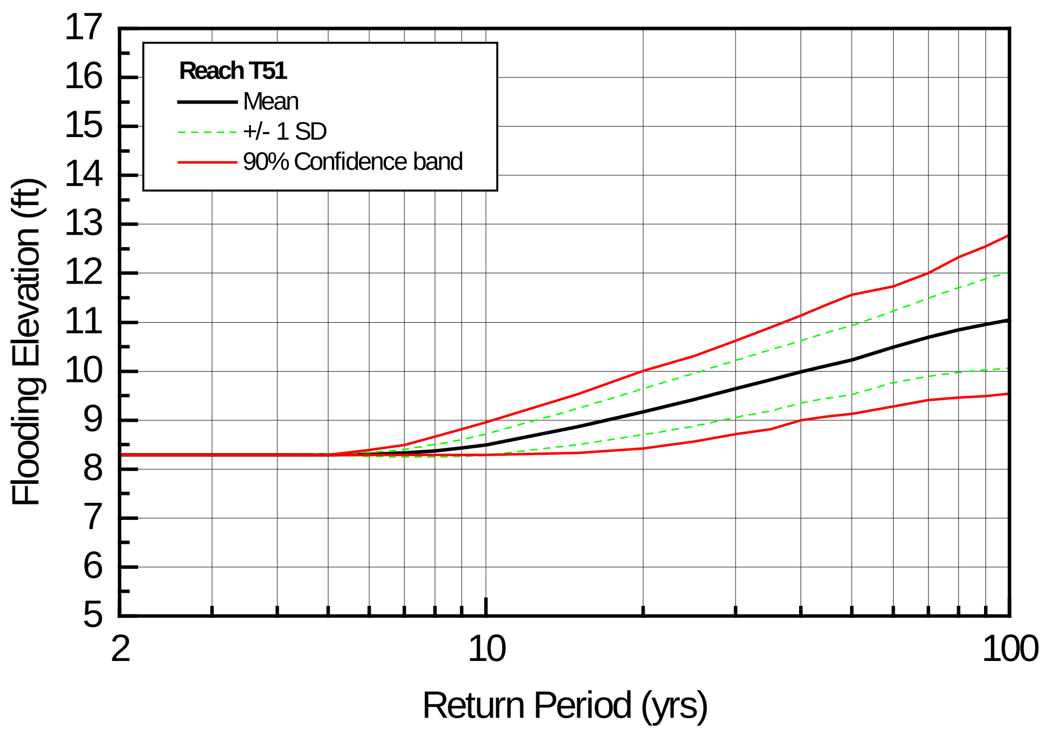

Figure 103. Stage-Frequency Curve for Damage Reach 51.

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 ft. These calculation estimates do not include any flood protection berm feature such as the temporary ones that the city puts in place during before and during a storm or any proposed structure.

7.1. Model Verification

Water level measurements during storm events against which the model results could be checked were limited because of the proactive nature of the community during storm events. The NSB actively combats flooding before and during every threatening storm event 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 comprised 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 the 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 event. 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 of 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 comprised 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 is melted, 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 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. The 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 relocate structures, roads and utilities that would be impacted by the erosion. Alternative land parcels would need to be available for the 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. Eroding bluffs have been successfully protected by revetments in many locations throughout Alaska. 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 the revetment include rock, supersacks, and articulated concrete mats. 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.

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 the beach nourishment was heavily damaged during a storm event 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. Four 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 known as the Bureau of Indian Affairs (BIA) site, a submerged spit off of Point Barrow (Figure 104), and Colville River.

All the potential sites except for the submerged spit and Colville River 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.

Seawalls. The purpose of a seawall (Figure 105) is to protect the land and developments behind it. 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 is often damaging, particularly to the shoreline in the zone of the reflected wave. 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.

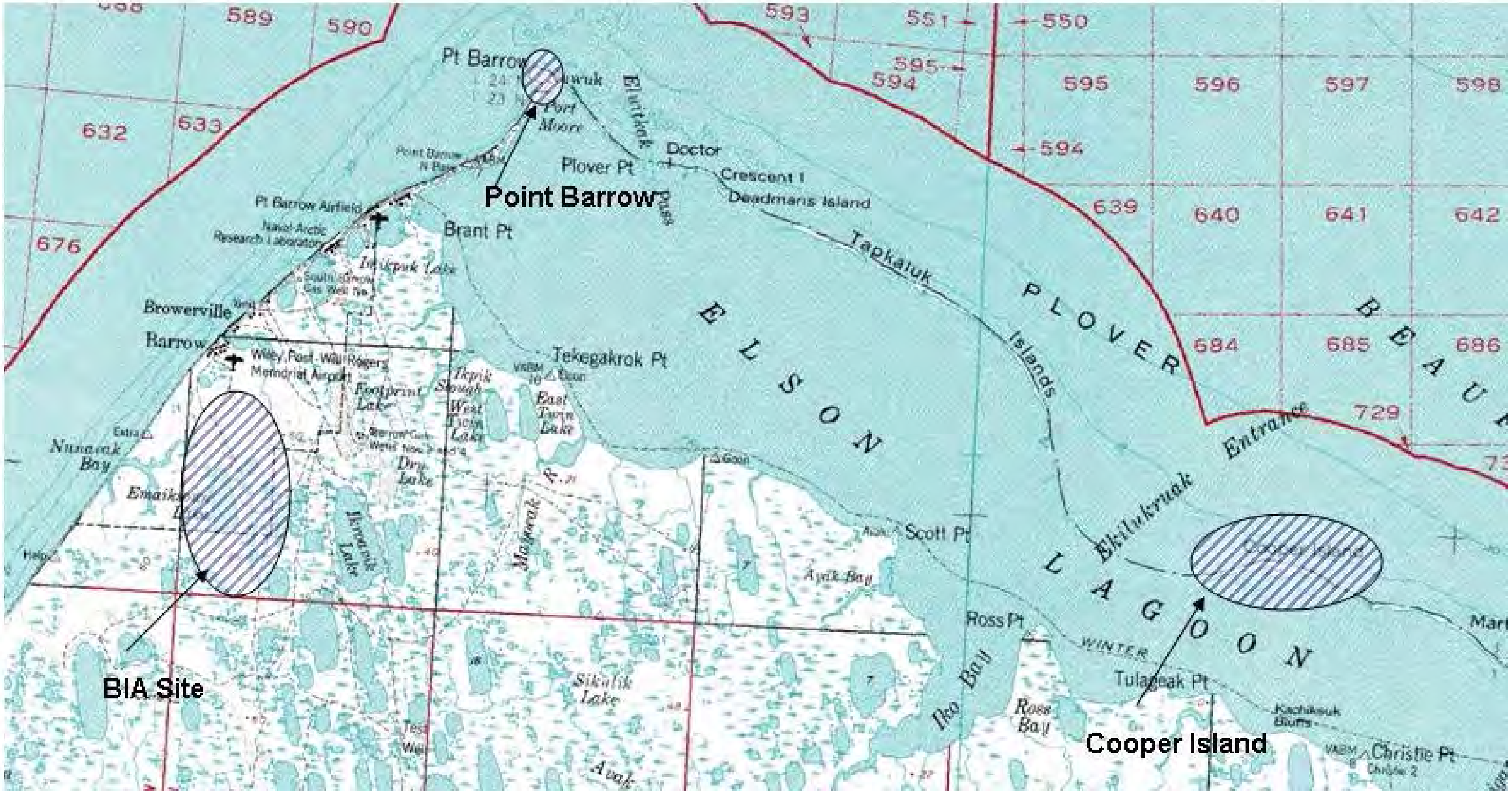

Figure 104. Potential Gravel Sites from Geotechnical Investigation.

Figure 105. 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 of the project area due to the interruption of the natural sediment transport system, so 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 14.

Table 14. 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 tor 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 storm events. Flooding occurs during storm events 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 of the flood area. This alternative would require that parcels be available for the structure relocation. Flood damage at Isatkoak Lagoon could be addressed by raising the height of the spillway, filling Tasigarook Lagoon, or building a revetted berm in from of the lagoon to protect the community's fresh water source.

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 Stevenson Street or Stevenson Street could be raised and the seaward side of the street could be revetted. 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 an increased maintenance requirements. The NSB 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, Browerville, and NARL. 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 sea wall 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 15.

Table 15. 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 tor 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, articulated concrete mats, and rock. The HESCO system 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 due to 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.

Beach Fill. Beach fill has not been used in Alaska to prevent erosion, but it is a viable solution in Barrow. The 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 or larger sand 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 and rock. The HESCO system 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 or coarse sand 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 run up elevation used in the design is the SBEACH elevation. The ADCIRC modeling is being updated for the 2004 to 2017 hindcast and the SBEACH modeling is being updated with CSHORE modeling.

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 further offshore. This adds an additional level of uncertainty to the EST results. The return frequency interval for storm setup (combined elevation of tide plus storm surge, plus wave setup) is shown in Figure 106.

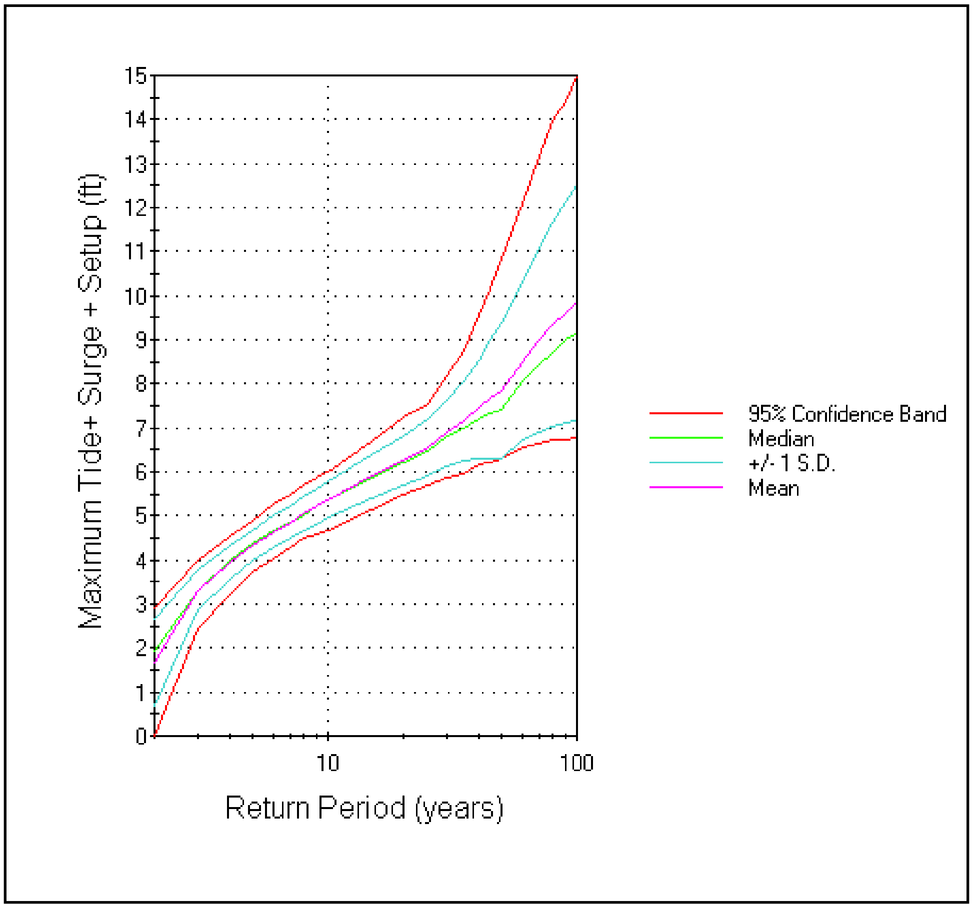

Figure 106. Stage Frequency Curve for Set Up Elevation.

A comparison of the two hand calculated results is shown in Table 16. The set up elevation with the base elevation from ADCIRC added in is shown in Table 17 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 16. Wave Set Up.

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 17. Water Levels.

Water Elevation ADCIRC + Wave Set Up	20-year Wave Set Up (feet)	50-year Wave Set Up (feet)	100-year Wave Set Up (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.

The 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.

Runup was calculated using methods for a rock armored surface shown in the Coastal Engineering Manual. The runup elevation was added to the SBEACH water elevation in Table 18 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 18.

Table 18. 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 19.

Table 19. 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

The 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 shore line; 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% 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 ton. 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 CRREL.

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. 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 of 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 107) 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 107. 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 108. Before and after pictures from the testing are shown in Figures 109 and 110.

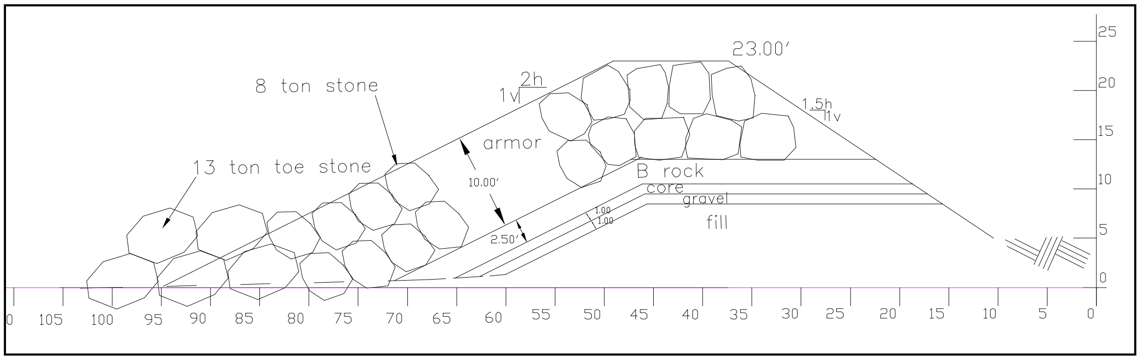

Figure 108. Idealized Cross Section from Ice Tests with Best Survivability from Physical Model.

There were many uncertainties associated with the ice testing. The recurrence interval of ivus and the 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 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 the stone quantity and elevation, the B stone layer was reduced from two layers to one for a revetment designed for ice (Figure 108).

Figure 109. 8-Ton Armor Stone (Blue Slope) with 13 Ton Toe (Red Toe Stone) Revetment Before Ice Testing.

Figure 110. 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

Two designs were pursued to determine which was most advantageous for coastal protection. Structures designed with armor stone sizing governed by wave height and beach nourishment alternatives assuming that gravel or coarse sand for nourishment would be imported. Structures designed to withstand most ivu events were not considered for a final design. This will require that the structures be inspected each year to access ice damage and maintenance performed as needed.

8.5.2 Bluff Protection Governed By Waves

Revetment. The revetment along the bluff area will consist of two layers of 2.7 ton armor stone on the structure slope and two layers of B stone (Figure 111). The B rock, core, and gravel filter layers will be buried to match the existing beach elevation. The crest height is set at 19 feet, which is 0.5 feet higher than the 50-year run up. The bluffs will not be excavated to provide a uniform slope on which to build, rather they will be dressed with local fill material to achieve a uniform slope. The bluffs are archaeologically rich, so no excavation will be permitted on the bluff face.

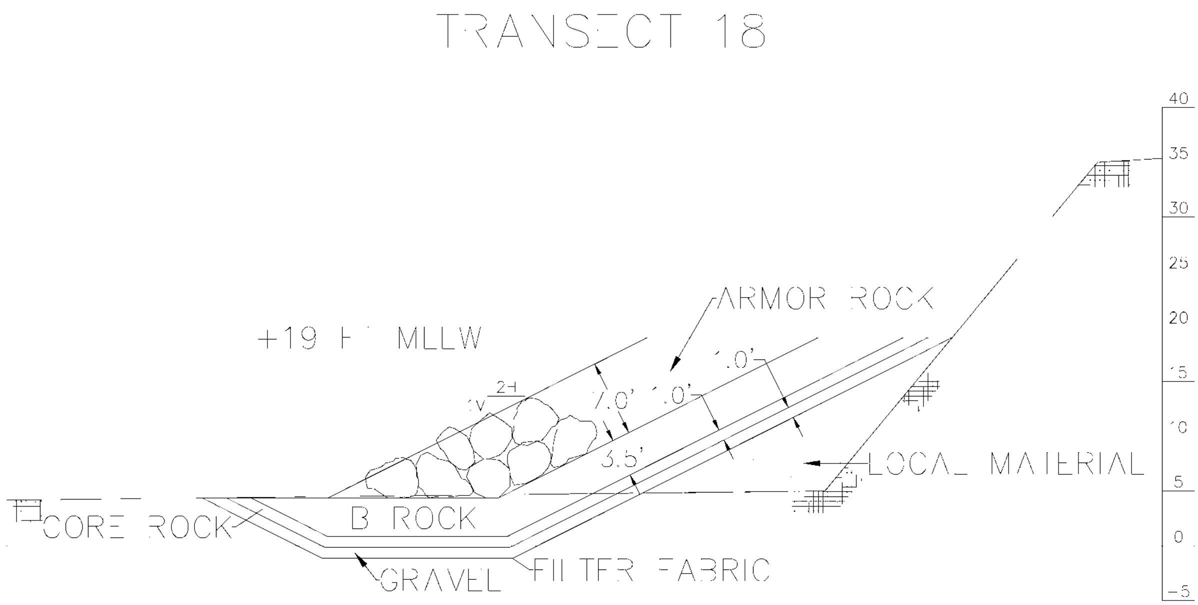

Figure 111. Bluff erosion protection with armor sized for wave protection.

Nourishment. Figure 112 shows a design for beach nourishment with gravel in the bluff area. The volume of nourishment will be dependent on the length of bluff/dune to be protected. The cross section is based on the fill needed to raise the beach at least three feet with a depth of closure assumed at -17 feet for the high bluff area. The construction of the nourishment will place all fill on the beach and let the waves natural spread it out over the cross-section to decrease depth by five feet. -17 is the depth at which the bathymetry begins to increase and an offshore bar is present. The depth of closure is assumed to decrease to -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. Volumes associated with different alternative beach fills are shown in Tables 20 to 22. The renourishment interval is based on the gross sediment transport estimates for the length of beach proposed for protection. This conservative renourishment estimate is used because of the narrow beach, shoreline analysis indicating 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.

Figure 112. Bluff Erosion Protection with Beach Nourishment.

An alternative design for beach nourishment is based on equilibrium profiles for different sediment sized (Figure 113). The equilibrium profile is the natural slope of the nearshore bathymetry below water level to the depth of closure and is the slope that the nearshore returns to after a storm when there is a mild wave climate. If larger sediment is placed in the nearshore, the steeper the beach naturally is, and the wider the beach is if the depth of closure is kept the same. Using equilibrium profiles to design the fill, the beach will be built up to an elevation of at least 10 feet and then built out two lengths of shoreline recession associated with infinitely long design storm surges. The volume of nourishment associated with this design is less than the nourishment designed for using gravel. This alternative may require more frequent re-nourishment and will depend on the availability of appropriate material. Estimated re-nourishment intervals would be based on Monte Carlo simulations to determine how long the nourishment will last until only 5 years of fill is left of the beach.

Figure 113. Bluff Erosion Protection with Beach Fill Design Based on CEM.

8.5.4. Low Lying Coast Protection Governed By Waves

Revetted Berm Structure. 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 the 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. Because the structure is set back from the beach, a two armor stone thickness will result in a 14.5 foot crest elevation (Figure 114). The filtering B layer, core, gravel, and fabric will be placed below the natural beach line for ice survivability. 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 will make the maintenance of the structure easier to perform and a stockpile of replacement stone will be kept at Barrow for maintenance activities. The B rock will be a double layer placed on a 1 foot layer of core, 1 foot layer a gravel, and an underlayment of filter fabric. The B rock, core, and gravel filter layers will be buried to match the existing beach elevation.

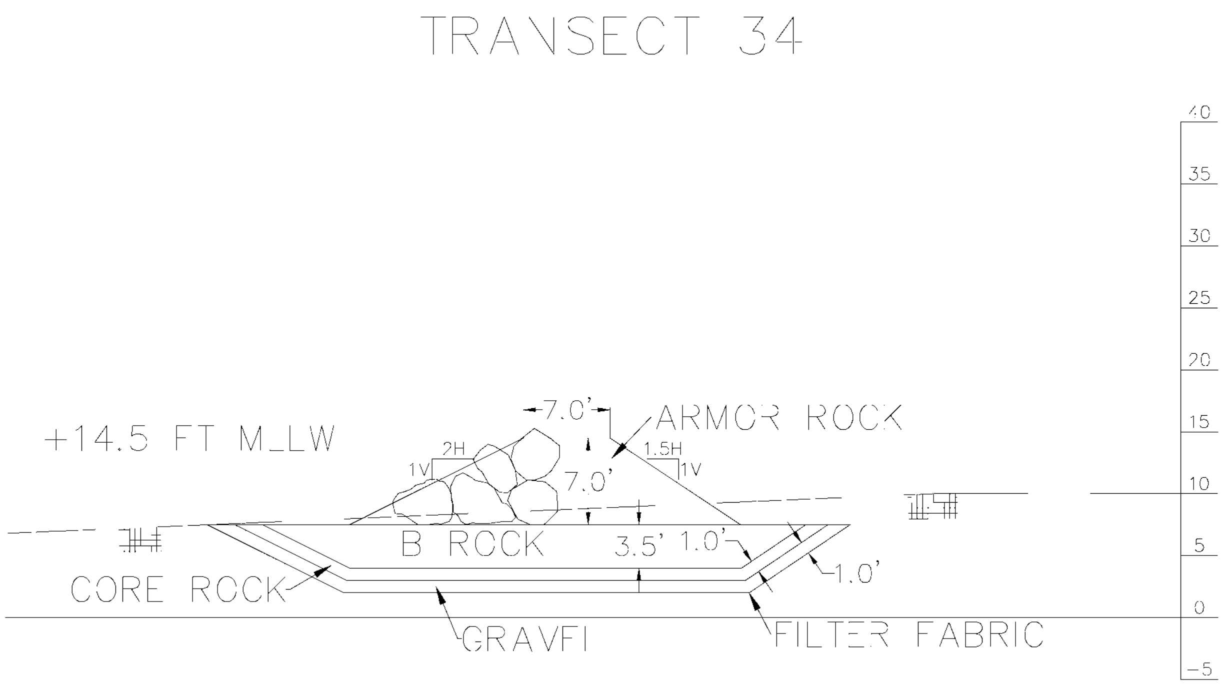

Figure 114. Revetted Berm Sized for Waves.

As an alternative to a revetted berm, Stevenson Street can be raised. Raising Stevenson Street as opposed to a revetted berm will decrease the quantity of armor rock and maintain a view of the ocean from the street. Stevenson Street will be raised to the elevation of the revetted berm with fill material to ensure a 100-year level of protection. The seaward slope of the street will be revetted with two layers of 2.7 ton armor stone and two layers of B stone (Figure 115). The B rock, core, and gravel filter layers will be buried to match the existing beach elevation.

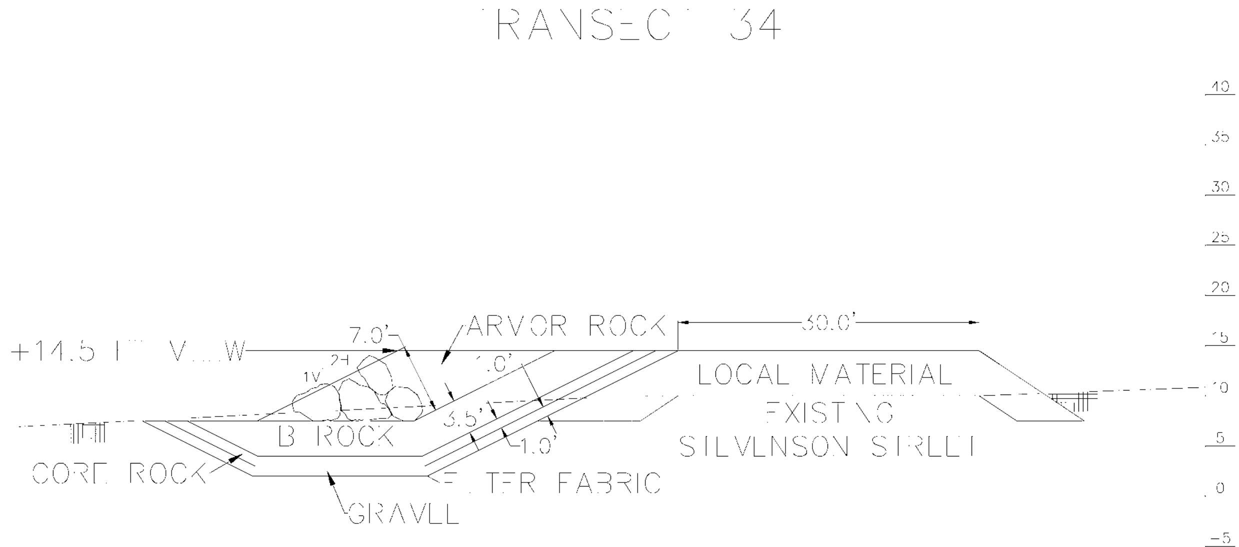

Figure 115. Stevenson Street Raised 4.5 Feet with Revetted Seaward Slope Sized for Waves.

Nourishment. Figure 116 shows a design for beach nourishment. Once the fill reaches the natural equilibrium, the beach level will be raised by three 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. The effects on sediment transport of ice reworking the beach and the transport associated with ice freezing to the beach material are unknown.

Figure 116. Preliminary Beach Fill Design for Low Lying Areas.

As for the bluff area, an alternative beach nourishment design can be used (Figure 117). This method is based on changing the equilibrium profile in the nearshore by increasing the mean sediment size of the beach material.

Figure 117. Alternative Beach Fill Design for Low Lying Areas Based on CEM.

An alternative to constructing a berm or nourishing in front of Tasigarook Lagoon, Isatkoak Lagoon could be filled. Filling in the lagoon had been proposed as a drainage solution by the NSB 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 NSB 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). Local material sources could be used for the fill. Upland run off drainage will be coordinated with the NSB.

8.5.5. Beach Access. In order to maintain access to the beach for subsistence and recreational activities, beach access ramps will be constructed with a revetted berm or raising Stevenson Street. The beach access ramp design will be completed once a final alternative is chosen and will be included for any revetted berm or raising of Stevenson Street that spans more than one mile.

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 118 to 126. Material volumes and maintenance intervals associated with each alternative are shown in Tables 20 to 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 will accrete around the toe of the structure. Once the accretion at the base of the structure reaches an equilibrium point and the normal sediment transport process will continue.

Table 20. Alternative 2.

Armored Revetment Coverage Area	Type of Protection	Armor [cy]	B Rock [cy]	Core [cy]	Gravel [cy]	Filter Fabric [sy]	Excavation [cy]	Local Material [cy]	Maintenance Interval / Length	Maintenance Armor [cy]	Maintenance B Rock [cy]	Maintenance Core [cy]
2a. Rock Revetment at bluff and Berm in front of Stevenson St. * all volumes are based on idealized cross-sections and are subject to change once LiDAR is collected and new storm surge calculations are performed												
Bluffs: Revetment	Armor sized for waves	25,800	23,200	8,000	8,700	26,900	19,700	21,900	5 yrs/2000 ft	8,700	7,900	3,500
Low Lying Areas: Revetted Berm	Armor sized for waves	111,300	108,900	35,600	43,400	135,700	191,800	NA	5 yrs/2000 ft	8,700	7,900	3,500
2b. Rock Revetment at bluff and Raise Stevenson St. * all volumes are based on idealized cross-sections and are subject to change once LiDAR is collected and new storm surge calculations are performed												
Armored Revetment Coverage Area	**Type of Protection**	**Armor [cy]**	**B Rock [cy]**	**Core [cy]**	**Gravel [cy]**	**Filter Fabric [sy]**	**Excavation [cy]**	**Local Material [cy]**	**Maintenance Interval / Length**	**Maintenance Armor [cy]**	**Maintenance B Rock [cy]**	**Maintenance Core [cy]**
Bluffs: Revetment	Armor sized for waves	25,800	23,200	8,000	8,700	26,900	19,700	21,900	5 yrs/2000 ft	8,700	7,900	3,500
Low Lying Areas: Raise Stevenson St.	Armor sized for waves	90,500	113,100	41,500	45,600	142,900	129,100	174,600	5 yrs/2000 ft	8,700	7,900	3,500

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Table 21. Alternative 5.

Armored Revetment Coverage Area	Type of Protection	Armor [cy]	B Rock [cy]	Core [cy]	Gravel [cy]	Filter Fabric [sy]	Excavation [cy]	Local Material [cy]	Maintenance Interval / Length	Maintenance Armor [cy]	Maintenance B Rock [cy]	Maintenance Core [cy]
5a. Protect Major Infrastructure * all volumes are based on idealized cross-sections and are subject to change once LiDAR is collected and new storm surge calculations are performed												
Bluffs: Revetment	Armor sized for waves	9,600	9,000	3,200	3,400	10,600	8,100	7,400	5 yrs/2000 ft	8,700	7,900	3,500
Tagisarook Lagoon: Revetted Berm	Armor sized for waves	16,500	16,100	5,900	6,400	20,100	28,400	NA	5 yrs/2000 ft	8,700	7,900	3,500
5b. Barrow and Browerville Neighborhoods * all volumes are based on idealized cross-sections and are subject to change once LiDAR is collected and new storm surge calculations are performed												
Armored Revetment Coverage Area	**Type of Protection**	**Armor [cy]**	**B Rock [cy]**	**Core [cy]**	**Gravel [cy]**	**Filter Fabric [sy]**	**Excavation [cy]**	**Local Material [cy]**	**Maintenance Interval / Length**	**Maintenance Armor [cy]**	**Maintenance B Rock [cy]**	**Maintenance Core [cy]**
Bluffs: Revetment	Armor sized for waves	25,800	23,200	8,000	8,700	26,900	19,700	21,900	5 yrs/2000 ft	8,700	7,900	3,500
Tasigarook Lagoon and Browerville: Revetted Berm	Armor sized for waves	38,400	37,600	16,700	15,000	46,900	66,200	NA	5 yrs/2000 ft	8,700	7,900	3,500
5c. Barrow and Browerville Neighborhoods plus NARL * all volumes are based on idealized cross-sections and are subject to change once LiDAR is collected and new storm surge calculations are performed												
Armored Revetment Coverage Area	**Type of Protection**	**Armor [cy]**	**B Rock [cy]**	**Core [cy]**	**Gravel [cy]**	**Filter Fabric [sy]**	**Excavation [cy]**	**Local Material [cy]**	**Maintenance Interval / Length**	**Maintenance Armor [cy]**	**Maintenance B Rock [cy]**	**Maintenance Core [cy]**
Bluffs: Revetment	Armor sized for waves	25,800	23,200	8,000	8,700	26,900	19,700	21,900	5 yrs/2000 ft	8,700	7,900	3,500
Tasigarook Lagoon and Browerville: Revetted Berm	Armor sized for waves	38,400	37,600	16,700	15,000	46,900	66,200	NA	5 yrs/2000 ft	8,700	7,900	3,500
NARL: Raise Stevenson St.	Armor sized for waves	22,800	28,600	10,500	11,500	36,100	32,600	44,100	5 yrs/2000 ft	8,700	7,900	3,500
5d. Barrow and Browerville Neighborhoods plus NARL and old Navy landfill * all volumes are based on idealized cross-sections and are subject to change once LiDAR is collected, new storm surge calculations are performed, and a final beach nourishment methodology is determined												
Armored Revetment Coverage Area	**Type of Protection**	**Armor [cy]**	**B Rock [cy]**	**Core [cy]**	**Gravel [cy]**	**Filter Fabric [sy]**	**Excavation [cy]**	**Local Material [cy]**	**Maintenance Interval / Length**	**Maintenance Armor [cy]**	**Maintenance B Rock [cy]**	**Maintenance Core [cy]**
Bluffs: Revetment	Armor sized for waves	25,800	23,200	8,000	8,700	26,900	19,700	21,900	5 yrs/2000 ft	8,700	7,900	3,500
Tasigarook Lagoon and Browerville: Revetted Berm	Armor sized for waves	38,400	37,600	16,700	15,000	46,900	66,200	NA	5 yrs/2000 ft	8,700	7,900	3,500
NARL: Raise Stevenson St.	Armor sized for waves	22,800	28,600	10,500	11,500	36,100	32,600	44,100	5 yrs/2000 ft	8,700	7,900	3,500

Beach Nourishment Coverage Area	Type of Protection	Initial Nourishment [cy]	Assumptions	Maintenance Interval	Maintenance Nourishment [cy]	Maintenance Assumptions
Old Navy Landfill: Beach Nourishment	Beach Nourishment raise beach 3 ft; protection level = 10 ft	452,700	Assume 3 ft increase in beach elevation, with gravel, cross-shore from Stevenson St. down to the depth of closure assumed to be at -19.5	25 yrs	384,500	Maintenance is triggered when 5 yrs of nourishment is remaining on the beach

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Table 22. Alternative 6.

6a. Combination of Rock Revetment, Raise Stevenson St., and Revetted Berm with Limited Beach Nourishment * all volumes are based on idealized cross-sections and are subject to change once LiDAR is collected, new storm surge calculations are performed, and a final beach nourishment methodology is determined												
Armored Revetment Coverage Area	**Type of Protection**	**Armor [cy]**	**B Rock [cy]**	**Core [cy]**	**Gravel [cy]**	**Filter Fabric [sy]**	**Excavation [cy]**	**Local Material [cy]**	**Maintenance Interval / Length**	**Maintenance Armor [cy]**	**Maintenance B Rock [cy]**	**Maintenance Core [cy]**
Bluffs: Revetment	Armor sized or waves	25,800	23,200	8,000	8,700	26,900	19,700	21,900	5 yrs / 2000 ft	8,700	7,900	3,500
Tagisarook Lagoon and Browerville: Revetted Berm	Armor sized for waves	39,100	38,300	13,900	15,200	47,700	67,400	NA	5 yrs / 2000 ft	8,700	7,900	3,500
Salt Lagoons through NARL: Raise Stevenson St.	Armor sized for waves	58,300	72,900	26,800	29,400	92,100	83,200	112,500	5 yrs / 2000 ft	8,700	7,900	3,500
Beach Nourishment Coverage Area	**Type of Protection**		**Initial Nourishment [cy]**	**Assumptions**				**Maintenance Interval**	**Maintenance Nourishment [cy]**	**Maintenance Assumptions**		
Tagisarook Lagoon: Beach Nourishment	Beach Nourishment raise beach 3 ft; protection level = 10 ft		411,100	Assume 3 ft increase in beach elevation, with gravel, cross-shore from Stevenson St. down to the depth of closure assumed to be at -19.5				25 yrs	345,500	Maintenance is triggered when 5 yrs of nourishment is remaining on the beach		
6b. Combination Rock Revetment, Raise Stevenson St., Revetted Berm, and Beach Nourishment * all volumes are based on idealized cross-sections and are subject to change once LiDAR is collected, new storm surge calculations are performed, and a final beach nourishment methodology is determined												
Armored Revetment Coverage Area	**Type of Protection**	**Armor [cy]**	**B Rock [cy]**	**Core [cy]**	**Gravel [cy]**	**Filter Fabric [sy]**	**Excavation [cy]**	**Local Material [cy]**	**Maintenance Interval / Length**	**Maintenance Armor [cy]**	**Maintenance B Rock [cy]**	**Maintenance Core [cy]**
Bluffs: Revetment	Armor sized for waves	25,800	23,200	8,000	8,700	26,900	19,700	21,900	5 yrs / 2000 ft	8,700	7,900	3,500
Tasigarook Lagoon and Browerville: Revetted Berm	Armor sized for waves	39,400	39,000	14,000	15,400	48,100	68,000	NA	5 yrs / 2000 ft	8,700	7,900	3,500
NARL: Raise Stevenson St.	Armor sized for waves	23,000	28,800	10,600	11,600	36,400	32,900	44,400	5 yrs / 2000 ft	8,700	7,900	3,500
Beach Nourishment Coverage Area	**Type of Protection**		**Initial Nourishment [cy]**	**Assumptions**				**Maintenance Interval**	**Maintenance Nourishment [cy]**	**Maintenance Assumptions**		
Salt Lagoons: Beach Nourishment	Beach Nourishment raise beach 3 ft; protection level = 10 ft		1,344,500	Assume 3 ft increase in beach elevation, with gravel, cross-shore from Stevenson St. down to the depth of closure assumed to be at -19.5				25 yrs	1,143,000	Maintenance is triggered when 5 yrs of nourishment is remaining on the beach		
6c. Beach Nourishment Only * all volumes are based on idealized cross-sections and are subject to change once LiDAR is collected, new storm surge calculations are performed, and a final beach nourishment methodology is determined												
Beach Nourishment Coverage Area	**Type of Protection**		**Initial Nourishment [cy]**	**Assumptions**				**Maintenance Interval**	**Maintenance Nourishment [cy]**	**Maintenance Assumptions**		
Beach Nourishment	Beach Nourishment raise beach 3 ft; protection level = 10 ft		2,742,300	Assume 3 ft increase in beach elevation, with gravel, cross-shore from Stevenson St. down to the depth of closure assumed to be at -19.5				25 yrs	2,331,000	Maintenance is triggered when 5 yrs of nourishment is remaining on the beach		

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9.2. Alternative 1: No Action

This alternative would be to take no action and leave the city susceptible to the effects storms. The bluff would continue to erode, the low lying areas will continue to flood, and the City will continue to fight to save the shoreline during storm events.

9.3. Alternative 2 (TSP: combination of A and B)

9.3.1. 2A Rock Revetment at Bluff and Berm in Front of Stevenson Street. This alternative would provide erosion protection for the bluffs starting in front of the airport until the bluffs transition to low lying areas in front of Tasigarook Lagoon, approximately 1 mile of bluff protection. This alternative would also include flood protection for the low lying areas starting in front of Tasigarook Lagoon with a smooth transition from a protected rock revetment in front of the bluffs to a revetted berm in front of Stevenson Street. The revetted berm would then continue in front of Stevenson Street until Stevenson Street intersects with Dewline Road on the far side of NARL. The revetted berm would run approximately 4 miles. This alternative would have a height of +14.5 feet.

9.3.2. 2B Rock Revetment at Bluff and Raise Stevenson Street. This alternative would provide the same level of protection as Alternative 2a. The erosion protection for the bluff would still run from in front of the airport to in front of Tasigarook Lagoon. Instead of constructing a revetted berm on the seaward side of Stevenson Street for the approximate four miles stretch, Stevenson Street would be raised. Stevenson Street would be raised to +14.5 feet and the seaward side of the street would be revetted. This would allow people driving on the road to still have a view of the ocean and could decrease the quantity of armor rock.

9.4. Alternative 5

All sub-alternatives for Alternative 5 include filling of Isatkoak Lagoon.

9.4.1. 5A Protect Major Infrastructure. This alternative would include erosion protection in the form of a rock revetment at the bluffs in front of the Barrow neighborhood that is currently protected by HESCO baskets. It would also include relocating public and private infrastructure at greatest risk due to erosion away from the shoreline. 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 23. 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 was shown in Figure 78.

Table 23. Bluff Erosion Distances.

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

This alternative would also include flood protection for the freshwater lagoon and the Utilidor. A revetted berm in front of the Tasigarook Lagoon would protect the community’s fresh water source and it would be extended north-easterly to protect pump station #3 of the Utilidor.

Infrastructure at greatest risk from flooding would be protected 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 exceedance probabilities and stage frequency flood plots in Table 13 and Figures 85 to 98.

9.4.2. 5B Barrow and Browerville Neighborhoods. Expanding on the previous alternative, the Barrow and Browerville Neighborhoods alternative would include a rock revetment for the bluffs starting at the airport and extend the revetted berm to the end of Browerville, near the intersect of Stevenson Street and Ahmoagak Avenue.

9.4.3. 5C Barrow and Browerville Neighborhoods Plus NARL. In addition to protecting the Barrow neighborhood from erosion and Tasigarook Lagoon and the Browerville neighborhood from flooding, this alternative would protect NARL from flooding by raising Stevenson Street in front of NARL.

9.4.4. 5D Barrow and Browerville Neighborhoods Plus NARL and Old Navy Landfill. In addition to protecting the Barrow neighborhood from erosion and Tasigarook Lagoon, the Browerville neighborhood, and NARL from flooding, this alternative would protect the old Navy landfill from flooding by nourishing the beach.

9.5 Alternative 6

9.5.1. 6A Combination Rock Revetment, Raise Stevenson Street, and Revetted Berm with Limited Beach Nourishment. This alternative includes erosion and flood protection in front of the airport through the end of NARL. Various protection measurements would be used for different stretches of the beach. The bluffs would be revetted, a revetted berm along with beach nourishment would be constructed in front of Tasigarook Lagoon, the berm would continue through the end of Browerville, and then Stevenson Street would be raised from the end of the berm through the end of NARL.

9.5.2. 6B Combination Rock Revetment, Raise Stevenson Street, Revetted Berm, and Beach Nourishment. Alternative 6B is similar to 6A in the type of protection measures and length of coast protected. However, instead of raising Stevenson Street in front of the salt lagoon and old Navy landfill, these areas would include beach nourishment.

9.5.3. 6C Beach Nourishment Only. This alternative only includes beach nourishment as a protection measure. Beach nourishment would be placed along approximately five miles of coastline, from the airport through the end of NARL where Stevenson Street intersects with Dewline Road. The beach nourishment could be gravel or coarse sand depending on the method of fill design. The interval of re-nourishment would depend on the size of material used for the initial nourishment.

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 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. The maintenance length was assumed to be 2,000 feet.

Figure 118. Alternative 2a: Rock Revetment at Bluff and Berm in Front of Stevenson Street.

Figure 119. Alternative 2b: Rock Revetment at Bluff and Raise Stevenson Street.

Figure 120. Alternative 5a: Protect Major Infrastructure.

Figure 121. Alternative 5b: Barrow and Browerville Neighborhoods.

Figure 122. Alternative 5c: Barrow and Browerville Neighborhoods Plus NARL.

Figure 123. Alternative 5d: Barrow and Browerville Neighborhoods Plus NARL and the Old Navy Landfill.

Figure 124. Alternative 6a: Combination Rock Revetment, Raise Stevenson Street, Revetted Berm with Limited Beach Nourishment.

Figure 125. Alternative 6b: Combination Rock Revetment, Raise Stevenson Street, Revetted Berm, and Beach Nourishment.

Figure 126. Alterative 6c: Beach Nourishment Only.

10.0. CONSTRUCTION CONSIDERATIONS AND MAINTENANCE

Construction of a coastal storm risk management 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 will be allowed and excavation into the bluffs would also be prohibited. All slope grooming would need to be performed using fill material to achieve a desired slope. There will be some excavation into the beach for construction that will have to be supervised by an archaeologist.

The project will need to be inspected for damage at least twice annually. One inspection will need to occur after the snow and ice melts and a second in the fall before freeze up. There will 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 in order 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 will be left at Barrow in order to have material on hand should repairs be necessary. The beach fill options assume that renourishment will 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 the wind, waves, currents, sediment transport, and ice development at the Barrow. Risk and uncertainty that directly affects this project is annual maintenance requirements due to increased storm frequency. The information gathered and analysis presented is the best data available at the present date.

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 which 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. The waves impacting the structure would continue to be depth limited unless there is significant sea level rise. The proposed rock structure will be above the water line and available for visual inspection for damage from storms or ice.

12.0. FUTURE WORK TO BE COMPLETED IN PED

The current designs for the alternatives was based on work that was done on data that ran through 2003. The hindcast is currently being updated for years 2004-2017 to include the two most recent storms in 2015 and 2017 and will be completed in PED. Data required to complete the storm modeling that will be used to determine the design wave height, storm surge, run-up, and inundation includes LiDAR, survey transects, and a tidal determination. New ADCIRC, STWAVE, and CSHORE (replacing SBEACH) models will be run and a Beach-fx light model will be used to determine re-nourishment intervals. The storm modeling will also determine if the frequency, duration, and/or intensity of the storms effecting Barrow has changed since 2004.

Barrow Alaska Coastal Erosion Feasibility Study

Appendix G: Cost Engineering Appendix

Barrow, Alaska

August 29, 2018

US Army Corps
of Engineers
Alaska District

TABLE OF CONTENTS

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

PROJECT: **Alternative 2A - Barrow Coastal Erosion**
PROJECT NO: 0
LOCATION: Barrow, AK

DISTRICT: Alaska
POC: CHIEF, COST ENGINEERING, xxx

PREPARED: 8/24/2018

This Estimate reflects the scope and schedule in report; Barrow Alaska Coastal Erosion Feasibility Study

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**						**TOTAL PROJECT COST (FULLY FUNDED)**			
						Program Year (Budget EC): 2019 Effective Price Level Date: 1 OCT 18									
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($K) *C*	CNTG ($K) *D*	CNTG (%) *E*	TOTAL ($K) *F*	ESC (%) *G*	COST ($K) *H*	CNTG ($K) *I*	**TOTAL ($K)** *J*	Spent Thru: **1-Oct-17** ($K)	**TOTAL FIRST COST** ($K) *K*	INFLATED (%) *L*	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
03	RESERVOIRS	$1,624	$781	48.1%	$2,405	2.0%	$1,657	$796	$2,453	$0	$2,453	8.0%	$1,789	$860	$2,649
04	DAMS	$121,049	$58,176	48.1%	$179,226	2.0%	$123,479	$59,344	$182,824	$0	$182,824	8.0%	$133,331	$64,079	$197,411
05	LOCKS	$201	$97	48.1%	$298	2.0%	$205	$99	$304	$0	$304	8.0%	$222	$107	$328
	CONSTRUCTION ESTIMATE TOTALS:	$122,875	$59,054		$181,929	2.0%	$125,342	$60,239	$185,581	$0	$185,581	8.0%	$135,342	$65,046	$200,388
01	LANDS AND DAMAGES	$0	$0	-	$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN	$12,288	$4,731	38.5%	$17,018	3.8%	$12,755	$4,911	$17,666	$0	$17,666	4.2%	$13,287	$5,116	$18,403
31	CONSTRUCTION MANAGEMENT	$7,373	$2,838	38.5%	$10,211	3.8%	$7,653	$2,946	$10,600	$0	$10,600	10.8%	$8,482	$3,266	$11,747
	PROJECT COST TOTALS:	$142,535	$66,623	46.7%	$209,158		$145,750	$68,096	**$213,847**	$0	**$213,847**	7.8%	$157,112	$73,427	$230,539

ESTIMATED TOTAL PROJECT COST: $230,539

______________________ **CHIEF, COST ENGINEERING, xxx**

______________________ **PROJECT MANAGER, xxx**

______________________ **CHIEF, REAL ESTATE, xxx**

______________________ **CHIEF, PLANNING, xxx**

______________________ **CHIEF, ENGINEERING, xxx**

______________________ **CHIEF, OPERATIONS, xxx**

______________________ **CHIEF, CONSTRUCTION, xxx**

______________________ **CHIEF, CONTRACTING,xxx**

______________________ **CHIEF, PM-PB, xxxx**

______________________ **CHIEF, DPM, xxx**

Filename: Barrow_Alt 2A_TPCS
TPCS

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

ALTERNATIVE 2A

****** CONTRACT COST SUMMARY ******

PROJECT: Alternative 2A - Barrow Coastal Erosion
LOCATION: Barrow, AK
This Estimate reflects the scope and schedule in report; Barrow Alaska Coastal Erosion Feasibility Study

DISTRICT: Alaska
POC: CHIEF, COST ENGINEERING, xxx

PREPARED: 8/24/2018

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			24-Aug-18	Program Year (Budget EC):			2019					
		Effective Price Level:			1-Oct-17	Effective Price Level Date:			1 OCT 18					
				RISK BASED										
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Alterantive 2A													
02	RELOCATIONS	$1,624	$781	48.1%	$2,405	2.0%	$1,657	$796	$2,453	2021Q4	8.0%	$1,789	$860	$2,649
16	BANK STABILIZATION	$121,049	$58,176	48.1%	$179,226	2.0%	$123,479	$59,344	$182,824	2021Q4	8.0%	$133,331	$64,079	$197,411
18	CULTURAL RESOURCE PRESERVATION	$201	$97	48.1%	$298	2.0%	$205	$99	$304	2021Q4	8.0%	$222	$107	$328
	CONSTRUCTION ESTIMATE TOTALS:	$122,875	$59,054	48.1%	**$181,929**		$125,342	$60,239	$185,581			$135,342	$65,046	$200,388
01	LANDS AND DAMAGES	$0	$0	48.1%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
1.5%	Project Management	$1,843	$710	38.5%	$2,553	3.8%	$1,913	$737	$2,650	2019Q3	2.0%	$1,951	$751	$2,702
1.0%	Planning & Environmental Compliance	$1,229	$473	38.5%	$1,702	3.8%	$1,276	$491	$1,767	2019Q3	2.0%	$1,300	$501	$1,801
3.0%	Engineering & Design	$3,686	$1,419	38.5%	$5,105	3.8%	$3,827	$1,473	$5,300	2019Q3	2.0%	$3,901	$1,502	$5,403
0.5%	Reviews, ATRs, IEPRs, VE	$614	$237	38.5%	$851	3.8%	$638	$246	$883	2019Q3	2.0%	$650	$250	$901
0.5%	Life Cycle Updates (cost, schedule, risks)	$614	$237	38.5%	$851	3.8%	$638	$246	$883	2019Q3	2.0%	$650	$250	$901
0.5%	Contracting & Reprographics	$614	$237	38.5%	$851	3.8%	$638	$246	$883	2019Q3	2.0%	$650	$250	$901
1.0%	Engineering During Construction	$1,229	$473	38.5%	$1,702	3.8%	$1,276	$491	$1,767	2021Q4	10.8%	$1,414	$544	$1,958
1.0%	Planning During Construction	$1,229	$473	38.5%	$1,702	3.8%	$1,276	$491	$1,767	2021Q4	10.8%	$1,414	$544	$1,958
0.5%	Adaptive Management & Monitoring	$614	$237	38.5%	$851	3.8%	$638	$246	$883	2021Q4	10.8%	$707	$272	$979
0.5%	Project Operations	$614	$237	38.5%	$851	3.8%	$638	$246	$883	2019Q3	2.0%	$650	$250	$901
31	CONSTRUCTION MANAGEMENT													
4.0%	Construction Management	$4,915	$1,892	38.5%	$6,807	3.8%	$5,102	$1,964	$7,066	2021Q4	10.8%	$5,655	$2,177	$7,832
1.0%	Project Operation:	$1,229	$473	38.5%	$1,702	3.8%	$1,276	$491	$1,767	2021Q4	10.8%	$1,414	$544	$1,958
1.0%	Project Management	$1,229	$473	38.5%	$1,702	3.8%	$1,276	$491	$1,767	2021Q4	10.8%	$1,414	$544	$1,958
	CONTRACT COST TOTALS:	$142,535	$66,623		$209,158		$145,750	$68,096	**$213,847**			$157,112	$73,427	**$230,539**

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

PROJECT: **Alternative 2B - Barrow Coastal Erosion**
PROJECT NO: 0
LOCATION: Barrow, AK

DISTRICT: Alaska
POC: CHIEF, COST ENGINEERING, xxx

PREPARED: 8/24/2018

This Estimate reflects the scope and schedule in report; Barrow Alaska Coastal Erosion Feasibility Study

Civil Works Work Breakdown Structure		**ESTIMATED COST**				**PROJECT FIRST COST (Constant Dollar Basis)**						**TOTAL PROJECT COST (FULLY FUNDED)**			
						Program Year (Budget EC): 2019 Effective Price Level Date: 1 OCT 18									
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	**TOTAL ($K)**	Spent Thru: **1-Oct-17** ($K)	**TOTAL FIRST COST** ($K)	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	***B***	***C***	***D***	***E***	***F***	***G***	***H***	***I***	***J***		***K***	***L***	***M***	***N***	***O***
03	RESERVOIRS	$1,624	$780	48.1%	$2,404	2.0%	$1,656	$796	$2,453	$0	$2,453	8.0%	$1,789	$860	$2,648
04	DAMS	$122,194	$58,726	48.1%	$180,920	2.0%	$124,647	$59,905	$184,552	$0	$184,552	8.0%	$134,592	$64,685	$199,277
05	LOCKS	$201	$97	48.1%	$298	2.0%	$205	$99	$304	$0	$304	8.0%	$222	$107	$328
	CONSTRUCTION ESTIMATE TOTALS:	$124,019	$59,603		$183,622	2.0%	$126,509	$60,800	$187,308	$0	$187,308	8.0%	$136,602	$65,651	$202,253
01	LANDS AND DAMAGES	$0	$0 -		$0	-	$0	$0	$0	$0	$0	-	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN	$12,402	$4,775	38.5%	$17,177	3.8%	$12,874	$4,956	$17,830	$0	$17,830	4.2%	$13,411	$5,163	$18,574
31	CONSTRUCTION MANAGEMENT	$7,441	$2,865	38.5%	$10,306	3.8%	$7,724	$2,974	$10,698	$0	$10,698	10.8%	$8,561	$3,296	$11,857
	PROJECT COST TOTALS:	$143,862	$67,243	46.7%	$211,105		$147,107	$68,730	**$215,837**	$0	**$215,837**	7.8%	$158,574	$74,110	$232,685

ESTIMATED TOTAL PROJECT COST: $232,685

__________________________ **CHIEF, COST ENGINEERING, xxx**

__________________________ **PROJECT MANAGER, xxx**

__________________________ **CHIEF, REAL ESTATE, xxx**

__________________________ **CHIEF, PLANNING, xxx**

__________________________ **CHIEF, ENGINEERING, xxx**

__________________________ **CHIEF, OPERATIONS, xxx**

__________________________ **CHIEF, CONSTRUCTION, xxx**

__________________________ **CHIEF, CONTRACTING,xxx**

__________________________ **CHIEF, PM-PB, xxxx**

__________________________ **CHIEF, DPM, xxx**

Filename: Barrow_Alt 2B_TPCS
TPCS

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

ALTERNATIVE 2B

****** CONTRACT COST SUMMARY ******

PROJECT: Alternative 2B - Barrow Coastal Erosion
LOCATION: Barrow, AK
This Estimate reflects the scope and schedule in report; Barrow Alaska Coastal Erosion Feasibility Study

DISTRICT: Alaska
POC: CHIEF, COST ENGINEERING, xxx
PREPARED: 8/24/2018

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared:			24-Aug-18	Program Year (Budget EC):			2019					
		Effective Price Level:			1-Oct-17	Effective Price Level Date:			1 OCT 18					
				RISK BASED										
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	Alterantive 2A													
02	RELOCATIONS	$1,624	$780	48.1%	$2,404	2.0%	$1,656	$796	$2,453	2021Q4	8.0%	$1,789	$860	$2,648
16	BANK STABILIZATION	$122,194	$58,726	48.1%	$180,920	2.0%	$124,647	$59,905	$184,552	2021Q4	8.0%	$134,592	$64,685	$199,277
18	CULTURAL RESOURCE PRESERVATION	$201	$97	48.1%	$298	2.0%	$205	$99	$304	2021Q4	8.0%	$222	$107	$328
	CONSTRUCTION ESTIMATE TOTALS:	$124,019	$59,603	48.1%	**$183,622**		$126,509	$60,800	$187,308			$136,602	$65,651	$202,253
01	LANDS AND DAMAGES	$0	$0	48.1%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
1.5%	Project Management	$1,860	$716	38.5%	$2,576	3.8%	$1,931	$743	$2,675	2019Q3	2.0%	$1,969	$758	$2,727
1.0%	Planning & Environmental Compliance	$1,240	$477	38.5%	$1,718	3.8%	$1,287	$496	$1,783	2019Q3	2.0%	$1,313	$505	$1,818
3.0%	Engineering & Design	$3,721	$1,432	38.5%	$5,153	3.8%	$3,862	$1,487	$5,349	2019Q3	2.0%	$3,938	$1,516	$5,454
0.5%	Reviews, ATRs, IEPRs, VE	$620	$239	38.5%	$859	3.8%	$644	$248	$892	2019Q3	2.0%	$656	$253	$909
0.5%	Life Cycle Updates (cost, schedule, risks)	$620	$239	38.5%	$859	3.8%	$644	$248	$892	2019Q3	2.0%	$656	$253	$909
0.5%	Contracting & Reprographics	$620	$239	38.5%	$859	3.8%	$644	$248	$892	2019Q3	2.0%	$656	$253	$909
1.0%	Engineering During Construction	$1,240	$477	38.5%	$1,718	3.8%	$1,287	$496	$1,783	2021Q4	10.8%	$1,427	$549	$1,976
1.0%	Planning During Construction	$1,240	$477	38.5%	$1,718	3.8%	$1,287	$496	$1,783	2021Q4	10.8%	$1,427	$549	$1,976
0.5%	Adaptive Management & Monitoring	$620	$239	38.5%	$859	3.8%	$644	$248	$892	2021Q4	10.8%	$713	$275	$988
0.5%	Project Operations	$620	$239	38.5%	$859	3.8%	$644	$248	$892	2019Q3	2.0%	$656	$253	$909
31	CONSTRUCTION MANAGEMENT													
4.0%	Construction Management	$4,961	$1,910	38.5%	$6,871	3.8%	$5,150	$1,983	$7,132	2021Q4	10.8%	$5,707	$2,197	$7,905
1.0%	Project Operation:	$1,240	$477	38.5%	$1,718	3.8%	$1,287	$496	$1,783	2021Q4	10.8%	$1,427	$549	$1,976
1.0%	Project Management	$1,240	$477	38.5%	$1,718	3.8%	$1,287	$496	$1,783	2021Q4	10.8%	$1,427	$549	$1,976
	CONTRACT COST TOTALS:	$143,862	$67,243		$211,105		$147,107	$68,730	**$215,837**			$158,574	$74,110	**$232,685**

BARROW ALASKA COASTAL EROSION FEASIBILITY STUDY

COST ESTIMATE NARRATIVE

1. Project Description

A. General: This work has been completed in support of the Economic Analysis Technical Appendix of the Barrow Alaska Coastal Erosion Feasibility Study. The economic appendix generated an array of alternatives that have been previously estimated. From this array two alternatives (2A and 2B) were selected to move forward with the development of more detailed cost estimates. The following report documents the assumptions and methodology used to develop detailed MCACES estimates for both the 2A and 2B alternatives.

B. Purpose: The purpose of this work is to develop a detailed cost estimate for two erosion protection projects – consistent to the conceptual level of design – for the cost and quantities of the project features per U.S. Army Corps of Engineers (USACE) guidance and regulations regarding construction cost estimating.

C. Design Features: Primary construction features include excavation, fill, armor rock, b-rock, core rock, and gravel placement.

2. Basis of Estimate

a. Basis of Design: Available design documents of the project elements are listed below. The project site plan is presented in Attachment A.

- Barrow Alaska Coastal Erosion Feasibility Study, USACE Alaska District, August 2018

A. Basis of Quantities: The cost estimate is based on conceptual level project quantity take-offs that have been calculated from the documents listed above by the USACE Alaska District. A quantity summary along with quantity take-offs are presented in Attachment B. The detailed quantities include waste/loss factors for the project materials as listed below:

Loose Soils	15%
Geotextiles	5%
Stone Waste/Loss	5%

3. Project Schedule

It is estimated that overall construction would take approximately 30 months to complete each alternative 2A and 2B. Construction is only assumed to occur during a roughly 5 month period between the beginning of May and end of September. Both alternatives assume starting the delivery of material and equipment prior to these dates. The three year work window for each alternative is primarily driven by discussions with shipping contractors. Most noted that it would likely take three seasons to deliver the necessary rock.

For calculation of Job Office Overhead (JOOH) within the MCACES, both alternatives assume 18 months, as this slightly more than the estimated on-site duration of the contractor to cover three construction periods. A simplified, tentative construction schedule for each alternative is presented in Attachment C.

4. Acquisition Plan

Each alternative assumes the same contracting plan. The estimates assume one contract being awarded for the total project. It is assumed that the bidding process would be unrestricted. All contractor and project mark-ups have been adjusted accordingly in the cost estimate. The estimate also assumes that the Prime Contractor would complete a majority of the work and would require a subcontractor to complete the necessary structure relocations.

5. Project Construction

A. Staging and Site Access: The cost estimates for both alternatives currently assume no significant staging area would be constructed. Given the length of the project, minor staging areas where stone could be stockpiled would be constructed as the project progresses. Other equipment and materials could be stored here as well. Costs for preparing and maintaining staging and site access locations has been included in the estimate.

B. Borrow/Disposal Areas and Materials: Currently, all excess materials are assumed to become property of the contractor and would be required to be removed off-site. The estimate assumes excess earth would be hauled 20-miles one way for disposal.

The estimate also assumes all stone material required for the bank protection would come from a quarry located in Nome, Alaska. Quotes for purchasing and obtaining the stone products have been obtained from the contractor currently operating the quarry. The estimate also includes the shipping of the material from Nome to Barrow. Several shipping contractors provided pricing information that was used as a basis for the price in the estimate. See attachment D for a summary of discussions with these contractors.

C. Construction Methodology:

The following is a brief discussion of assumptions made for the unit costs used in the MCACES estimates for both alternatives:

- Mobilization and Demobilization – Assumes mobilizing and demobilizing equipment to and from Anchorage for the three construction windows necessary to complete the work.
- Excavation – Unit cost assumes excavation to be completed with use of hydraulic excavators, and material would be stockpiled on-site prior to disposing.
- Hauling – Unit price assumes hauling with 12-cubic yard (cy) dump trucks to a local disposal site in Barrow. No tipping fee is assumed to be required as material would likely be able to be re-used for future projects in Barrow.
- Armor Rock, B-rock, Core Rock and Gravel – Unit prices assume all rock for the berms and revetments would be delivered to Barrow from other locations in Alaska. The source of the rock would be from Nome, where the material would be loaded onto barges for delivery to Barrow. Other locations are possible, but may

require longer shipping distances and thus higher costs. The prices used in the current estimate are based on quotes provided by several contractors familiar with the Nome quarry and with shipping of construction materials throughout Alaska.

- Filter Fabric – Unit price assumes placement of filter fabric at designated locations.
- Local Material – Unit price assumes the gravel pit in Barrow has sufficient material to provide as local fill. This material would be delivered by truck to the placement location, placed and then compacted.
- Structure Raise and/or Relocation – The exact requirements for the structure relocations are not set. Previous USACE cost estimates and documentation included approximately $150k for certain structure relocations. Given escalation factors, and potential for historic structures to require relocations, $200k per structure has been used until more details are developed in future phases of the project.
- On-Site Archaeologist – Due to the significant cultural resources that are found throughout Barrow, it is assumed that an archaeologist would be on-site for the duration of construction.

D. Unusual Conditions: (Soil, Water, Weather, Traffic). Possible cold temperatures, working near ocean shore, significant ocean shipping.

E. Unique Construction Techniques: None anticipated.

F. Equipment/Labor Availability and Distance Traveled: All equipment and labor should be available in the greater Alaska region, and is assumed to primarily come from Anchorage.

6. Effective Dates for Labor, Equipment and Material Pricing

The labor, equipment, and material pricing were developed using the MCACES 2016 English Unit Cost Library, 2018 Alaska Statewide Labor Library (see Attachment E for Davis Bacon Wage Rates), and the 2016 Equipment Library (Region IV) for the base cost estimates. The index pricing data has been prepared in August 2018 dollars.

The base cost estimates have been updated with current quoted fuel prices of $3.75/gal for off-road diesel, $3.38/gal for on-road diesel and $3.25 /gal for gasoline in the state of Alaska.

7. Estimated Production Rates

Much of the construction cost estimate was developed utilizing user defined crews and production rates. See Attachment F for the Estimated Production Rates developed for this estimate.

8. Project Markups

A. Escalation: Price levels have been escalated from effective price levels of the construction cost estimate for August 2018 (4Q18) to the mid-points of construction for each alternative. The appropriate escalation cost factors for each date and for each feature account have been calculated within the Total Project Cost Summary.

B. Contingency: An abbreviated risk analysis (ARA) was completed in order to develop the contingencies for the proposed alternatives. Due to the similarity in the alternatives, only one risk register has been developed, but both alternatives have specific contingencies calculated. The ARA and calculated alternative contingencies can be found in Attachment G.

C. Sales Tax: A 7.75% sales tax markups has been used on the purchase of materials for the construction of both alternatives. However, it should be noted that the quotes provided on the rock included sales tax, and therefore the sales tax has been removed from the MCAES for those items to avoid double counting.

D. Overtime: No overtime currently assumed in the estimate.

9. Functional Costs

Functional costs associated with this work were estimated as follows:

A. 01 Account – Lands and Damages: No costs for purchasing any lands are currently assumed to be required at this time.

B. 02 Account – Relocations: The estimates for both alternatives assumes the relocation and/or raising of six structures located adjacent to the construction site. Further design phases will determine whether these structures need to be fully relocated, or if they can be temporarily relocated and replaced after construction. Costs for these relocations are included in the MCACES.

C. 09 Account – Channels: Costs for this account have been estimated within the MCACES construction cost estimate. Costs include the primary construction features required to complete the erosion protection.

D. 30 Account - Planning, Engineering, and Design: Costs for this account were estimated at 10% of construction costs. This account covers the preparation of plans, specifications, and engineering during construction.

E. 31 Account - Construction Management: Costs for this account were estimated to be 6% of construction costs. This account covers construction management during the construction phase.

10. MCACES Construction Cost Estimate

The construction cost estimate was developed using MCACES 2nd Generation (MII) estimating software in accordance with guidance contained in ER 1110-2-1302, Civil Works Cost Engineering. See Attachment H for the MII output report.

12. References

U.S. Army Corps of Engineers, 1993, *Engineering and Design Cost Engineering Policy and General Requirements, Engineering Regulation 1110-1-1300,* Department of the Army, Washington D.C., 26 March 1993.

U.S. Army Corps of Engineers, 1999, *Engineering and Design For Civil Works Projects, Engineering Regulation 1110-2-1150,* Department of the Army, Washington D.C., 31 August 1999.

U.S. Army Corps of Engineers, 2008a, *Civil Works Cost Engineering, Engineering Regulation 1110-2-1302,* Department of the Army, Washington D.C., 15 September 2008.

U.S. Army Corps of Engineers, 2008b, *Construction Cost Estimating Guide For Civil Works, Engineering Technical Letter 1110-2-573,* Department of the Army, Washington D.C., 30 September 2008.

U.S. Army Corps of Engineers, 2018, *Civil Works Construction Cost Index System, Engineering Manual 1110-2-1304,* Department of the Army, Washington D.C., 31 March 2018.

ATTACHMENT A

Site Plan

Site Map


0
0.5
1
2 Miles
STUDY AREA EXTENT ALONG COASTLINE
Chukchi Sea
to Point Barrow
Elson Lagoon
North Salt Lagoon
NARL
Imikpuk Lake
Top of the World Bridge
Landfill
Sewage Lagoon
Middle Salt Lagoon
South Salt Lagoon
Browerville
Tasigrook Lagoon
Historic Village
Isatkoak Lagoon
Bluff
Barrow
Gravel Pits

ATTACHMENT B

Project Quantities and Detailed Quantity Take-Offs

MCACES QUANTITY SUMMARY

Item Description	UOM	Alt 2A	Alt 2B
19 ft Revetment			
Excavation	CY	16,000	16,000
B-rock Rock	CY	19,000	19,000
Armor Rock	CY	22,000	22,000
Core Rock	CY	7,000	7,000
Gravel	CY	7,000	7,000
Filter Fabric	YD^2	22,000	22,000
Local material	CY	20,000	20,000
14 ft Revetment			
Excavation	CY	4,000	4,000
B-rock Rock	CY	4,000	4,000
Armor Rock	CY	4,000	4,000
Core Rock	CY	1,000	1,000
Gravel	CY	2,000	2,000
Filter Fabric	YD^2	5,000	5,000
Local material	CY	2,000	5,000
14 ft Berm			
Excavation	CY	192,000	-
B-rock Rock	CY	109,000	-
Armor Rock	CY	111,000	-
Core Rock	CY	40,000	-
Gravel	CY	43,000	-
Filter Fabric	YD^2	136,000	-
14 ft Raise Stevenon Street			
Excavation	CY	-	129,000
B-rock Rock	CY	-	113,000
Armor Rock	CY	-	90,000
Core Rock	CY	-	42,000
Gravel	CY	-	46,000
Filter Fabric	YD^2	-	143,000
Local material	CY	-	175,000

Total Quantities	UOM	Alt 2A	Alt 2B
Excavation	CY	212,000	149,000
B-rock Rock	CY	132,000	136,000
Armor Rock	CY	137,000	116,000
Core Rock	CY	48,000	50,000
Gravel	CY	52,000	55,000
Filter Fabric	YD^2	163,000	170,000
Local Material	CY	22,000	200,000

ALTERNATIVE 2A QUANTITIES

Revetment and Berm

Length of 19 ft Revet	2700	ft	0.51	miles	51,300	ft^2	373,300
Length of 14 ft Revet	700	ft	0.13	miles	9800	ft^2	
Length of 14 ft Berm	22,300	ft	4.22	miles	312200	ft^2	

19 ft Revetment

Armor Rock	Transect	
Volume per linear foot of revet	219	ft^2
	591,651	ft^3
	21,913	cy
Volume Armor	**22,000**	**cy**
B-rock Rock	Transect	
Volume per linear foot of revet	192	ft^2
	517,698	ft^3
	19,174	cy
Volume B-rock	**19,000**	**cy**
Core Rock	Transect	
Volume per linear foot of revet	66	ft^2
	177,957	ft^3
	6,591	cy
Volume Core	**7,000**	**cy**
Gravel	Transect	
Volume per linear foot of revet	71	ft^2
	191,214	ft^3
	7,082	cy
Volume Gravel	**7,000**	**cy**
Filter Fabric	Transect	
Feet per linear foot of revet	73	ft
	197,964	ft^2
	21,996	yd^2
Total Filter Fabric	**22,000**	**yd^2**
Excavation	Transect	
Volume per linear foot of revet	156	ft^2
	422,091	ft^3
	15,633	cy
Volume Excavation	**16,000**	**cy**
Local Material	Transect	
Volume per linear foot of revet	196	ft^2
	529,200	ft^3
	19,600	cy
Volume Local Material	**20,000**	**cy**

14 ft Revetment

Armor Rock	Transect	
Volume per linear foot of revet	149	ft^2
	104,090	ft^3
	3,855	cy
Volume Armor	**4,000**	**cy**
B-rock Rock	Transect	
Volume per linear foot of revet	157	ft^2
	109,564	ft^3
	4,058	cy
Volume B-rock	**4,000**	**cy**
Core Rock	Transect	
Volume per linear foot of revet	56	ft^2
	39,095	ft^3
	1,448	cy
Volume Core	**1,000**	**cy**
Gravel	Transect	
Volume per linear foot of revet	61	ft^2
	42,553	ft^3
	1,576	cy
Volume Gravel	**2,000**	**cy**
Filter Fabric	Transect	
Feet per linear foot of revet	63	ft
	44,282	ft^2
	4,920	yd^2
Total Filter Fabric	**5,000**	**yd^2**
Excavation	Transect	
Volume per linear foot of revet	156	ft^2
	109,431	ft^3
	4,053	cy
Volume Excavation	**4,000**	**cy**
Local Material	Transect	
Volume per linear foot of revet	90	ft^2
	63,175	ft^3
	2,340	cy
Volume Local Material	**2,000**	**cy**

14 ft Berm

Armor Rock	Transect	
Volume per linear foot of revet	135	ft^2
	3,004,925	ft^3
	111,294	cy
Volume Armor	**111,000**	**cy**
B-rock Rock	Transect	
Volume per linear foot of revet	132	ft^2
	2,939,586	ft^3
	108,874	cy
Volume B-rock	**109,000**	**cy**
Core Rock	Transect	
Volume per linear foot of revet	48	ft^2
	1,068,839	ft^3
	39,587	cy
Volume Core	**40,000**	**cy**
Gravel	Transect	
Volume per linear foot of revet	52	ft^2
	1,170,527	ft^3
	43,353	cy
Volume Gravel	**43,000**	**cy**
Filter Fabric	Transect	
Feet per linear foot of revet	55	ft
	1,221,594	ft^2
	135,733	yd^2
Total Filter Fabric	**136,000**	**yd^2**
Excavation	Transect	
Volume per linear foot of revet	232	ft^2
	5,178,952	ft^3
	191,813	cy
Volume Excavation	**192,000**	**cy**

ALTERNATIVE 2B QUANTITIES

Revetment and Raise Stevenson Street						
Length of 19 ft Revet	2700	ft	0.51	miles	1997	
Length of 14 ft Revet	700	ft	0.13	miles		
Length of 14 ft Raise Stevenson	22,300	ft	4.22	miles		

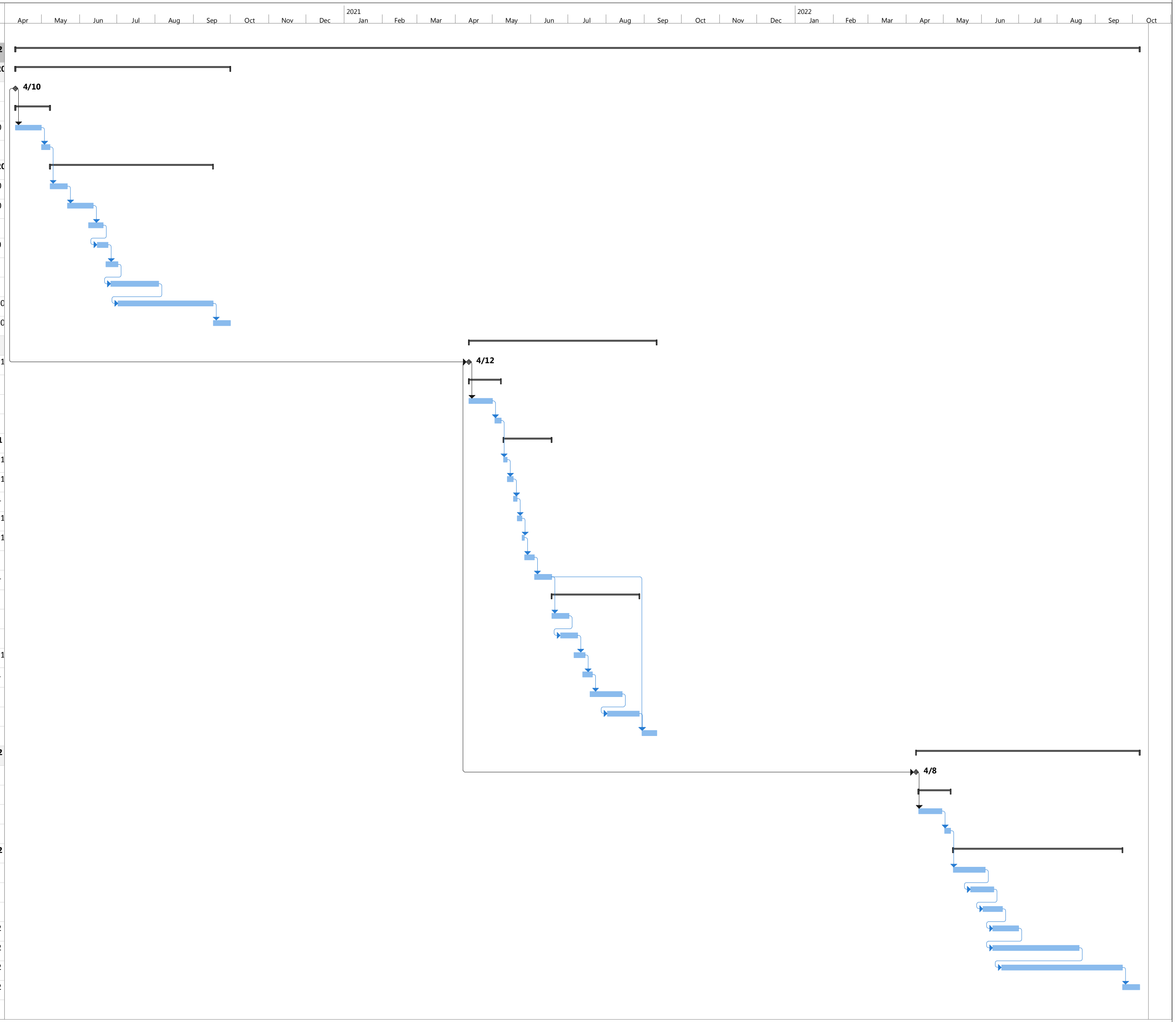
19 ft Revetment			**14 ft Revetment**			**14 ft Raise Stevenon Street**		
Armor Rock	Transect		Armor Rock	Transect		Armor Rock	Transect	
Volume per linear foot of revet	219	ft^2	Volume per linear foot of revet	149	ft^2	Volume per linear foot of revet	110	ft^2
	591,651	ft^3		104,090	ft^3		2,443,411	ft^3
	21,913	cy		3,855	cy		90,497	cy
Volume Armor	**22,000**	**cy**	**Volume Armor**	**4,000**	**cy**	**Volume Armor**	**90,000**	**cy**
B-rock Rock	Transect		B-rock Rock	Transect		B-rock Rock	Transect	
Volume per linear foot of revet	192	ft^2	Volume per linear foot of revet	157	ft^2	Volume per linear foot of revet	137	ft^2
	517,698	ft^3		109,564	ft^3		3,054,208	ft^3
	19,174	cy		4,058	cy		113,119	cy
Volume B-rock	**19,000**	**cy**	**Volume B-rock**	**4,000**	**cy**	**Volume B-rock**	**113,000**	**cy**
Core Rock	Transect		Core Rock	Transect		Core Rock	Transect	
Volume per linear foot of revet	66	ft^2	Volume per linear foot of revet	56	ft^2	Volume per linear foot of revet	50	ft^2
	177,957	ft^3		39,095	ft^3		1,120,798	ft^3
	6,591	cy		1,448	cy		41,511	cy
Volume Core	**7,000**	**cy**	**Volume Core**	**1,000**	**cy**	**Volume Core**	**42,000**	**cy**
Gravel	Transect		Gravel	Transect		Gravel	Transect	
Volume per linear foot of revet	71	ft^2	Volume per linear foot of revet	61	ft^2	Volume per linear foot of revet	55	ft^2
	191,214	ft^3		42,553	ft^3		1,230,960	ft^3
	7,082	cy		1,576	cy		45,591	cy
Volume Gravel	**7,000**	**cy**	**Volume Gravel**	**2,000**	**cy**	**Volume Gravel**	**46,000**	**cy**
Filter Fabric	Transect		Filter Fabric	Transect		Filter Fabric	Transect	
Feet per linear foot of revet	73	ft	Feet per linear foot of revet	63	ft	Feet per linear foot of revet	58	ft
	197,964	ft^2		44,282	ft^2		1,286,041	ft^2
	21,996	yd^2		4,920	yd^2		142,893	yd^2
Total Filter Fabric	**22,000**	**yd^2**	**Total Filter Fabric**	**5,000**	**yd^2**	**Total Filter Fabric**	**143,000**	**yd^2**
Excavation	Transect		Excavation	Transect		Excavation	Transect	
Volume per linear foot of revet	156	ft^2	Volume per linear foot of revet	156	ft^2	Volume per linear foot of revet	156	ft^2
	422,091	ft^3		109,431	ft^3		3,486,159	ft^3
	15,633	cy		4,053	cy		129,117	cy
Volume Excavation	**16,000**	**cy**	**Volume Excavation**	**4,000**	**cy**	**Volume Excavation**	**129,000**	**cy**
Local Material	Transect		Local Material	Transect		Local Material	Transect	
Volume per linear foot of revet	196	ft^2	Volume per linear foot of revet	90	ft^2	Volume per linear foot of revet	211	ft^2
	529,200	ft^3		63,175	ft^3		4,713,328	ft^3
	19,600	cy		2,340	cy		174,568	cy
Volume Local Material	**20,000**	**cy**	**Volume Local Material**	**2,000**	**cy**	**Volume Local Material**	**175,000**	**cy**

ATTACHMENT C

Tentative Construction Schedule

Barrow Coastal Erosion Feasibility Study
Tentative Construction Schedule

ID	Task Name	Duration	Start	Finish
1	BARROW COASTAL EROSION PROTECTION	1 day	Fri 8/24/18	Fri 8/24/18
2	**ALTERNATIVE 2A**	**650 days**	**Fri 4/10/20**	**Thu 10/6/22**
3	**Alternative 2A Construction - Phase I**	**124 days**	**Fri 4/10/20**	**Wed 9/30/20**
4	Notice to Proceed	0 days	Fri 4/10/20	Fri 4/10/20
5	**Mobilization and Preparatory Work**	**20 days**	**Fri 4/10/20**	**Thu 5/7/20**
6	Mobilization	15 days	Fri 4/10/20	Thu 4/30/20
7	Site Access and Staging	5 days	Fri 5/1/20	Thu 5/7/20
8	**19 Ft Revetment**	**94 days**	**Fri 5/8/20**	**Wed 9/16/20**
9	Excavation	10 days	Fri 5/8/20	Thu 5/21/20
10	Local Material Fill	15 days	Fri 5/22/20	Thu 6/11/20
11	Filter Fabric	10 days	Mon 6/8/20	Fri 6/19/20
12	Gravel	7 days	Mon 6/15/20	Tue 6/23/20
13	Core Rock	8 days	Mon 6/22/20	Wed 7/1/20
14	B-rock	27 days	Fri 6/26/20	Mon 8/3/20
15	Armor Rock	55 days	Thu 7/2/20	Wed 9/16/20
16	Demobilization	10 days	Thu 9/17/20	Wed 9/30/20
17	**Alternative 2A Construction - Phase II**	**110 days**	**Mon 4/12/21**	**Fri 9/10/21**
18	Notice to Proceed	0 days	Mon 4/12/21	Mon 4/12/21
19	**Mobilization and Preparatory Work**	**20 days**	**Mon 4/12/21**	**Fri 5/7/21**
20	Mobilization	15 days	Mon 4/12/21	Fri 4/30/21
21	Site Access and Staging	5 days	Mon 5/3/21	Fri 5/7/21
22	**14 Ft Revetment**	**29 days**	**Mon 5/10/21**	**Thu 6/17/21**
23	Excavation	3 days	Mon 5/10/21	Wed 5/12/21
24	Local Material Fill	3 days	Thu 5/13/21	Mon 5/17/21
25	Filter Fabric	3 days	Tue 5/18/21	Thu 5/20/21
26	Gravel	2 days	Fri 5/21/21	Mon 5/24/21
27	Core Rock	2 days	Tue 5/25/21	Wed 5/26/21
28	B-rock	6 days	Thu 5/27/21	Thu 6/3/21
29	Armor Rock	10 days	Fri 6/4/21	Thu 6/17/21
30	**14 FT Berm**	**51 days**	**Fri 6/18/21**	**Fri 8/27/21**
31	Excavation	10 days	Fri 6/18/21	Thu 7/1/21
32	Filter Fabric	10 days	Fri 6/25/21	Thu 7/8/21
33	Gravel	7 days	Tue 7/6/21	Wed 7/14/21
34	Core Rock	6 days	Tue 7/13/21	Tue 7/20/21
35	B-rock	20 days	Mon 7/19/21	Fri 8/13/21
36	Armor Rock	20 days	Mon 8/2/21	Fri 8/27/21
37	Demobilization	10 days	Mon 8/30/21	Fri 9/10/21
38	**Alternative 2A Construction - Phase III**	**129 days**	**Fri 4/8/22**	**Thu 10/6/22**
39	Notice to Proceed	0 days	Fri 4/8/22	Fri 4/8/22
40	**Mobilization and Preparatory Work**	**20 days**	**Mon 4/11/22**	**Fri 5/6/22**
41	Mobilization	15 days	Mon 4/11/22	Fri 4/29/22
42	Site Access and Staging	5 days	Mon 5/2/22	Fri 5/6/22
43	**14 FT Berm (continued)**	**99 days**	**Mon 5/9/22**	**Thu 9/22/22**
44	Excavation	20 days	Mon 5/9/22	Fri 6/3/22
45	Filter Fabric	15 days	Mon 5/23/22	Fri 6/10/22
46	Gravel	12 days	Thu 6/2/22	Fri 6/17/22
47	Core Rock	15 days	Fri 6/10/22	Thu 6/30/22
48	B-rock	50 days	Fri 6/10/22	Thu 8/18/22
49	Armor Rock	70 days	Fri 6/17/22	Thu 9/22/22
50	Demobilization	10 days	Fri 9/23/22	Thu 10/6/22
51				

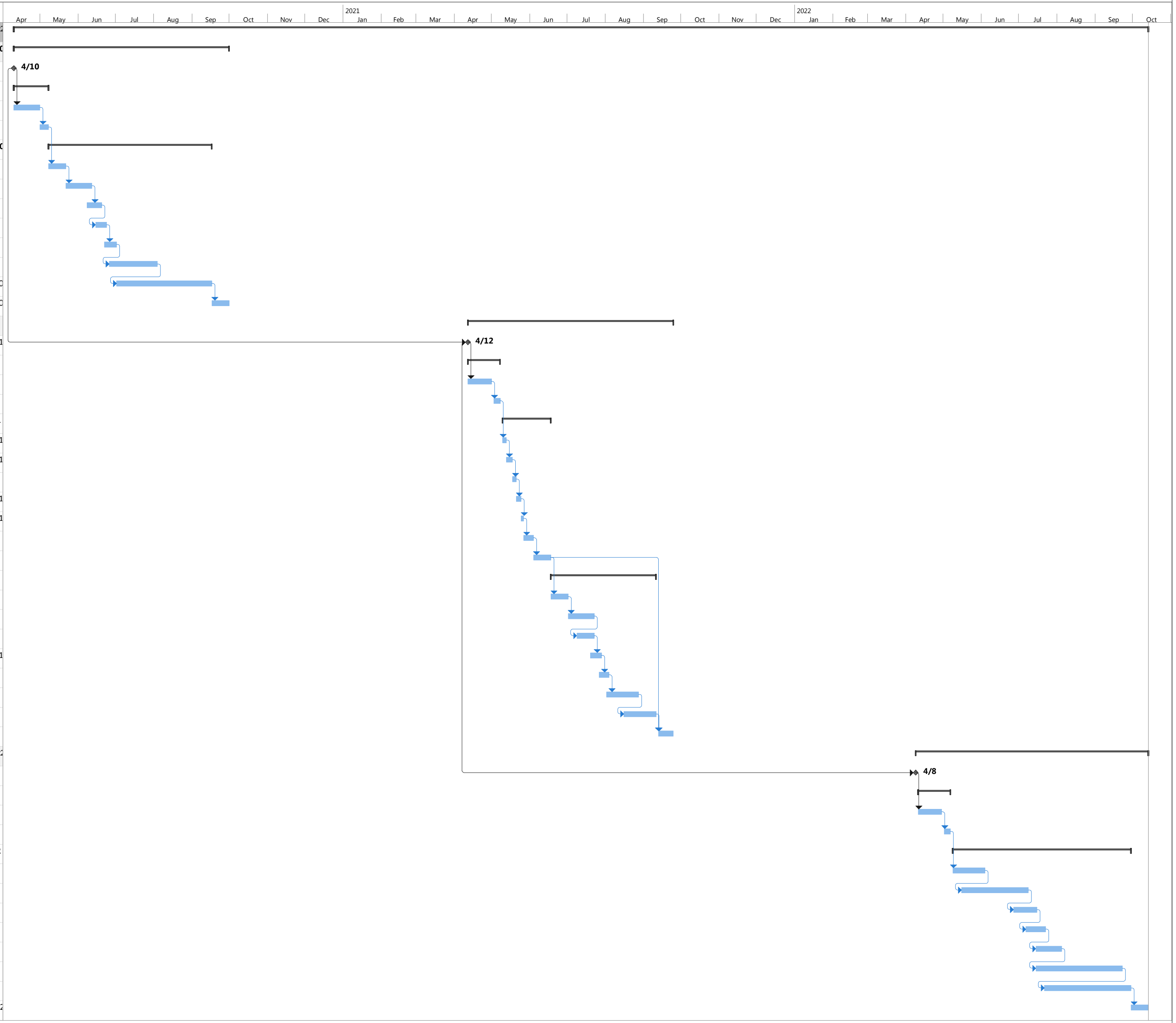


Project: Barrow_Schedule_WOR
Date: Fri 8/24/18

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

Barrow Coastal Erosion Feasibility Study
Tentative Construction Schedule

ID	Task Name	Duration	Start	Finish
52	**ALTERNATIVE 2B**	**655 days**	**Fri 4/10/20**	**Thu 10/13/2**
53	**Alternative 2B Construction - Phase I**	**124 days**	**Fri 4/10/20**	**Wed 9/30/20**
54	Notice to Proceed	0 days	Fri 4/10/20	Fri 4/10/20
55	**Mobilization and Preparatory Work**	**20 days**	**Fri 4/10/20**	**Thu 5/7/20**
56	Mobilization	15 days	Fri 4/10/20	Thu 4/30/20
57	Site Access and Staging	5 days	Fri 5/1/20	Thu 5/7/20
58	**19 Ft Revetment**	**94 days**	**Fri 5/8/20**	**Wed 9/16/20**
59	Excavation	10 days	Fri 5/8/20	Thu 5/21/20
60	Local Material Fill	15 days	Fri 5/22/20	Thu 6/11/20
61	Filter Fabric	10 days	Mon 6/8/20	Fri 6/19/20
62	Gravel	7 days	Mon 6/15/20	Tue 6/23/20
63	Core Rock	8 days	Mon 6/22/20	Wed 7/1/20
64	B-rock	27 days	Fri 6/26/20	Mon 8/3/20
65	Armor Rock	55 days	Thu 7/2/20	Wed 9/16/20
66	Demobilization	10 days	Thu 9/17/20	Wed 9/30/20
67	**Alternative 2B Construction - Phase II**	**120 days**	**Mon 4/12/21**	**Fri 9/24/21**
68	Notice to Proceed	0 days	Mon 4/12/21	Mon 4/12/21
69	**Mobilization and Preparatory Work**	**20 days**	**Mon 4/12/21**	**Fri 5/7/21**
70	Mobilization	15 days	Mon 4/12/21	Fri 4/30/21
71	Site Access and Staging	5 days	Mon 5/3/21	Fri 5/7/21
72	**14 Ft Revetment**	**29 days**	**Mon 5/10/21**	**Thu 6/17/21**
73	Excavation	3 days	Mon 5/10/21	Wed 5/12/21
74	Local Material Fill	3 days	Thu 5/13/21	Mon 5/17/21
75	Filter Fabric	3 days	Tue 5/18/21	Thu 5/20/21
76	Gravel	2 days	Fri 5/21/21	Mon 5/24/21
77	Core Rock	2 days	Tue 5/25/21	Wed 5/26/21
78	B-rock	6 days	Thu 5/27/21	Thu 6/3/21
79	Armor Rock	10 days	Fri 6/4/21	Thu 6/17/21
80	**14 Ft Raise Stevenson Street**	**61 days**	**Fri 6/18/21**	**Fri 9/10/21**
81	Excavation	10 days	Fri 6/18/21	Thu 7/1/21
82	Local Material Fill	15 days	Fri 7/2/21	Thu 7/22/21
83	Filter Fabric	10 days	Fri 7/9/21	Thu 7/22/21
84	Gravel	7 days	Tue 7/20/21	Wed 7/28/21
85	Core Rock	6 days	Tue 7/27/21	Tue 8/3/21
86	B-rock	20 days	Mon 8/2/21	Fri 8/27/21
87	Armor Rock	20 days	Mon 8/16/21	Fri 9/10/21
88	Demobilization	10 days	Mon 9/13/21	Fri 9/24/21
89	**Alternative 2B Construction - Phase III**	**134 days**	**Fri 4/8/22**	**Thu 10/13/2**
90	Notice to Proceed	0 days	Fri 4/8/22	Fri 4/8/22
91	**Mobilization and Preparatory Work**	**20 days**	**Mon 4/11/22**	**Fri 5/6/22**
92	Mobilization	15 days	Mon 4/11/22	Fri 4/29/22
93	Site Access and Staging	5 days	Mon 5/2/22	Fri 5/6/22
94	**14 Ft Raise Stevenson Street (continued)**	**104 days**	**Mon 5/9/22**	**Thu 9/29/22**
95	Excavation	20 days	Mon 5/9/22	Fri 6/3/22
96	Local Material Fill	40 days	Mon 5/16/22	Fri 7/8/22
97	Filter Fabric	15 days	Mon 6/27/22	Fri 7/15/22
98	Gravel	12 days	Thu 7/7/22	Fri 7/22/22
99	Core Rock	15 days	Fri 7/15/22	Thu 8/4/22
100	B-rock	50 days	Fri 7/15/22	Thu 9/22/22
101	Armor Rock	50 days	Fri 7/22/22	Thu 9/29/22
102	Demobilization	10 days	Fri 9/30/22	Thu 10/13/2



Project: Barrow_Schedule_WOR
Date: Fri 8/24/18

Task | Split | Milestone | Summary | Project Summary | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | External Tasks | External Milestone | Deadline | Progress | Manual Progress

ATTACHMENT D

Price Quotes

Material Costs

Grayed out notes indicate that information remains outstanding

- Nome Quarry | Larry Pedersen, Bering Straits Native Corporation
  - By material, in consideration of typical rock specs:
    - Armor: $113/ton base cost
    - B rock: $88/ton
    - Core: $68/ton
    - Gravel: $28/ton
  - Add $12/ton for trucking to Nome dock (do not add for loading at quarry)
  - Can apply approx. 20% savings due to job size efficiencies. With savings:
    - Armor: $90.40 /ton
    - B rock: $70.40 /ton
    - Core: $54.40 /ton
    - Gravel: $22.40 /ton

- Nome Quarry | Parry Rekers, Knik Construction (Lynden)
  - By material, all prices are cost delivered to Nome dock, and do not include any savings for job size/efficiency, and were provided without consideration of the rock spec.
    - Armor: $130 /ton
    - B rock: $115 /ton
    - Core: $75 /ton
    - Gravel: $15 /ton

- Bering Shai Rock and Gravel | Bill Shaishnikoff
  - Indicated that the quarry could provide all necessary material to Corps spec, though a job of this size would be very large compared to typical work
    - A - Rock. $41.00 per CY. Add $2.00 per CY to load onto barge
    - B - Rock. $38.00 per CY. Add 2.00 per CY to load on barge
    - Core - Rock. $34.00 per CY. Add $1.25 per CY to load on barge
    - 3 "- minus. $27.00 per CY. Add $1.00 per CY to add on barge
    - 1" - minus. $29.00 per CY. Add $1.00 to load on barge
  - The quarry has a barge ramp. The barge fee applies when a barge with a drop gate is in use. Presently the quarry cannot side load a barge as the mooring piling have not yet been installed. If they are not installed at the time this project is out to bid, then the quarry would have to truck the products to a dock that has that capability, which has been done in the past.

Material Transport Costs

Grayed out notes indicate that information remains outstanding

- UIC Marine | Don Gray
  - $60-65 per ton, given:
    - Assume barges moving to/from Nome quarry
    - Barges may originate in Puget Sound and carry up initial load of rock
    - Includes lighterage to shore at Barrow; excludes offload/trucking onshore
    - No contingencies included
    - Assumes 3 seasons

- Cook Inlet Tug & Barge (Foss) | Mike O'Shea
  - *Consistent with UIC Marine estimate with contingencies removed…*
  - $85 per ton, given:
    - Assume barges moving to/from Nome quarry
    - Barges may originate in Puget Sound and carry up initial load of rock
    - Excludes loading/offload of barges and any lighterage (assumes barges can pull up to shore for load/unload)
    - Cost includes 25% contingency and placeholder assumptions for delays
    - 3 seasons to complete

- Bowhead Transport | Billy Jarrett
  - $80 per ton including loading/offload at Nome/Barrow
    - Awaiting clarifying information about assumed contingencies

- Bryce Marine | Drew McIntyre
  - $73 – 81 per ton ROM cost, given all rock from Nome:
    - Between 3-yr and 4-yr completion timeline, multiple barges
    - $44M for 600,000 tons
    - Assumes $5/gal fuel
    - Excluded unloading
  - $110 per ton ROM cost, given all rock from Bering Shai (Dutch Harbor)
    - Between 3-yr and 4-yr completion timeline, multiple barges
    - $44M for 600,000 tons
    - Assumes $5/gal fuel
    - Excluded unloading

- Lynden via UIC Marine | Don Gray
  - ________ per ton using large 250,000 ton ship out of Vancouver BC
    - Awaiting data. Don Gray is talking with a contact at Lynden. Initial conversations with them indicated that it might be economical to use one large ship that could move all necessary material in 3 trips to Barrow in one season.

ATTACHMENT E

Local Market Labor Rates

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General Decision Number: AK180001 08/24/2018  AK1

Superseded General Decision Number: AK20170001

State: Alaska

Construction Types: Building and Heavy

Counties: Alaska Statewide.

BUILDING AND HEAVY CONSTRUCTION PROJECTS (does not include
residential construction consisting of single family homes and
apartments up to and including 4 stories)

Note: Under Executive Order (EO) 13658, an hourly minimum wage
of $10.35 for calendar year 2018 applies to all contracts
subject to the Davis-Bacon Act for which the contract is
awarded (and any solicitation was issued) on or after January
1, 2015. If this contract is covered by the EO, the contractor
must pay all workers in any classification listed on this wage
determination at least $10.35 per hour (or the applicable wage
rate listed on this wage determination, if it is higher) for
all hours spent performing on the contract in calendar year
2018. The EO minimum wage rate will be adjusted annually.
Please note that this EO applies to the above-mentioned types
of contracts entered into by the federal government that are
subject to the Davis-Bacon Act itself, but it does not apply to
contracts subject only to the Davis-Bacon Related Acts,
including those set forth at 29 CFR 5.1(a)(2)-(60). Additional
information on contractor requirements and worker protections
under the EO is available at www.dol.gov/whd/govcontracts.


Modification Number     Publication Date
          0              01/05/2018
          1              01/12/2018
          2              02/09/2018
          3              03/30/2018
          4              04/06/2018
          5              04/20/2018
          6              04/27/2018
          7              06/01/2018
          8              08/03/2018
          9              08/17/2018
          10             08/24/2018

 ASBE0097-001 01/01/2018

                                  Rates          Fringes

Asbestos Workers/Insulator
(includes application of all
insulating materials
protective coverings,
coatings and finishings to
all types of mechanical
systems).........................$ 38.68          21.57
HAZARDOUS MATERIAL HANDLER
(includes preparation,
wetting, stripping, removal
scrapping, vacuming, bagging,
and disposing of all
insulation materials, whether
they contain asbestos or not,
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from mechanical systems).........$ 37.38            19.55
----------------------------------------------------------------
 BOIL0502-002 08/01/2016

                                  Rates          Fringes

BOILERMAKER......................$ 44.26            28.41
----------------------------------------------------------------
 BRAK0001-002 07/01/2017

                                  Rates          Fringes

Bricklayer, Blocklayer,
Stonemason, Marble Mason,
Tile Setter, Terrazzo Worker.....$ 40.81            19.19
Tile & Terrazzo Finisher.........$ 34.79            19.19
----------------------------------------------------------------
 CARP1501-001 09/01/2016

                                  Rates          Fringes

MILLWRIGHT.......................$ 36.74            22.99
----------------------------------------------------------------
 CARP2520-003 09/01/2017

                                  Rates          Fringes

Diver
     Stand-by....................$ 42.65            25.16
     Tender......................$ 41.65            25.16
     Working.....................$ 82.45            25.16
Piledriver
     Piledriver; Skiff Operator
     and Rigger..................$ 38.34            25.16
     Sheet Stabber...............$ 38.34            25.16
     Welder......................$ 43.90            25.16

DEPTH PAY PREMIUM FOR DIVERS BELOW WATER SURFACE:
50-100 feet                 $1.00 per foot
101 feet and deeper         $2.00 per foot

ENCLOSURE PAY PREMIUM WITH NO VERTICAL ASCENT:
5-50 FEET                   $1.00 PER FOOT/DAY
51-100 FEET                 $2.00 PER FOOT/DAY
101 FEET AND ABOVE          $3.00 PER FOOT/DAY

SATURATION DIVING:
  The standby rate applies until saturation starts. The
  saturation diving rate applies when divers are under
  pressure continuously until work task and decompression are
  complete. the diver rate shall be paid for all saturation
  hours.

WORK IN COMBINATION OF CLASSIFICATIONS:
  Employees working in any combination of classifications
  within the diving crew (except dive supervisor) in a shift
  are paid in the classification with the highest rate for
  that shift.

----------------------------------------------------------------
 CARP4059-001 09/01/2016

                                  Rates          Fringes

CARPENTER
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     Including Lather and
     Drywall Hanging.............$ 38.34            25.04
----------------------------------------------------------------
 ELEC1547-004 04/01/2018

                                  Rates          Fringes

CABLE SPLICER....................$ 39.82        3%+$26.44
ELECTRICIAN......................$ 39.49        3%+$26.69
----------------------------------------------------------------
 ELEC1547-005 04/01/2018

Line Construction

                                  Rates          Fringes

CABLE SPLICER....................$ 52.57         3%+30.81
Linemen (Including Equipment
Operators, Technician)...........$ 50.52         3%+30.81
Powderman........................$ 48.52         3%+30.81
TREE TRIMMER.....................$ 36.21         3%+24.19
----------------------------------------------------------------
 ELEV0019-002 01/01/2018

                                  Rates          Fringes

ELEVATOR MECHANIC................$ 55.45       32.645+a+b

FOOTNOTE: a.  Employer contributes 8% of the basic hourly rate
    for over 5 year's service and 6% of the basic
    hourly rate for 6 months to 5 years' of service
    as vacation paid credit.   b. Eight paid holidays:
    New Year's Day; Memorial Day; Independence Day;
    Labor Day; Veteran's Day; Thanksgiving Day; Friday after
    Thanksgiving, and Christmas Day

----------------------------------------------------------------
 ENGI0302-002 04/01/2018

                                  Rates          Fringes

POWER EQUIPMENT OPERATOR
     GROUP 1.....................$ 40.28            23.05
     GROUP 1A....................$ 42.04            23.05
     GROUP 2.....................$ 39.51            23.05
     GROUP 3.....................$ 38.79            23.05
     GROUP 4.....................$ 32.58            23.05
     TUNNEL WORK
      GROUP 1....................$ 44.31            23.05
      GROUP 1A...................$ 46.24            23.05
      GROUP 2....................$ 43.46            23.05
      GROUP 3....................$ 42.67            23.05
      GROUP 4....................$ 35.84            23.05

POWER EQUIPMENT OPERATOR CLASSIFICATIONS

  GROUP 1:  Asphalt Roller: Breakdown, Intermediate, and
  Finish; Back Filler; Barrier Machine (Zipper); Beltcrete
  with power pack and similar conveyors; Bending Machine;
  Boat Coxwains; Bulldozers; Cableways, Highlines and
  Cablecars; Cleaning Machine; Coating Machine; Concrete
  Hydro Blaster; Cranes-45 tons and under or 150 foot boom
  and under (including jib and attachments): (a) Hydralifts
  or Transporters, all track or truck type,(b) Derricks;
  Crushers; Deck Winches-Double Drum; Ditching or Trenching
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Machine (16 inch or over); Drilling Machines, core, cable,
rotary and exploration; Finishing Machine Operator,
Concrete Paving, Laser Screed, Sidewalk, Curb and Gutter
Machine; Helicopters; Hover Craft, Flex Craft, Loadmaster,
Air Cushion, All Terrain Vehicle, Rollagon, Bargecable,
Nodwell, and Snow Cat; Hydro Ax: Feller Buncher and
similar; Loaders (2 1/2 yards through 5 yards, including
all attachments): Forklifts with telescopic boom and swing
attachment, Overhead and front end, 2 1/2 yards through 5
yards, Loaders with forks or pipe clamps; Loaders,
elevating belt type, Euclid and similar types; Mechanics,
Bodyman; Micro Tunneling Machine; Mixers: Mobile type
w/hoist combination; Motor Patrol Grader; Mucking Machines:
Mole, Tunnel Drill, Horizontal/Directional Drill Operator,
and/or Shield; Operator on Dredges; Piledriver Engineers,
L. B. Foster, Puller or similar Paving Breaker; Power
Plant, Turbine Operator, 200 k.w. and over (power plants or
combination of power units over 300 k.w.); Scrapers-through
40 yards; Service Oiler/Service Engineer; Sidebooms-under
45 tons; Shot Blast Machine; Shovels, Backhoes, Excavators
with all attachments, and Gradealls (3 yards and under),
Spreaders, Blaw Knox, Cedarapids, Barber Greene, Slurry
Machine; Sub-grader (Gurries, Reclaimer, and similar
types); Tack tractor; Truck mounted Concrete Pumps,
Conveyor, Creter; Water Kote Machine; Unlicensed off road
hauler

GROUP 1A:  Camera/Tool/Video Operator (Slipline),
Cranes-over 45 tons or 150 foot (including jib and
attachments): (a) Clamshells and Draglines (over 3 yards),
(b) Tower cranes; Licensed Water/Waste Water Treatment
Operator; Loaders over 5 yds.; Certified Welder, Electrical
Mechanic, Camp Maintenance Engineer, Mechanic (over 10,000
hours); Motor Patrol Grader, Dozer, Grade Tractor,
Roto-mill/Profiler (finish: when finishing to final grade
and/or to hubs, or for asphalt); Power Plants: 1000 k.w.
and over; Quad; Screed; Shovels, Backhoes, Excavators with
all attachments (over 3 yards), Sidebooms over 45 tons;
Slip Form Paver, C.M.I. and similar types; Scrapers over 40
yards;

GROUP 2: Boiler-fireman; Cement Hog and Concrete Pump
Operator; Conveyors (except as listed in group 1); Hoist on
steel erection; Towermobiles and Air Tuggers;
Horizontal/Directional Drill Locator;Licensed Grade
Technician; Loaders, (i.e., Elevating Grader and Material
Transfer Vehicle); Locomotives: rod and geared engines;
Mixers; Screening, Washing Plant; Sideboom (cradling rock
drill regardless of size); Skidder; Trencing Machine under
16 inches; Waste/ Waste Water Treatment Operator.

GROUP 3: "A" Frame Trucks, Deck Winches: single power drum;
Bombardier (tack or tow rig); Boring Machine; Brooms-power;
Bump Cutter; Compressor; Farm tractor; Forklift, industrial
type; Gin Truck or Winch Truck with poles when used for
hoisting; Grade Checker and Stake Hopper; Hoist, Air
Tuggers, Elevators; Loaders: (a) Elevating-Athey, Barber
Green and similar types  (b) Forklifts or Lumber Carrier
(on construction job site)  (c) Forklifts with Tower  (d)
Overhead and Front-end, under 2 1/2 yds. Locomotives:Dinkey
(air, steam, gas and electric) Speeders; Mechanics (light
duty); Oil, Blower Distribution; Post Hole Diggers,
mechanical; Pot Fireman (power agitated); Power Plant,
Turbine Operator, under 200 k.w.; Pumps-water; Roller-other
than Plantmix; Saws, concrete; Skid Steer with all
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attachments; Straightening Machine; Tow Tractor

GROUP 4: Rig Oiler/Crane Assistant Engineer;Parts and Equipment Coordinator; Swamper (on trenching machines or shovel type equipment); Spotter; Steam Cleaner; Drill Helper.

FOOTNOTE: Groups 1-4 receive 10% premium while performing tunnel or underground work. Rig Oiler/Crane Assistant Engineer shall be required on cranes over 85 tons or over 100 feet of boom.

IRON0751-003 07/01/2017

	Rates	Fringes
Ironworkers:		
BRIDGE, STRUCTURAL, ORNAMENTAL, REINFORCING MACHINERY MOVER, RIGGER, SHEETER, STAGE RIGGER, BENDER OPERATOR	$ 37.25	30.43
FENCE, BARRIER INSTALLER	$ 33.75	30.08
GUARDRAIL INSTALLERS	$ 34.75	30.08
GUARDRAIL LAYOUT MAN	$ 34.49	30.08
HELICOPTER, TOWER	$ 38.25	30.43

LABO0341-005 04/01/2018

	Rates	Fringes
Laborers: South of the 63rd Parallel & West of Longitude 138 Degrees		
GROUP 1	$ 30.26	27.01
GROUP 2	$ 31.26	27.01
GROUP 3	$ 32.16	27.01
GROUP 3A	$ 35.44	27.01
GROUP 3B	$ 39.98	24.30
GROUP 4	$ 19.83	27.01
TUNNELS, SHAFTS, AND RAISES		
GROUP 1	$ 33.29	27.01
GROUP 2	$ 34.39	27.01
GROUP 3	$ 35.38	27.01
GROUP 3A	$ 38.98	27.01
GROUP 3B	$ 42.88	24.30

LABORERS CLASSIFICATIONS

GROUP 1: Asphalt Workers (shovelman, plant crew); Brush Cutters; Camp Maintenance Laborer; Carpenter Tenders; Choke Setters, Hook Tender, Rigger, Signalman; Concrete Laborer(curb and gutter, chute handler, grouting, curing, screeding); Crusher Plant Laborer; Demolition Laborer; Ditch Diggers; Dump Man; Environmental Laborer (asbestos (limited to nonmechanical systems), hazardous and toxic waste, oil spill); Fence Installer; Fire Watch Laborer; Flagman; Form Strippers; General Laborer; Guardrail Laborer, Bridge Rail Installers; Hydro-Seeder Nozzleman; Laborers (building); Landscape or Planter; Laying of Decorative Block (retaining walls, flowered decorative block 4 feet and below); Material Handlers; Pneumatic or Power Tools; Portable or Chemical Toilet Serviceman; Pump Man or Mixer Man; Railroad Track Laborer; Sandblast, Pot

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   Tender; Saw Tenders; Scaffold Building and Erecting; Slurry
   Work; Stake Hopper; Steam Point or Water Jet Operator;
   Steam Cleaner Operator; Tank Cleaning; Utiliwalk, Utilidor
   Laborer and Conduit Installer; Watchman (construction
   projects); Window Cleaner

   GROUP 2: Burning and Cutting Torch; Cement or Lime Dumper or
   Handler (sack or bulk); Choker Splicer; Chucktender (wagon,
   airtrack and hydraulic drills); Concrete Laborers (power
   buggy, concrete saws, pumpcrete nozzleman, vibratorman);
   Culvert Pipe Laborer; Cured in place Pipelayer;
   Environmental Laborer (marine work, oil spill skimmer
   operator, small boat operator); Foam Gun or Foam Machine
   Operator; Green Cutter (dam work); Gunnite Operator; Hod
   Carriers; Jackhammer or Pavement Breakers (more than 45
   pounds);Laying of Decorative Block (retaining walls,
   flowered decorative block above 4 feet); Mason Tender and
   Mud Mixer (sewer work); Pilot Car; Plasterer, Bricklayer
   and Cement Finisher Tenders; Power Saw Operator; Railroad
   Switch Layout Laborer; Sandblaster; Sewer Caulkers; Sewer
   Plant Maintenance Man; Thermal Plastic Applicator; Timber
   Faller, chain saw operator, filer; Timberman

   GROUP 3: Alarm Installer; Bit Grinder; Guardrail Machine
   Operator; High Rigger and tree topper; High Scaler;
   Multiplate; Slurry Seal Squeegee Man

   GROUP 3A: Asphalt Raker, Asphalt Belly dump lay down; Drill
   Doctor (in the field); Drillers (including, but not limited
   to, wagon drills, air track drills; hydraulic drills);
   Powderman; Pioneer Drilling and Drilling Off Tugger (all
   type drills); Pipelayers

   GROUP 3B: Grade checker (setting or transfering of grade
   marks, line and grade)

 GROUP 4:  Final Building Cleanup

 TUNNELS, SHAFTS, AND RAISES CLASSIFICATIONS

   GROUP 1:  Brakeman; Muckers; Nippers; Topman and Bull Gang;
   Tunnel Track Laborer

   GROUP 2:  Burning and Cutting Torch; Concrete Laborers;
   Jackhammers; Nozzleman, Pumpcrete or Shotcrete.

 GROUP 3:  Miner; Retimberman

   GROUP 3A: Asphalt Raker, Asphalt Belly dump lay down; Drill
   Doctor (in the field); Drillers (including, but not limited
   to, wagon drills, air track drills; hydraulic drills);
   Powderman; Pioneer Drilling and Drilling Off Tugger (all
   type drills); Pipelayers.

   GROUP 3B:  Grade checker (setting or transfering of grade
   marks, line and grade)

   Tunnel shaft and raise rates only apply to workers regularly
   employed inside a tunnel portal or shaft collar.

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  LABO0942-001 04/01/2018

                                Rates          Fringes
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Laborers: North of the 63rd
Parallel & East of Longitude
138 Degrees
    GROUP 1....................$ 30.26            27.21
    GROUP 2....................$ 31.26            27.21
    GROUP 3....................$ 32.16            27.21
    GROUP 3A...................$ 35.44            27.21
    GROUP 3B...................$ 38.98            24.50
    GROUP 4....................$ 19.83            27.21
    TUNNELS, SHAFTS, AND RAISES
     GROUP 1...................$ 33.29            27.21
     GROUP 2...................$ 34.39            27.21
     GROUP 3...................$ 35.38            27.21
     GROUP 3A..................$ 38.98            27.21
     GROUP 3B..................$ 42.88            24.50
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LABORERS CLASSIFICATIONS

GROUP 1: Asphalt Workers (shovelman, plant crew); Brush Cutters; Camp Maintenance Laborer; Carpenter Tenders; Choke Setters, Hook Tender, Rigger, Signalman; Concrete Laborer(curb and gutter, chute handler, grouting, curing, screeding); Crusher Plant Laborer; Demolition Laborer; Ditch Diggers; Dump Man; Environmental Laborer (asbestos (limited to nonmechanical systems), hazardous and toxic waste, oil spill); Fence Installer; Fire Watch Laborer; Flagman; Form Strippers; General Laborer; Guardrail Laborer, Bridge Rail Installers; Hydro-Seeder Nozzleman; Laborers (building); Landscape or Planter; Laying of Decorative Block (retaining walls, flowered decorative block 4 feet and below); Material Handlers; Pneumatic or Power Tools; Portable or Chemical Toilet Serviceman; Pump Man or Mixer Man; Railroad Track Laborer; Sandblast, Pot Tender; Saw Tenders; Scaffold Building and Erecting; Slurry Work; Stake Hopper; Steam Point or Water Jet Operator; Steam Cleaner Operator; Tank Cleaning; Utiliwalk, Utilidor Laborer and Conduit Installer; Watchman (construction projects); Window Cleaner

GROUP 2: Burning and Cutting Torch; Cement or Lime Dumper or Handler (sack or bulk); Choker Splicer; Chucktender (wagon, airtrack and hydraulic drills); Concrete Laborers (power buggy, concrete saws, pumpcrete nozzleman, vibratorman); Culvert Pipe Laborer; Cured in place Pipelayer; Environmental Laborer (marine work, oil spill skimmer operator, small boat operator); Foam Gun or Foam Machine Operator; Green Cutter (dam work); Gunnite Operator; Hod Carriers; Jackhammer or Pavement Breakers (more than 45 pounds);Laying of Decorative Block (retaining walls, flowered decorative block above 4 feet); Mason Tender and Mud Mixer (sewer work); Pilot Car; Plasterer, Bricklayer and Cement Finisher Tenders; Power Saw Operator; Railroad Switch Layout Laborer; Sandblaster; Sewer Caulkers; Sewer Plant Maintenance Man; Thermal Plastic Applicator; Timber Faller, chain saw operator, filer; Timberman

GROUP 3: Alarm Installer; Bit Grinder; Guardrail Machine Operator; High Rigger and tree topper; High Scaler; Multiplate; Slurry Seal Squeegee Man

GROUP 3A: Asphalt Raker, Asphalt Belly dump lay down; Drill Doctor (in the field); Drillers (including, but not limited to, wagon drills, air track drills; hydraulic drills); Powderman; Pioneer Drilling and Drilling Off Tugger (all type drills); Pipelayers

GROUP 3B: Grade checker (setting or transfering of grade marks, line and grade)

GROUP 4: Final Building Cleanup

TUNNELS, SHAFTS, AND RAISES CLASSIFICATIONS

GROUP 1: Brakeman; Muckers; Nippers; Topman and Bull Gang; Tunnel Track Laborer

GROUP 2: Burning and Cutting Torch; Concrete Laborers; Jackhammers; Nozzleman, Pumpcrete or Shotcrete.

GROUP 3: Miner; Retimberman

GROUP 3A: Asphalt Raker, Asphalt Belly dump lay down; Drill Doctor (in the field); Drillers (including, but not limited to, wagon drills, air track drills; hydraulic drills); Powderman; Pioneer Drilling and Drilling Off Tugger (all type drills); Pipelayers.

GROUP 3B: Grade checker (setting or transfering of grade marks, line and grade)

Tunnel shaft and raise rates only apply to workers regularly employed inside a tunnel portal or shaft collar.

PAIN1959-001 07/01/2018

NORTH OF THE 63RD PARALLEL

	Rates	Fringes
PAINTER		
BRUSH/ROLLER PAINT OR WALL COVERER	$ 32.09	21.09
TAPING, TEXTURING, STRUCTURAL PAINTING, SANDBLASTING, POT TENDER, FINISH METAL, SPRAY, BUFFER OPERATOR, RADON MITIGATION, LEAD BASED PAINT ABATEMENT, HAZARDOUS MATERIAL HANDLER	$ 32.61	21.09

PAIN1959-002 07/01/2018

SOUTH OF THE 63RD PARALLEL

	Rates	Fringes
PAINTER		
Brush, Roller, Sign, Paper and Vinyl, Swing Stage, Hand Taper/Drywall, Structural Steel, and Commercial Spray	$ 32.09	21.09
Machine Taper/Drywall	$ 32.61	21.09
Spray-Sand/Blast, Epoxy and Tar Applicator	$ 32.61	20.09

PAIN1959-003 07/01/2018

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NORTH OF THE 63RD PARALLEL

                                  Rates          Fringes

GLAZIER..........................$ 39.28            23.49
----------------------------------------------------------------
 PAIN1959-004 07/01/2018

                                  Rates          Fringes

FLOOR LAYER:  Carpet.............$ 29.13            14.06
----------------------------------------------------------------
 PAIN1959-006 07/01/2018

SOUTH OF THE 63RD PARALLEL

                                  Rates          Fringes

GLAZIER..........................$ 39.28            23.49
----------------------------------------------------------------
 PLAS0867-001 02/01/2016

                                  Rates          Fringes

PLASTERER
     North of the 63rd parallel..$ 37.25            20.41
     South of the 63rd parallel..$ 37.00            20.41
----------------------------------------------------------------
 PLAS0867-004 02/01/2016

                                  Rates          Fringes

CEMENT MASON/CONCRETE FINISHER
     North of the 63rd parallel..$ 37.25            20.41
     South of the 63rd parallel..$ 37.00            20.41
----------------------------------------------------------------
 PLUM0262-002 01/01/2017

East of the 141st Meridian

                                  Rates          Fringes

Plumber; Steamfitter.............$ 38.02            26.72
----------------------------------------------------------------
 PLUM0367-002 07/01/2017

South of the 63rd Parallel

                                  Rates          Fringes

Plumber; Steamfitter.............$ 39.00            23.80
----------------------------------------------------------------
 PLUM0375-002 07/01/2018

North of the 63rd Parallel

                                  Rates          Fringes

Plumber; Steamfitter.............$ 41.16            26.55
----------------------------------------------------------------
 PLUM0669-002 04/01/2017

                                  Rates          Fringes

SPRINKLER FITTER.................$ 46.00            23.29
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ROOF0189-006 04/01/2018

	Rates	Fringes
ROOFER	$ 44.62	15.50

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* SHEE0023-003 07/01/2018

South of the 63rd Parallel

	Rates	Fringes
SHEET METAL WORKER	$ 42.70	26.40

SHEE0023-004 07/01/2017

North of the 63rd Parallel

	Rates	Fringes
SHEET METAL WORKER	$ 47.74	23.48

TEAM0959-003 03/01/2018

	Rates	Fringes
TRUCK DRIVER		
GROUP 1	$ 39.59	23.62
GROUP 1A	$ 40.86	23.62
GROUP 2	$ 38.33	23.62
GROUP 3	$ 37.51	23.62
GROUP 4	$ 36.93	23.62
GROUP 5	$ 36.17	23.62

GROUP 1: Semi with Double Box Mixer; Dump Trucks (including rockbuggy and trucks with pups) over 40 yards up to and including 60 yards; Deltas, Commanders, Rollogans and similar equipment when pulling sleds, trailers or similar equipment; Boat Coxswain; Lowboys including attached trailers and jeeps, up to and including 12 axles; Ready-mix over 12 yards up to and including 15 yards); Water Wagon (250 Bbls and above); Tireman, Heavy Duty/Fueler

GROUP 1A: Dump Trucks (including Rockbuggy and Trucks with pups) over 60 yards up to and including 100 yards; Jeeps (driver under load)

GROUP 2: Turn-O-Wagon or DW-10 not self-loading; All Deltas, Commanders, Rollogans, and similar equipment; Mechanics; Dump Trucks (including Rockbuggy and Trucks with pups) over 20 yards up to and including 40 yards; Lowboys including attached trailers and jeeps up to and including 8 axles; Super vac truck/cacasco truck/heat stress truck; Ready-mix over 7 yards up to and including 12 yards; Partsman; Stringing Truck

GROUP 3: Dump Trucks (including Rockbuggy and Trucks with pups) over 10 yards up to and including 20 yards; batch trucks 8 yards and up; Oil distributor drivers; Oil Distributor Drivers; Trucks/Jeeps (push or pull); Traffic Control Technician

GROUP 4: Buggymobile; Semi or Truck and trailer; Dumpster; Tireman (light duty); Dump Trucks (including Rockbuggy and

Truck with pups) up to and including 10 yards; Track Truck Equipment; Grease Truck; Flat Beds, dual rear axle; Hyster Operators (handling bulk aggregate); Lumber Carrier; Water Wagon, semi; Water Truck, dual axle; Gin Pole Truck, Winch Truck, Wrecker, Truck Mounted "A" Frame manufactured rating over 5 tons; Bull Lifts and Fork Lifts with Power Boom and Swing attachments, over 5 tons; Front End Loader with Forks; Bus Operator over 30 passengers; All Terrain Vehicles; Boom Truck/Knuckle Truck over 5 tons; Foam Distributor Truck/dual axle; Hydro-seeders, dual axle; Vacuum Trucks, Truck Vacuum Sweepers; Loadmaster (air and water); Air Cushion or similar type vehicle; Fire Truck/Ambulance Driver; Combination Truck-fuel and grease; Compactor (when pulled by rubber tired equipment); Rigger (air/water/oilfield); Ready Mix, up to and including 7 yards;

GROUP 5: Gravel Spreader Box Operator on Truck; Flat Beds, single rear axle; Boom Truck/Knuckle Truck up to and including 5 tons; Pickups (Pilot Cars and all light duty vehicles); Water Wagon (Below 250 Bbls); Gin Pole Truck, Winch Truck, Wrecker, Truck Mounted "A" Frame, manufactured rating 5 tons and under; Bull Lifts and Fork Lifts (fork lifts with power broom and swing attachments up to and including 5 tons); Buffer Truck; Tack Truck; Farm type Rubber Tired Tractor (when material handling or pulling wagons on a construction project); Foam Distributor, single axle; Hydro-Seeders, single axle; Team Drivers (horses, mules and similar equipment); Fuel Handler (station/bulk attendant); Batch Truck, up to and including 7 yards; Gear/Supply Truck; Bus Operator, Up to 30 Passengers; Rigger/Swamper

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WELDERS - Receive rate prescribed for craft performing operation to which welding is incidental.

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Note: Executive Order (EO) 13706, Establishing Paid Sick Leave for Federal Contractors applies to all contracts subject to the Davis-Bacon Act for which the contract is awarded (and any solicitation was issued) on or after January 1, 2017. If this contract is covered by the EO, the contractor must provide employees with 1 hour of paid sick leave for every 30 hours they work, up to 56 hours of paid sick leave each year. Employees must be permitted to use paid sick leave for their own illness, injury or other health-related needs, including preventive care; to assist a family member (or person who is like family to the employee) who is ill, injured, or has other health-related needs, including preventive care; or for reasons resulting from, or to assist a family member (or person who is like family to the employee) who is a victim of, domestic violence, sexual assault, or stalking. Additional information on contractor requirements and worker protections under the EO is available at www.dol.gov/whd/govcontracts.

Unlisted classifications needed for work not included within the scope of the classifications listed may be added after award only as provided in the labor standards contract clauses (29CFR 5.5 (a) (1) (ii)).

The body of each wage determination lists the classification and wage rates that have been found to be prevailing for the cited type(s) of construction in the area covered by the wage determination. The classifications are listed in alphabetical order of "identifiers" that indicate whether the particular rate is a union rate (current union negotiated rate for local), a survey rate (weighted average rate) or a union average rate (weighted union average rate).

Union Rate Identifiers

A four letter classification abbreviation identifier enclosed in dotted lines beginning with characters other than "SU" or "UAVG" denotes that the union classification and rate were prevailing for that classification in the survey. Example: PLUM0198-005 07/01/2014. PLUM is an abbreviation identifier of the union which prevailed in the survey for this classification, which in this example would be Plumbers. 0198 indicates the local union number or district council number where applicable, i.e., Plumbers Local 0198. The next number, 005 in the example, is an internal number used in processing the wage determination. 07/01/2014 is the effective date of the most current negotiated rate, which in this example is July 1, 2014.

Union prevailing wage rates are updated to reflect all rate changes in the collective bargaining agreement (CBA) governing this classification and rate.

Survey Rate Identifiers

Classifications listed under the "SU" identifier indicate that no one rate prevailed for this classification in the survey and the published rate is derived by computing a weighted average rate based on all the rates reported in the survey for that classification. As this weighted average rate includes all rates reported in the survey, it may include both union and non-union rates. Example: SULA2012-007 5/13/2014. SU indicates the rates are survey rates based on a weighted average calculation of rates and are not majority rates. LA indicates the State of Louisiana. 2012 is the year of survey on which these classifications and rates are based. The next number, 007 in the example, is an internal number used in producing the wage determination. 5/13/2014 indicates the survey completion date for the classifications and rates under that identifier.

Survey wage rates are not updated and remain in effect until a new survey is conducted.

Union Average Rate Identifiers

Classification(s) listed under the UAVG identifier indicate that no single majority rate prevailed for those classifications; however, 100% of the data reported for the classifications was union data. EXAMPLE: UAVG-OH-0010 08/29/2014. UAVG indicates that the rate is a weighted union average rate. OH indicates the state. The next number, 0010 in the example, is an internal number used in producing the wage determination. 08/29/2014 indicates the survey completion date for the classifications and rates under that identifier.

A UAVG rate will be updated once a year, usually in January of each year, to reflect a weighted average of the current negotiated/CBA rate of the union locals from which the rate is based.

WAGE DETERMINATION APPEALS PROCESS

1.) Has there been an initial decision in the matter? This can be:

* an existing published wage determination
* a survey underlying a wage determination
* a Wage and Hour Division letter setting forth a position on a wage determination matter
* a conformance (additional classification and rate) ruling

On survey related matters, initial contact, including requests for summaries of surveys, should be with the Wage and Hour Regional Office for the area in which the survey was conducted because those Regional Offices have responsibility for the Davis-Bacon survey program. If the response from this initial contact is not satisfactory, then the process described in 2.) and 3.) should be followed.

With regard to any other matter not yet ripe for the formal process described here, initial contact should be with the Branch of Construction Wage Determinations. Write to:

Branch of Construction Wage Determinations
Wage and Hour Division
U.S. Department of Labor
200 Constitution Avenue, N.W.
Washington, DC 20210

2.) If the answer to the question in 1.) is yes, then an interested party (those affected by the action) can request review and reconsideration from the Wage and Hour Administrator (See 29 CFR Part 1.8 and 29 CFR Part 7). Write to:

Wage and Hour Administrator
U.S. Department of Labor
200 Constitution Avenue, N.W.
Washington, DC 20210

The request should be accompanied by a full statement of the interested party's position and by any information (wage payment data, project description, area practice material, etc.) that the requestor considers relevant to the issue.

3.) If the decision of the Administrator is not favorable, an interested party may appeal directly to the Administrative Review Board (formerly the Wage Appeals Board). Write to:

Administrative Review Board
U.S. Department of Labor
200 Constitution Avenue, N.W.
Washington, DC 20210

4.) All decisions by the Administrative Review Board are final.

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END OF GENERAL DECISION

ATTACHMENT F

Estimated Production Rates

TITLE:	Barrow Alaska Coastal Erosion Feasibility Study		
SUBJECT:	Output Rates for Excavation		
MADE BY:	SKV	JOB NO.:	
CHECKED BY:		DATE:	8/24/2018

CSI TASK:

EMBANKMENT EXCAVATION

CREW: *Hydraul. Excavation Crew* — 2 crew members

1 Equip. Oper. Heavy
1 Oiler
1 Hydraul. Excavator, 2-cy Bucket

PRODUCTION

2.5	cy bucket
0.85	% fill
55	min/hr
1.00	cycle/min

117 cy/crew hr

PUSH EXCAVATED MATERIAL TO STOCKPILE

CREW: *Push to/from Stockpile Crew* — 1 crew members

1 Equip. Oper. Medium
1 Dozer

PRODUCTION

5.0	cy bucket
0.85	% fill
55	min/hr
0.50	cycle/min

117 cy/crew hr

TITLE:	Barrow Alaska Coastal Erosion Feasibility Study		
SUBJECT:	Output Rates for Loading and Hauling Material to Disposal		
MADE BY:	SKV	JOB NO.:	
CHECKED BY:		DATE:	8/24/2018

CSI TASK:

HAUL TO DISPOSAL SITE

SUB-CREW: Load and Haul Crew — 2 crew members

1 Truck Driver, Heavy
1 Equip. Oper. Medium
1 12-cy Dump Truck
1 Front End Loader

PRODUCTION

12	cy truck
0.95	% fill
5.0	min. for loading
4	mi. to disposal location
20	mph haul speed
2.5	min. dump time
60	min/hr

QUANTITY PER TRUCK 11.4 cy/truck

DURATION OF HAULING 0.53 hr

21.7 cy/hr

TITLE:	Barrow Alaska Coastal Erosion Feasibility Study		
SUBJECT:	Output Rates for Fill and Compact From Stockpile		
MADE BY:	SKV	JOB NO.:	
CHECKED BY:		DATE:	8/24/2018

CSI TASK:

FILL AND COMPACT FROM STOCKPILE
[300-ft Haul , 3-cy Bucket, Vibro Compacted, with 3,000-gal Water Truck]

CREW NAME: *Fill and Compact from Stockpile Crew* — 5 crew members

- 3 Eq. Oper. Med.
- 1 Laborers
- 1 Truck Driver, Heavy
- 1 Dozer
- 1 Front End Loader 3-cy Bucket
- 1 Vibratory Roller
- 1 Dozer
- 1 Water Truck, 3000-gal

OVERALL PRODUCTION RATE → **98 cy/crew hr**

FILL FROM STOCKPILE

SUB-CREW: Fill From Stockpile Crew — 3 crew members

- 2 Eq. Oper. Med.
- 0.5 Laborer
- 1 Dozer
- 1 Front End Loader, 3-cy Bucket

PRODUCTION

3	cy bucket (avg.)
0.85	% fill
55	min/hr
0.70	cycle/min

→ 98 cy/crew hr

COMPACT FILL

SUB-CREW: Compaction Crew — 1.5 crew members

- 0.5 laborer
- 1 Equip. Oper. Medium
- 1 Vibratory Roller

PRODUCTION 0.24 min/cy → 250 cy/hr

0.39 crews/equipment members to match overall production rate

1.00 total number of crews needed

WATER TRUCK

SUB-CREW:	Water Truck Crew	1 crew members
	1 Truck Driver, Heavy	
	1 Water Truck, 3000-gal	
PRODUCTION	0.48 min/cy	125 cy/hr
	0.79 crews/equipment members to match overall production rate	
	1.00 total number of crews needed	

TITLE:	Barrow Alaska Coastal Erosion Feasibility Study		
SUBJECT:	Output Rates for Stone Placement		
MADE BY:	SKV	JOB NO.:	
CHECKED BY:		DATE:	8/24/2018

CSI TASK:

ARMOR ROCK, PLACEMENT

CREW: *Rock Placement Crew* — 5 crew members

2 Laborers
1 Truck Driver
1 Oiler
1 Equip. Oper. Heavy
1 Hydraulic Excavator
1 12 cy Dump Truck

2.5	cy bucket
0.65	% fill
55	min/hr
0.40	cycle/min

OVERALL PRODUCTION RATE — **36 cy/hr**

B-ROCK PLACEMENT

CREW: *Rock Placement Crew* — 5 crew members

2 Laborers
1 Truck Driver
1 Oiler
1 Equip. Oper. Heavy
1 Hydraulic Excavator
1 12 cy Dump Truck

2.5	cy bucket
0.75	% fill
55	min/hr
0.55	cycle/min

OVERALL PRODUCTION RATE — **57 cy/hr**

B-ROCK PLACEMENT

CREW: *Rock Placement Crew* — 5 crew members

2 Laborers
1 Truck Driver
1 Oiler
1 Equip. Oper. Heavy
1 Hydraulic Excavator
1 12 cy Dump Truck

2.5	cy bucket
0.80	% fill
55	min/hr
0.60	cycle/min

OVERALL PRODUCTION RATE — **66 cy/hr**

TITLE:	Barrow Alaska Coastal Erosion Feasibility Study		
SUBJECT:	Output Rates for Stone Placement		
MADE BY:	SKV	JOB NO.:	
CHECKED BY:		DATE:	8/24/2018

CSI TASK:

GRAVEL PLACEMENT

CREW: *Rock Placement Crew* — 5 crew members

2 Laborers
1 Truck Driver
1 Oiler
1 Equip. Oper. Heavy
1 Hydraulic Excavator
1 12 cy Dump Truck

2.5	cy bucket
0.90	% fill
55	min/hr
0.85	cycle/min

OVERALL PRODUCTION RATE — **105 cy/hr**

TITLE:	Barrow Alaska Coastal Erosion Feasibility Study		
SUBJECT:	Output Rates for Loading and Hauling Material to Disposal		
MADE BY:	SKV	JOB NO.:	
CHECKED BY:		DATE:	8/24/2018

CSI TASK:

BARGE MOB/DEMOB

Barge Mob/Demob Crek

PRODUCTION

2200	Distance (mi.)
7.5	mph speed
24.0	Prep time (hrs.)

DURATION OF SHIPPING 317.33 hrs/trip

0.0032 trip/hr

ATTACHMENT G

Abbreviated Risk Analysis

BARROW COASTAL EROSION FEASIBILITY STUDY

CONTINGENCY CALCULATIONS

Alternative 2A

Item Description	Contingency		Alternative 2A Costs		Alternative 2A Contingency	
Mob, Demob and Site Prep.	38.23%		$	2,315,203	$	886,000
19 ft Revetment	48.36%		$	18,314,821	$	8,858,000
14 ft Revetment	48.36%		$	3,845,357	$	1,860,000
14 ft Berm	48.36%		$	96,573,916	$	46,704,000
14 ft Raise Stevenson Street	48.36%		$	-	$	-
Cultural Resource and Historic Structures	42.26%		$	201,356	$	86,000
Relocations	40.34%		$	1,624,404	$	656,000
			$	122,875,057	$	59,050,000
Weighted Construction Contingency						**48.06%**
Planning, Engineering, & Design	**38.50%**		$	12,288,000	$	4,731,000
Construction Management	**38.50%**		$	7,373,000	$	2,839,000

Totals:	$	142,536,057	$	66,620,000
Total Alternative Contingency:		**46.7%**		

Alternative 2B

Item Description	Contingency		Alternative 2B Costs		Alternative 2B Contingency	
Mob, Demob and Site Prep.	38.23%		$	2,314,462	$	885,000
19 ft Revetment	48.36%		$	18,308,962	$	8,855,000
14 ft Revetment	48.36%		$	3,507,881	$	1,697,000
14 ft Berm	48.36%		$	-	$	-
14 ft Raise Stevenson Street	48.36%		$	98,062,350	$	47,423,000
Cultural Resource and Historic Structures	42.26%		$	201,291	$	86,000
Relocations	40.34%		$	1,623,885	$	656,000
			$	124,018,831	$	59,602,000
Weighted Construction Contingency						**48.06%**
Planning, Engineering, & Design	**38.50%**		$	12,402,000	$	4,775,000
Construction Management	**38.50%**		$	7,441,000	$	2,865,000

Totals:	$	143,861,831	$	67,242,000
Total Alternative Contingency:		**46.7%**		

Abbreviated Risk Analysis

Project (less than $40M): **Barrow Coastal Erosion** — **Alternative:** **N/A**

Project Development Stage/Alternative: **Feasibility (Alternatives)**

Risk Category: **Moderate Risk: Typical Project Construction Type** — **Meeting Date:** **5/9/2018**

Total Estimated Construction Contract Cost = **$ 9,000,000**

	CWWBS	Feature of Work	Estimated Cost		% Contingency	$ Contingency	Total
	01 LANDS AND DAMAGES	Real Estate	$ -		0.0%	$ -	$ -
1	16 BANK STABILIZATION	Mob, Demob and Site Prep.	$ 1,000,000		38.2%	$ 382,276	$ 1,382,276
2	16 BANK STABILIZATION	19 ft Revetment	$ 1,000,000		48.4%	$ 483,637	$ 1,483,637
3	16 BANK STABILIZATION	14 ft Revetment	$ 1,000,000		48.4%	$ 483,637	$ 1,483,637
4	16 BANK STABILIZATION	14 ft Berm	$ 1,000,000		48.4%	$ 483,637	$ 1,483,637
5	16 BANK STABILIZATION	14 ft Raise Stevenson Street	$ 1,000,000		48.4%	$ 483,637	$ 1,483,637
6					0.0%	$ -	$ -
7					0.0%	$ -	$ -
8	18 CULTURAL RESOURCE PRESERVATION	Cultural Resource and Historic Structures	$ 1,000,000		42.3%	$ 422,611	$ 1,422,611.29
9	02 RELOCATIONS	Building Relocations and Imrovements	$ 1,000,000		40.3%	$ 403,374	$ 1,403,374.20
10			$ -		0.0%	$ -	$ -
11			$ -		0.0%	$ -	$ -
12	All Other	**Remaining Construction Items**	$ 2,000,000	*28.6%*	12.0%	$ 240,000	$ 2,240,000
13	30 PLANNING, ENGINEERING, AND DESIGN	**Planning, Engineering, & Design**	$ 1,000,000		38.5%	$ 384,960	$ 1,384,960
14	31 CONSTRUCTION MANAGEMENT	**Construction Management**	$ 1,000,000		38.5%	$ 384,960	$ 1,384,960
XX	FIXED DOLLAR RISK ADD (EQUALLY DISPERSED TO ALL, MUST INCLUDE JUSTIFICATION SEE BELOW)					$ -	

Totals	Estimated Cost	% Contingency	$ Contingency	Total
Real Estate	$ -	0.0%	$ -	$ -
Total Construction Estimate	$ 9,000,000	37.6%	$ 3,382,811	$ 12,382,811
Total Planning, Engineering & Design	$ 1,000,000	38.5%	$ 384,960	$ 1,384,960
Total Construction Management	$ 1,000,000	38.5%	$ 384,960	$ 1,384,960
Total Excluding Real Estate	**$ 11,000,000**	**37.8%**	**$ 4,152,731**	**$ 15,152,731**

	Base	50%	80%
Confidence Level Range Estimate ($000's)	$11,000k	$13,492k	$15,153k

* 50% based on base is at 5% CL.

Fixed Dollar Risk Add: (Allows for additional risk to be added to the risk analsyis. Must include justification. Does not allocate to Real Estate.	

Barrow Coastal Erosion N/A

Feasibility (Alternatives)

Abbreviated Risk Analysis

Meeting Date: 9-May-18

Risk Level

	Negligible	Marginal	Moderate	Significant	Critical
Very Likely	2	3	4	5	5
Likely	1	2	3	4	5
Possible	0	1	2	3	4
Unlikely	0	0	1	2	3

Risk Register

Risk Element	Feature of Work	Concerns	PDT Discussions & Conclusions (Include logic & justification for choice of Likelihood & Impact)	Impact	Likelihood	Risk Level
Project Management & Scope Growth				**Maximum Project Growth**		**75%**
PS-1	Mob, Demob and Site Prep.	Alternative estimates based on conceptual level designs; Investigations and studies remain to be completed;	Alternatives are based on limited data and are conceptual alternatives for comparison. Many studies remain outstanding that could change the designs. But this is unlikely to occur, and overall cost impacts would be moderate as the current assumptions cover the primary cost drivers of any potential alternatives.	Marginal	Possible	1
PS-2	19 ft Revetment	See concerns listed above.	See discussion above.	Moderate	Unlikely	1
PS-3	14 ft Revetment	See concerns listed above.	See discussion above.	Moderate	Unlikely	1
PS-4	14 ft Berm	See concerns listed above.	See discussion above.	Moderate	Unlikely	1
PS-5	14 ft Raise Stevenson Street	See concerns listed above.	See discussion above.	Moderate	Unlikely	1
PS-6						
PS-7						
PS-8	Cultural Resource and Historic Structures	See concerns listed above.	See discussion above.	Moderate	Unlikely	1
PS-9	Building Relocations and Imrovements	See concerns listed above.	See discussion above.	Moderate	Unlikely	1
PS-10	0			Negligible	Unlikely	0
PS-11	0			Negligible	Unlikely	0
PS-12	Remaining Construction Items			Negligible	Unlikely	0
PS-13	Planning, Engineering, & Design	See concerns listed above.	See discussion above.	Marginal	Possible	1
PS-14	Construction Management	See concerns listed above.	See discussion above.	Marginal	Possible	1

Acquisition Strategy

					Maximum Project Growth	30%
AS-1	Mob, Demob and Site Prep.	No contracting plan has been established; Accelerated schedules could be possibility; Harsh weather may be encountered; Could be limited bid competition given location;	Given the location of the project there could be limited contractors capable of completing work. Also the location can provide problems given the potential weather situations both in Barrow, and in the seas where the contractor would be transporting significant quantities of materials. Given the potential for these issues, it is possible that the costs of the alternatives could be impacted, and significant cost impacts would be felt if these risks occured.	Significant	Possible	3
AS-2	19 ft Revetment	See concerns listed above.	See discussion above.	Significant	Possible	3
AS-3	14 ft Revetment	See concerns listed above.	See discussion above.	Significant	Possible	3
AS-4	14 ft Berm	See concerns listed above.	See discussion above.	Significant	Possible	3
AS-5	14 ft Raise Stevenson Street	See concerns listed above.	See discussion above.	Significant	Possible	3
AS-6						
AS-7						
AS-8	Cultural Resource and Historic Structures	See concerns listed above.	See discussion above.	Significant	Possible	3
AS-9	Building Relocations and Imrovements	See concerns listed above.	See discussion above.	Significant	Possible	3
AS-10	0			Negligible	Unlikely	0
AS-11	0			Negligible	Unlikely	0
AS-12	Remaining Construction Items			Negligible	Unlikely	0
AS-13	Planning, Engineering, & Design	See concerns listed above.	See discussion above.	Significant	Possible	3
AS-14	Construction Management	See concerns listed above.	See discussion above.	Significant	Possible	3

Construction Elements

					Maximum Project Growth	25%
CE-1	Mob, Demob and Site Prep.	Phased schedule and harsh weather conditions; near water construction; no dewatering or diversion included;	All work for this item considered to be constructed in the dry with no dewatering or diversion efforts required. May be small chance of dewatering efforts would be required, but would likely be limited efforts.	Moderate	Unlikely	1
CE-2	19 ft Revetment	See concerns listed above.	All work for this item considered to be constructed in the dry with no dewatering or diversion efforts required. May be small chance of dewatering efforts would be required, but would likely be limited efforts.	Moderate	Unlikely	1
CE-3	14 ft Revetment	See concerns listed above.	All work for this item considered to be constructed in the dry with no dewatering or diversion efforts required. May be small chance of dewatering efforts would be required, but would likely be limited efforts.	Moderate	Unlikely	1
CE-4	14 ft Berm	See concerns listed above.	All work for this item considered to be constructed in the dry with no dewatering or diversion efforts required. May be small chance of dewatering efforts would be required, but would likely be limited efforts.	Moderate	Unlikely	1
CE-5	14 ft Raise Stevenson Street	See concerns listed above.	All work for this item considered to be constructed in the dry with no dewatering or diversion efforts required. May be small chance of dewatering efforts would be required, but would likely be limited efforts.	Moderate	Unlikely	1
CE-6						
CE-7						
CE-8	Cultural Resource and Historic Structures	See concerns listed above.	No significant risks anticipated for this item.	Moderate	Unlikely	1
CE-9	Building Relocations and Imrovements	See concerns listed above.	No significant risks anticipated for this item.	Moderate	Unlikely	1
CE-10	0			Negligible	Unlikely	0
CE-11	0			Negligible	Unlikely	0
CE-12	Remaining Construction Items			Negligible	Unlikely	0
CE-13	Planning, Engineering, & Design	See concerns listed above.		Moderate	Unlikely	1
CE-14	Construction Management	See concerns listed above.		Moderate	Unlikely	1

Specialty Construction or Fabrication					Maximum Project Growth	65%
SC-1	Mob, Demob and Site Prep.	None anticipated.	No significant risks anticipated for this item.	Negligible	Unlikely	0
SC-2	19 ft Revetment	Purchase and transportation of rock and fill materials.	Contractor will likely have experience in obtaining and transporting materials throughout Alaska. But given the large quantities of rock/fill to be barged in, there is still a risk of delays due to availability and/or transport issues.	Moderate	Unlikely	1
SC-3	14 ft Revetment	Purchase and transportation of rock and fill materials.	Contractor will likely have experience in obtaining and transporting materials throughout Alaska. But given the large quantities of rock/fill to be barged in, there is still a risk of delays due to availability and/or transport issues.	Moderate	Unlikely	1
SC-4	14 ft Berm	Purchase and transportation of rock and fill materials.	Contractor will likely have experience in obtaining and transporting materials throughout Alaska. But given the large quantities of rock/fill to be barged in, there is still a risk of delays due to availability and/or transport issues.	Moderate	Unlikely	1
SC-5	14 ft Raise Stevenson Street	Purchase and transportation of rock and fill materials.	Contractor will likely have experience in obtaining and transporting materials throughout Alaska. But given the large quantities of rock/fill to be barged in, there is still a risk of delays due to availability and/or transport issues.	Moderate	Unlikely	1
SC-6						
SC-7						
SC-8	Cultural Resource and Historic Structures	None anticipated.	No significant risks anticipated for this item.	Negligible	Unlikely	0
SC-9	Building Relocations and Imrovements	None anticipated.	No significant risks anticipated for this item.	Negligible	Unlikely	0
SC-10	0			Negligible	Unlikely	0
SC-11	0			Negligible	Unlikely	0
SC-12	Remaining Construction Items			Negligible	Unlikely	0
SC-13	Planning, Engineering, & Design	Purchase and transportation of rock and fill materials.	PED costs could be impacted based on efforts required to find suitable materials required for the project.	Moderate	Unlikely	1
SC-14	Construction Management	Purchase and transportation of rock and fill materials.	CM costs could be impacted based on delays in obtaining and/or transporting all necessary materials to Barrow.	Moderate	Unlikely	1

Technical Design & Quantities					Maximum Project Growth	30%
T-1	Mob, Demob and Site Prep.	Low level of design; Further investigations required to provide more accurate quantities;	Potential quantity changes would not significantly impact mob/demob, and therefore this would have low impact.	Moderate	Unlikely	1
T-2	19 ft Revetment	Low level of design; Further investigations required to provide more accurate quantities;	Earthwork and rock quantities are based on conceptual level information. Typical sections were used which could potential change in future design phases. Any changes to these typical sections would likely have significant impacts to the overal quantities, and thus impact costs significantly as well.	Significant	Possible	3
T-3	14 ft Revetment	Low level of design; Further investigations required to provide more accurate quantities;	Earthwork and rock quantities are based on conceptual level information. Typical sections were used which could potential change in future design phases. Any changes to these typical sections would likely have significant impacts to the overal quantities, and thus impact costs significantly as well.	Significant	Possible	3
T-4	14 ft Berm	Low level of design; Further investigations required to provide more accurate quantities;	Earthwork and rock quantities are based on conceptual level information. Typical sections were used which could potential change in future design phases. Any changes to these typical sections would likely have significant impacts to the overal quantities, and thus impact costs significantly as well.	Significant	Possible	3
T-5	14 ft Raise Stevenson Street	Low level of design; Further investigations required to provide more accurate quantities;	Earthwork and rock quantities are based on conceptual level information. Typical sections were used which could potential change in future design phases. Any changes to these typical sections would likely have significant impacts to the overal quantities, and thus impact costs significantly as well.	Significant	Possible	3
T-6						
T-7						
T-8	Cultural Resource and Historic Structures	Number of historic structures in project area;	Further analysis is required to fully determine the exact number of historic structures that need to be relocated during construction. The current assumption may change, but overall impact is not anticipated to be significant.	Moderate	Possible	2
T-9	Building Relocations and Imrovements	Number of buildings requiring relocation;	Further analysis is required to fully determine the exact number of structures that need to be relocated during construction. The current assumption may change, but overall impact is not anticipated to be significant.	Moderate	Unlikely	1
T-10	0			Negligible	Unlikely	0
T-11	0			Negligible	Unlikely	0
T-12	Remaining Construction Items			Negligible	Unlikely	0
T-13	Planning, Engineering, & Design	Low level of design; Further investigations required to provide more accurate quantities;	Potential quantity changes would not significantly impact PED, and therefore this would have low impact.	Moderate	Unlikely	1
T-14	Construction Management	Low level of design; Further investigations required to provide more accurate quantities;	Potential quantity changes would not significantly impact CM, and therefore this would have low impact.	Moderate	Unlikely	1

Cost Estimate Assumptions

						Maximum Project Growth 35%
EST-1	Mob, Demob and Site Prep.	Mob/demob assumed percentage	Mob/demob is currently assumed to be 10%. Based on scale of projects this percentage likely covers all of a contractors mob and demob needs. However there is a possibility of contractor requiring more mob/demob efforts given the location of the project, the delivery needs (rock/fill), and other issues.	Moderate	Unlikely	1
EST-2	19 ft Revetment	Price quotes for rock and borrow fill materials;	The main cost drivers of each alternative is the rock and fill materials. Depending on availability and location of the source for these materials, the potential unit cost could vary widely. A conservative approach has been incorporated to account for this, but there still could be a cost increase if different sources are used in the future. This could result in longer barge routes, increased purchase prices, etc.	Moderate	Possible	2
EST-3	14 ft Revetment	Price quotes for rock and borrow fill materials;	The main cost drivers of each alternative is the rock and fill materials. Depending on availability and location of the source for these materials, the potential unit cost could vary widely. A conservative approach has been incorporated to account for this, but there still could be a cost increase if different sources are used in the future. This could result in longer barge routes, increased purchase prices, etc.	Moderate	Possible	2
EST-4	14 ft Berm	Price quotes for rock and borrow fill materials;	The main cost drivers of each alternative is the rock and fill materials. Depending on availability and location of the source for these materials, the potential unit cost could vary widely. A conservative approach has been incorporated to account for this, but there still could be a cost increase if different sources are used in the future. This could result in longer barge routes, increased purchase prices, etc.	Moderate	Possible	2
EST-5	14 ft Raise Stevenson Street	Price quotes for rock and borrow fill materials;	The main cost drivers of each alternative is the rock and fill materials. Depending on availability and location of the source for these materials, the potential unit cost could vary widely. A conservative approach has been incorporated to account for this, but there still could be a cost increase if different sources are used in the future. This could result in longer barge routes, increased purchase prices, etc.	Moderate	Possible	2
EST-6						
EST-7						
EST-8	Cultural Resource and Historic Structures	Assumptions used for historic structure relocations	Assumptions are based on best available information, and have the possibility of increasing based on more information regarding relocation efforts.	Moderate	Possible	2

EST-9	Building Relocations and Imrovements	Assumptions used for building relocations	Assumptions are based on best available information, and have the possibility of increasing based on more information regarding relocation efforts.	Moderate	Possible	**2**
EST-10	0			Negligible	Unlikely	**0**
EST-11	0			Negligible	Unlikely	**0**
EST-12	Remaining Construction Items			Negligible	Unlikely	**0**
EST-13	Planning, Engineering, & Design	PED percentage	Based on scale of projects, current PED percentage likely covers the PED costs needed for this project. Therefore no risk of cost increase.	Marginal	Unlikely	**0**
EST-14	Construction Management	CM percentage	Based on scale of projects, current CM percentage likely covers the CM costs needed for this project. Therefore no risk of cost increase.	Marginal	Unlikely	**0**

External Project Risks					Maximum Project Growth	40%
EX-1	Mob, Demob and Site Prep.	Potential harsh weather events; Lack of political support; unanticipated inflations in key borrow materials (rock/fill);	There are limited windows to complete construction due to the climate in Barrow. Therefore any significant weather events could impact the schedule and increase costs. The alternatives may have difficulty being implemented due to the overall scale and total costs. Also, any unanticipated inflations in rock and fill materials could significantly impact costs of a potential project.	Significant	Unlikely	2
EX-2	19 ft Revetment	See concerns listed above.	See discussion above.	Significant	Unlikely	2
EX-3	14 ft Revetment	See concerns listed above.	See discussion above.	Significant	Unlikely	2
EX-4	14 ft Berm	See concerns listed above.	See discussion above.	Significant	Unlikely	2
EX-5	14 ft Raise Stevenson Street	See concerns listed above.	See discussion above.	Significant	Unlikely	2
EX-6						
EX-7						
EX-8	Cultural Resource and Historic Structures	See concerns listed above.	See discussion above.	Significant	Unlikely	2
EX-9	Building Relocations and Imrovements	See concerns listed above.	See discussion above.	Significant	Unlikely	2
EX-10	0			Negligible	Unlikely	0
EX-11	0			Negligible	Unlikely	0
EX-12	Remaining Construction Items			Negligible	Unlikely	0
EX-13	Planning, Engineering, & Design	See concerns listed above.	See discussion above.	Moderate	Possible	2
EX-14	Construction Management	See concerns listed above.	See discussion above.	Moderate	Possible	2

Barrow Coastal Erosion N/A
Feasibility (Alternatives)
Abbreviated Risk Analysis

Risk Evaluation

WBS	Potential Risk Areas	Project Management & Scope Growth	Acquisition Strategy	Construction Elements	Specialty Construction or Fabrication	Technical Design & Quantities	Cost Estimate Assumptions	External Project Risks	Cost in Thousands
01 LANDS AND DAMAGES	**Real Estate**								$0
16 BANK STABILIZATION	**Mob, Demob and Site Prep.**	1	3	1	0	1	1	2	$1,000
16 BANK STABILIZATION	19 ft Revetment	1	3	1	1	3	2	2	$1,000
16 BANK STABILIZATION	14 ft Revetment	1	3	1	1	3	2	2	$1,000
16 BANK STABILIZATION	14 ft Berm	1	3	1	1	3	2	2	$1,000
16 BANK STABILIZATION	14 ft Raise Stevenson Street	1	3	1	1	3	2	2	$1,000
0	0	0	0	0	0	0	0	0	$0
0	**0**	0	0	0	0	0	0	0	$0
18 CULTURAL RESOURCE PRESERVATION	**Cultural Resource and Historic Structures**	1	3	1	0	2	2	2	$1,000
02 RELOCATIONS	**Building Relocations and Imrovements**	1	3	1	0	1	2	2	$1,000
0	**0**	0	0	0	0	0	0	0	$0
0	**0**	0	0	0	0	0	0	0	$0
All Other	Remaining Construction Items	0	0	0	0	0	0	0	$2,000
30 PLANNING, ENGINEERING, AND DESIGN	Planning, Engineering, & Design	1	3	1	1	1	0	2	$1,000
31 CONSTRUCTION MANAGEMENT	Construction Management	1	3	1	1	1	0	2	$1,000
									$11,000
Risk		$ 213	$ 1,771	$ 941	$ 138	$ 426	$ 269	$ 394	**$4,153**
Fixed Dollar Risk Allocation		$ -	$ -	$ -	$ -	$ -	$ -	$ -	**$0**
	Risk	$ 213	$ 1,771	$ 941	$ 138	$ 426	$ 269	$ 394	**$4,153**
								Total	**$15,153**

ATTACHMENT H

MCACES Construction Cost Estimate

Estimated by Tetra Tech, Inc.
Designed by Tetra Tech, Inc.
Prepared by Tetra Tech, Inc
Preparation Date 8/24/2018
Effective Date of Pricing 8/24/2018
Estimated Construction Time 917 Days

Description	Quantity	UOM	ContractCost	ProjectCost	CostOverride
Project Cost Summary Report			**246,893,888**	**246,893,888**	
Barrow Coastal Erosion Cost Estimate - Alternative Selection	**1.00**	**LS**	**246,893,888**	**246,893,888**	
2A Alternative 2A	**1.00**	**LS**	**122,875,057**	**122,875,057**	
2A 02 02 - Relocations	**1.00**	**LS**	**1,624,404**	**1,624,404**	
			270,734.04	*270,734.04*	
2A 02 01 Structure Raise and/or Relocation	**6.00**	**EA**	**1,624,404**	**1,624,404**	
2A 16 16 - Bank Stabilization	**1.00**	**LS**	**121,049,297**	**121,049,297**	
2A 16 01 Mobilization and Demobilization	**1.00**	**LS**	**2,315,203**	**2,315,203**	
2A 16 01 01 Mobilization	**1.00**	**LS**	**953,264**	**953,264**	
2A 16 01 02 Demobilization	**1.00**	**LS**	**953,264**	**953,264**	
2A 16 01 03 Site Preparation	**1.00**	**LS**	**408,676**	**408,676**	
			6,783.27	*6,783.27*	
2A 16 02 19-ft Revetment	**2,700.00**	**LF**	**18,314,821**	**18,314,821**	
			19.01	*19.01*	
2A 16 02 01 Excavation	**16,000.00**	**CY**	**304,203**	**304,203**	
			4.31	*4.31*	
2A 16 02 01 01 Excavation	**16,000.00**	**CY**	**68,989**	**68,989**	
			12.78	*12.78*	
2A 16 02 01 02 Hauling	**18,400.00**	**CY**	**235,214**	**235,214**	
			43.07	*43.07*	
2A 16 02 02 Local Material	**20,000.00**	**CY**	**861,372**	**861,372**	
			2.77	*2.77*	
2A 16 02 03 Filter Fabric	**22,000.00**	**SY**	**60,941**	**60,941**	
			310.70	*310.70*	
2A 16 02 04 Rock Placement	**55,000.00**	**CY**	**17,088,305**	**17,088,305**	
			168.18	*168.18*	
2A 16 02 04 01 Gravel	**7,000.00**	**CY**	**1,177,236**	**1,177,236**	
			225.72	*225.72*	
2A 16 02 04 02 Core Rock	**7,000.00**	**CY**	**1,580,050**	**1,580,050**	
			302.96	*302.96*	
2A 16 02 04 03 B-rock	**19,000.00**	**CY**	**5,756,252**	**5,756,252**	
			389.76	*389.76*	

Description	Quantity	UOM	ContractCost	ProjectCost	CostOverride
2A 16 02 04 04 Armor Rock	**22,000.00**	**CY**	**8,574,767**	**8,574,767**	
			5,493.37	*5,493.37*	
2A 16 03 14-ft Revetment	**700.00**	**LF**	**3,845,357**	**3,845,357**	
			19.01	*19.01*	
2A 16 03 01 Excavation	**4,000.00**	**CY**	**76,051**	**76,051**	
			4.31	*4.31*	
2A 16 03 01 01 Excavation	**4,000.00**	**CY**	**17,247**	**17,247**	
			12.78	*12.78*	
2A 16 03 01 02 Hauling	**4,600.00**	**CY**	**58,803**	**58,803**	
			43.07	*43.07*	
2A 16 03 02 Local Material	**2,000.00**	**CY**	**86,137**	**86,137**	
			2.77	*2.77*	
2A 16 03 03 Filter Fabric	**5,000.00**	**SY**	**13,850**	**13,850**	
			333.57	*333.57*	
2A 16 03 04 Rock Placement	**11,000.00**	**CY**	**3,669,319**	**3,669,319**	
			168.18	*168.18*	
2A 16 03 04 01 Gravel	**4,000.00**	**CY**	**672,706**	**672,706**	
			225.72	*225.72*	
2A 16 03 04 02 Core Rock	**1,000.00**	**CY**	**225,721**	**225,721**	
			302.96	*302.96*	
2A 16 03 04 03 B-rock	**4,000.00**	**CY**	**1,211,843**	**1,211,843**	
			389.76	*389.76*	
2A 16 03 04 04 Armor Rock	**4,000.00**	**CY**	**1,559,049**	**1,559,049**	
			4,330.67	*4,330.67*	
2A 16 04 14-ft Berm	**22,300.00**	**LF**	**96,573,916**	**96,573,916**	
			19.01	*19.01*	
2A 16 04 01 Excavation	**192,000.00**	**CY**	**3,650,433**	**3,650,433**	
			4.31	*4.31*	
2A 16 04 01 01 Excavation	**192,000.00**	**CY**	**827,868**	**827,868**	
			12.78	*12.78*	
2A 16 04 01 02 Hauling	**220,800.00**	**CY**	**2,822,565**	**2,822,565**	
			2.77	*2.77*	

Description	Quantity	UOM	ContractCost	ProjectCost	CostOverride
2A 16 04 03 Filter Fabric	**136,000.00**	**SY**	**376,729**	**376,729**	
			305.43	*305.43*	
2A 16 04 04 Rock Placement	**303,000.00**	**CY**	**92,546,754**	**92,546,754**	
			168.18	*168.18*	
2A 16 04 04 01 Gravel	**43,000.00**	**CY**	**7,231,591**	**7,231,591**	
			225.72	*225.72*	
2A 16 04 04 02 Core Rock	**40,000.00**	**CY**	**9,028,854**	**9,028,854**	
			302.96	*302.96*	
2A 16 04 04 03 B-rock	**109,000.00**	**CY**	**33,022,711**	**33,022,711**	
			389.76	*389.76*	
2A 16 04 04 04 Armor Rock	**111,000.00**	**CY**	**43,263,598**	**43,263,598**	
2A 18 18 - Cultural Resources	**1.00**	**LS**	**201,356**	**201,356**	
			201,355.63	*201,355.63*	
2A 18 01 On-Site Archaeologist	**1.00**	**MO**	**201,356**	**201,356**	
2B Alternative 2B	**1.00**	**LS**	**124,018,831**	**124,018,831**	
2B 02 02 - Relocations	**1.00**	**LS**	**1,623,885**	**1,623,885**	
			270,647.42	*270,647.42*	
2B 02 01 Structure Raise and/or Relocation	**6.00**	**EA**	**1,623,885**	**1,623,885**	
2B 16 16 - Bank Stabilization	**1.00**	**LS**	**122,193,655**	**122,193,655**	
2B 16 01 Mobilization and Demobilization	**1.00**	**LS**	**2,314,462**	**2,314,462**	
2B 16 01 01 Mobilization	**1.00**	**LS**	**952,959**	**952,959**	
2B 16 01 02 Demobilization	**1.00**	**LS**	**952,959**	**952,959**	
2B 16 01 03 Site Preparation	**1.00**	**LS**	**408,545**	**408,545**	
			6,781.10	*6,781.10*	
2B 16 02 19-ft Revetment	**2,700.00**	**LF**	**18,308,962**	**18,308,962**	
			19.01	*19.01*	
2B 16 02 01 Excavation	**16,000.00**	**CY**	**304,105**	**304,105**	
			4.31	*4.31*	
2B 16 02 01 01 Excavation	**16,000.00**	**CY**	**68,967**	**68,967**	
			12.78	*12.78*	
2B 16 02 01 02 Hauling	**18,400.00**	**CY**	**235,138**	**235,138**	
			43.05	*43.05*	

Description	Quantity	UOM	ContractCost	ProjectCost	CostOverride
2B 16 02 02 Local Material	**20,000.00**	**CY**	**861,097**	**861,097**	
			2.77	*2.77*	
2B 16 02 03 Filter Fabric	**22,000.00**	**SY**	**60,922**	**60,922**	
			310.60	*310.60*	
2B 16 02 04 Rock Placement	**55,000.00**	**CY**	**17,082,838**	**17,082,838**	
			168.12	*168.12*	
2B 16 02 04 01 Gravel	**7,000.00**	**CY**	**1,176,859**	**1,176,859**	
			225.65	*225.65*	
2B 16 02 04 02 Core Rock	**7,000.00**	**CY**	**1,579,544**	**1,579,544**	
			302.86	*302.86*	
2B 16 02 04 03 B-rock	**19,000.00**	**CY**	**5,754,411**	**5,754,411**	
			389.64	*389.64*	
2B 16 02 04 04 Armor Rock	**22,000.00**	**CY**	**8,572,024**	**8,572,024**	
			5,011.26	*5,011.26*	
2B 16 03 14-ft Revetment	**700.00**	**LF**	**3,507,881**	**3,507,881**	
			19.01	*19.01*	
2B 16 03 01 Excavation	**4,000.00**	**CY**	**76,026**	**76,026**	
			4.31	*4.31*	
2B 16 03 01 01 Excavation	**4,000.00**	**CY**	**17,242**	**17,242**	
			12.78	*12.78*	
2B 16 03 01 02 Hauling	**4,600.00**	**CY**	**58,785**	**58,785**	
			43.05	*43.05*	
2B 16 03 02 Local Material	**2,000.00**	**CY**	**86,110**	**86,110**	
			2.77	*2.77*	
2B 16 03 03 Filter Fabric	**5,000.00**	**SY**	**13,846**	**13,846**	
			302.90	*302.90*	
2B 16 03 04 Rock Placement	**11,000.00**	**CY**	**3,331,899**	**3,331,899**	
			168.12	*168.12*	
2B 16 03 04 01 Gravel	**2,000.00**	**CY**	**336,245**	**336,245**	
			225.65	*225.65*	
2B 16 03 04 02 Core Rock	**1,000.00**	**CY**	**225,649**	**225,649**	
			302.86	*302.86*	

Description	Quantity	UOM	ContractCost	ProjectCost	CostOverride
2B 16 03 04 03 B-rock	**4,000.00**	**CY**	**1,211,455**	**1,211,455**	
			389.64	*389.64*	
2B 16 03 04 04 Armor Rock	**4,000.00**	**CY**	**1,558,550**	**1,558,550**	
			4,397.41	*4,397.41*	
2B 16 04 14-ft Raise Stevenson Street	**22,300.00**	**LF**	**98,062,350**	**98,062,350**	
			19.01	*19.01*	
2B 16 04 01 Excavation	**192,000.00**	**CY**	**3,649,265**	**3,649,265**	
			4.31	*4.31*	
2B 16 04 01 01 Excavation	**192,000.00**	**CY**	**827,603**	**827,603**	
			12.78	*12.78*	
2B 16 04 01 02 Hauling	**220,800.00**	**CY**	**2,821,662**	**2,821,662**	
			43.05	*43.05*	
2B 16 04 02 Local Material	**175,000.00**	**CY**	**7,534,596**	**7,534,596**	
			2.77	*2.77*	
2B 16 04 03 Filter Fabric	**136,000.00**	**SY**	**376,609**	**376,609**	
			297.26	*297.26*	
2B 16 04 04 Rock Placement	**291,000.00**	**CY**	**86,501,880**	**86,501,880**	
			168.12	*168.12*	
2B 16 04 04 01 Gravel	**46,000.00**	**CY**	**7,733,645**	**7,733,645**	
			225.65	*225.65*	
2B 16 04 04 02 Core Rock	**42,000.00**	**CY**	**9,477,264**	**9,477,264**	
			302.86	*302.86*	
2B 16 04 04 03 B-rock	**113,000.00**	**CY**	**34,223,601**	**34,223,601**	
			389.64	*389.64*	
2B 16 04 04 04 Armor Rock	**90,000.00**	**CY**	**35,067,370**	**35,067,370**	
2B 18 18 - Cultural Resources	**1.00**	**LS**	**201,291**	**201,291**	
			201,291.21	*201,291.21*	
2B18 01 On-Site Archaeologist	**1.00**	**MO**	**201,291**	**201,291**	

Barrow Alaska Coastal Erosion Feasibility Study

Appendix H: Correspondence

Barrow, Alaska

August 29, 2018

US Army Corps of Engineers
Alaska District

THE STATE of ALASKA

GOVERNOR BILL WALKER

Department of Natural Resources

DIVISION OF PARKS & OUTDOOR RECREATION
Office of History & Archaeology

550 West 7th Ave., Suite 1310
Anchorage, Alaska 99501-3565
Main. 907 269.8721
http //dnr.alaska.gov/parks/oha

August 20, 2018

File No.: 3130-1R COE-ENV
2018-00912

Joseph Sparaga
USACE, Alaska District
CEPOA-PM-C-ER
P.O. Box 6898
JBER, Alaska 99506-0898

SUBJECT: Barrow (Utqiagvik) Coastal Erosion Project

Dear Mr. Sparaga:

The Alaska State Historic Preservation Office (AK SHPO) received your correspondence on July 20, 2018. Upon review, we offer the following comments for your consideration:

The correspondence indicates there are multiple project alternatives which may be added on, or further explored, prior to implementation of the subject project. The documentation states that while an 'adverse effect' is definitively anticipated to BAR-00002, potential adverse impacts to other historic properties are yet to be determined. Subsequently, the USACE makes a finding of 'Adverse Effect' and indicates that development of a Memorandum of Agreement (MOA) is anticipated. However, in accordance with the *36 CFR 800* regulations and Advisory Council on Historic Preservation (ACHP) guidance, the purpose of an MOA is to outline stipulations with the intent to minimize and mitigate *known* adverse effects. A Programmatic Agreement (PA), is the appropriate option when adverse effects cannot be fully understood in advance of project authorization—and therefore an alternative to the standard Section 106 process is needed.

- If USACE is unable to determine how the undertaking may affect historic properties prior to approval, we recommend consideration of a PA. If development of a PA is chosen, please let our office and the other consulting parties know of this intent as soon as possible.
- If USACE determines there is enough time prior to authorization to understand which historic properties will be adversely affected, and re-engage in consultation with our office and the other consulting parties regarding MOA development, we look forward to consulting with USACE at that time.

Thank you for the opportunity to review and comment, please let us know if USACE would like to discuss these options further. Please contact Mckenzie Johnson at 907-269-8726 or mckenzie.johnson@alaska.gov if we can be of further assistance.

Sincerely,

Judith E Bittner

Judith E. Bittner
State Historic Preservation Officer
JEB:msj

From:	Sparaga, Joseph E CIV USARMY CEPOA (US)
To:	Johnson, McKenzie S (DNR)
Cc:	Eldridge, Kelly A CIV USARMY CEPOA (US); Cate, Jenipher R CIV USARMY CEPOA (US); Metallo, Amber C CIV USARMY CEPOA (US)
Subject:	Barrow Alaska Coastal Erosion project
Date:	Saturday, August 25, 2018 2:35:07 PM

Dear McKenzie,

Thank you for your response to our assessment of effect regarding the Barrow Alaska Coastal Erosion project. We are currently in the Feasibility Phase of this project. Our assessment of adverse effect on BAR-002 is based off of preliminary designs of a preferred construction alternative. We will have more concrete information about the construction design during the Planning Phase of the project. After talking with the Project Manager Jen Cate, we determined that there will be sufficient time during the Planning Phase prior to the Construction Phase to develop an appropriate mitigation plan through a Memorandum of Agreement. The Construction Phase is not expected to begin until 2022. Per your letter, we will re-engage in consultation with your office and other consulting parties during the Planning Phase of the Barrow Alaska Coastal Erosion project.

Please let me know if you have any questions or concerns.

Thank you for your time,

Joey

Joseph Sparaga
Archaeologist, Alaska District
US Army Corps of Engineers
Email: joseph.e.sparaga@usace.army.mil
Phone: 907.753.2640

DEPARTMENT OF THE ARMY
ALASKA DISTRICT, U.S. ARMY CORPS OF ENGINEERS
P.O. BOX 6898
JBER, AK 99506-0898

Ms. Judith Bittner
State Historic Preservation Officer
Office of History and Archaeology
550 West 7th Avenue, Suite 1310
Anchorage, AK 99501-3565

Jul 19 2018

Dear Ms. Bittner,

The U.S. Army Corps of Engineers (USACE), Alaska District, Civil Works Division, is planning to construct a five mile barrier along the cost of Barrow (Utqiaġvik), Alaska, to protect the village and resources from further coastal erosion per Section 116 of the Energy and Water Development and Related Agencies Appropriations Act of 2010 (PL 111-85). To facilitate construction of the barrier, the USACE proposes to construct a combination of revetments and berms. The project may also involve raising the Stephenson Street if a berm or wall is found to not be feasible. Construction is planned along approximately five miles of the coast (Section 6, T22N, R18W, and Sections 14, 15, 21, 22, 28, 29, 31, and 32, T23N, R18W, Seward Meridian, USGS Quad Barrow B-4; Figure 1). In compliance with Section 106 of the National Historic Preservation Act of 1966 [36 CFR § 800.2(a)(4)], the purpose of this letter is to notify you of a proposed Federal undertaking and to seek your concurrence on an assessment of effect.

Context

Precontact History

Several archaeological sites in the Brooks Range have been dated to the American Paleoarctic tradition, at around 11,500 years before present (BP) (Grover and Laughlin 2012). It is assumed that with no coastal sites documented, any coastal paleoindian sites have been covered by rising sea levels after the Younger Dryas period began (Jensen 2014). The earliest coastal archaeological sites in northern Alaska date to the Denbigh Flint Complex, an early regional variant of the Arctic Small Tool tradition, at approximately 4,000 years ago in the Norton Sound (Dumond 1998a; Tremayne and Rasic 2016).

The number of coastal settlements in northern Alaska began to increase around 2,500 BP (Anderson 1984; Dumond 1998b). Beginning around 1,550 BP, the climate had a second warming period which decreased the amount of offshore ice, creating summer season open waters and new resources. This required changes and the development of new hunting techniques adapted to the open waters during summer seasons (Friesen and Mason 2016). During this time, whale hunting increased at some coastal sites (McClenahan 1993). These new cultural developments were labeled the Birnirk culture, and have been identified at the Utqiaġvik (BAR-002) and Birnirk (BAR-001) sites at Utqiaġvik, and the Kugusugaruk site (BAR-003), Coffin site (BAR-014), and Walakpa sites to the southwest (Anderson 1998; Gerlach and Mason 1992; Stanford 1976).

Figure 1: Project area; proposed construction along the shore facing the orange line.

By about 1,000 BP, the Thule people inhabiting the coast of northern Alaska were "easily recognizable" as the "direct ancestors" of the Iñupiat people (McClenahan 1993). Material culture artifacts 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 the Western Thule culture at or near Utqiaġvik include Walakpa, Utqiaġvik, Nuvuk (BAR-011), and Birnirk (Jensen 2016).

Russian Alaska

Northern Alaska was not noticeably affected during the Russian period; impacts from Western cultures were not discernable until approximately 1850 (Hall 1984). The Russian government did not consider the northern parts of Alaska a priority due to the lower quantity of fur-bearing animals in the vicinity. However, trade goods such as tobacco, iron, copper, and glass beads did make it north via traditional trade fairs and routes (Jensen 2015; Kunz et al. 2005; Murdoch 1892).

The first two recorded visits to North Slope of Alaska both took place in 1826. Captain Frederick Beechey of the English Royal Navy, in command of the fifteen-gun sloop *HMS Blossom*, led an expedition into Bering Strait and east to Icy Cape (Beechey 1832), while Sir John Franklin's expedition traveled west from the Mackenzie River until they reached Return Island just west of Prudhoe Bay (Franklin 1828). Although Beechey and *Blossom* did not make it much past Icy Cape and due to shallow waters, the *Blossom*'s barge under the command of Thomas Elson and William Smyth made it as far as Point Barrow and the settlement of Nuvuk (Beechey 1832).

In the 1840s, commercial whalers began hunting in the Bering Strait, followed by the Chukchi Sea in the 1850s and the Beaufort Sea soon after (Bockstoce 1986). Euroamericans established shore-based whaling stations, including one at Point Belcher slightly north of Wainwright (Allen 1978; Brower 1842; Cassell 2000, 2005), and many local Iñupiat moved from subsistence whaling to participating in the commercial whaling industry. While the initial targeting of whales was primarily for the purpose of gaining whale oil from the blubber, there was also a secondary market through the baleen trade which continued to support the industry even after the discovery of petroleum in the eastern United States. A combination of the collapse of the baleen market and the depletion of the whale stock essentially ended commercial whaling in about 1916 (Bockstoce 1986; Spencer 1959; Stefansson 1913, 1914).

American Period

There were limited changes in Barrow during the WWII; however, the beginnings of the Territorial Guard were being created throughout Alaska. Barrow was determined to be the location of one of the Alaska Scout Battalions after the war; in 1949 the C Company of the 1st Battalion was stationed at Barrow (Hendricks 1985). This military unit was formed to protect and keep watch of Alaska's northern shores, but are considered more relevant during the Cold War period.

The Cold War period had significant impacts on the village of Barrow and its inhabitants. In 1948, the Office of Naval Research established the Naval Arctic Research Laboratory (NARL) in Barrow with the purpose of conducting research in the arctic environment to better the military's responses in the region (Hummel 2005). The development of the Research Laboratory increased the population during the summer season as military and civilian researchers used the site. One of the greatest impacts to northern Alaska came in the form of the Distant Early Warning (DEW) radar system, whose stations stretched over 3,000 miles across Alaska and northern Canada to alert the military in the case of a circumpolar Soviet attack (Hummel 2005). In addition to DEW Line station, listed as POW-MAIN as it was Point Barrow Main location, which was constructed in 1955 and served as a main hub for the northern Alaskan DEW stations. There was also a military garrison established in Barrow comprised of National Guard and Alaska Territorial Guard, who have also been known as the "Eskimo Scouts" (Hummel 2005). Construction work and other associated jobs attracted people to the area, and the town of Barrow grew.

Project Description

This project involves construction of barriers to protect Barrow from further storm surge impacts over the next 50 years. The project area spans five miles from the Barrow Bluffs to the NARL station (Figure 2). Two types of barriers will be constructed: the first consists of a revetment wall along a portion of the seaward side of the bluff and Barrow proper (one mile), and the second is a berm or raised wall along the Stephenson Road (four miles). Final determination of whether to use a berm or raise Stephenson Street has not been finalized, and the effect and any mitigation will be re-evaluated during the formulation of a memorandum of agreement (MOA) based on a chosen path forward.

Figure 2: The proposed barrier plans along the Utqiaġvik coast. The symbols used stand for V: Revetment, B: Berm, R: Raise Stephenson Street.

The proposed project would start with the construction of a rock revetment along the seaward facing bluff area, extending from the bluff in front of the airport to the start of Tasigarook Lagoon (an approximate 1 mile stretch). The revetment would stabilize the bank and reduce undercutting from waves and slow the localized melting of permafrost, which results in slumping of material and block (ice-wedge) failure. The revetment would consist of fill material, filter fabric, gravel then core material overlaid by two layers of type B-rock fill and two layers of 2.7-ton armor rock. The fill material would be buried to match the existing beach elevation below the armor rock to prevent any of the existing beach material from being washed through the armor layer. The impact to cultural resources would be reduced by using fill material to achieve the design slope rather than excavating into the bluffs to set the design slope.

The four northern miles of the project between Tasigarook Lagoon and the NARL campus has two proposed versions of the barrier (Figure 3). The first is raising Stephenson Street and constructing a revetment berm on the seaward side which would reduce wave run up, and reduce the flooding in the low-lying beach areas. The surface would consist of two layers of 2.7 ton armor rock with a 2:1 horizontal:vertical seaward slope and a 1.5:1 landward slope. The B-rock would be a double layer, placed on top of a 1-foot layer of core, on top of 1-foot layer of gravel, which is then underlain with filter fabric. The B-rock and subsequent layers would be buried to match the existing beach elevation. The second version does not include raising or creating a revetment alongside the road, but a berm running parallel to the beach and constructed on the beach in the same manner as the revetment. Three beach access ramps would be maintained along the length of the berm.

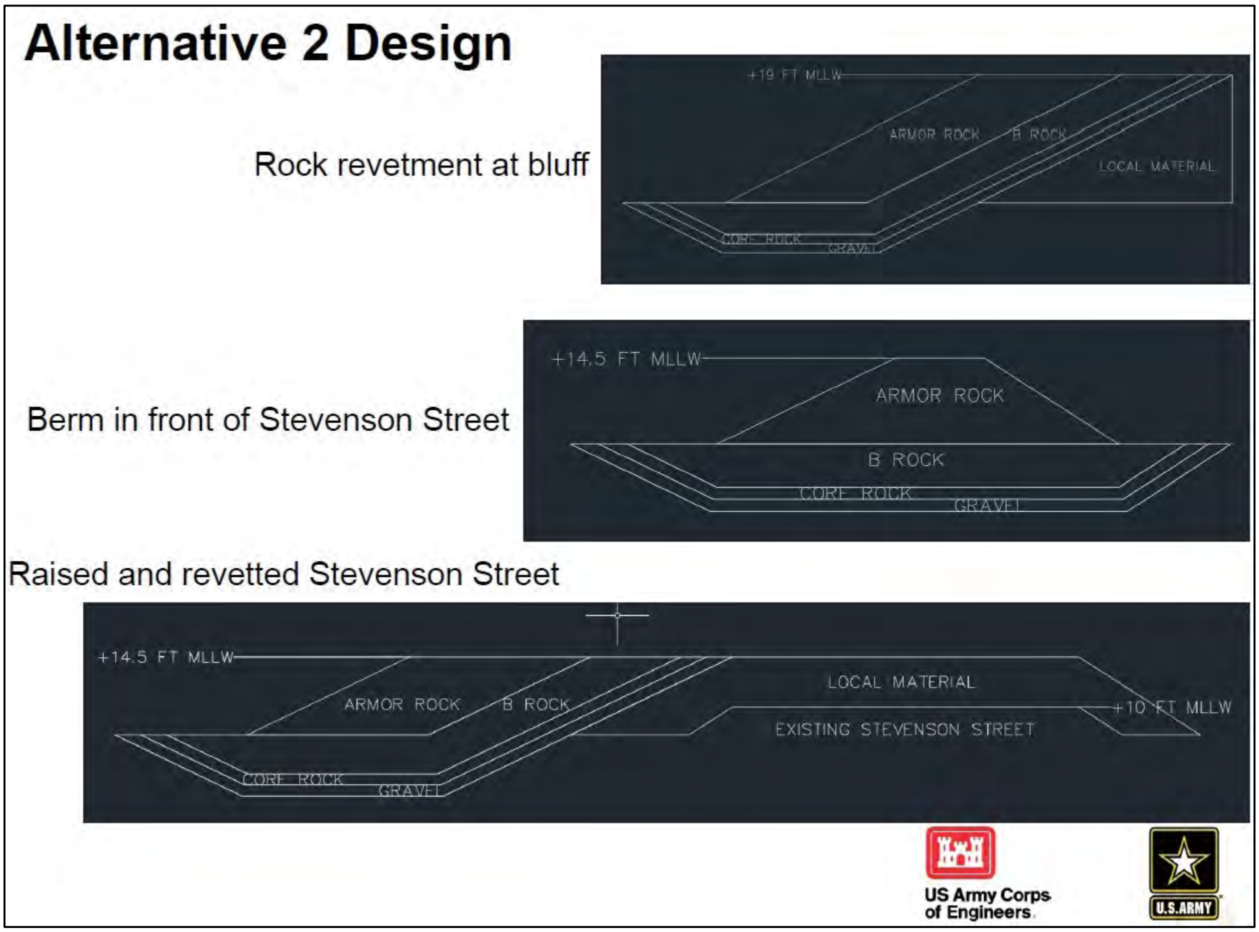

Figure 3: The three different barrier designs proposed for construction along the coastline.

Assessment of Effect

There are 42 known cultural resources in the vicinity of the project's area of potential effect (APE; Figure 4; Table 1). The archaeological site known as Utqiaġvik Village Site (BAR-002) is located within the APE; this site is a large and important cultural resource in the area and is eligible for includision on the National Register of Historic Places (NRHP).. The site is on the southwestern end of Barrow, on a bluff which has been eroding over the years (Figure 5). There also have been a number of structures which have been constructed on top and around the site. The proposed revetment will cause increased physical pressure from above and from the side, which can cause problems as the permafrost thaws and ground settles on cultural remains.

Figure 4: A map of Utqiaġvik with the relative locations of the number of sites within the vicinity.

Figure 5: View of the eroding bluff face at Utqiaġvik site BAR-002. The view is from the shoreline looking towards the east, with archaeological debris visible.

Table 1: AHRS Sites located near the proposed APE.

AHRS #	Site Name	Type	NRHP DOE	In APE
BAR-001	Birnirk	Subsurface	National Historic Landmark	No
BAR-002	Utqiaġvik Village Site	Subsurface	Eligible	**Yes**
BAR-004	Utqiaġvik Presbyterian Church Manse	Structural	Listed	No
BAR-007	Browerville	Structural	Unknown	**Yes**
BAR-009	Esatkuat	Subsurface	Unknown	**Yes**
BAR-011	Nuwuk	Subsurface	Eligible	No
BAR-012	Refuge Station (Brower Café)	Structural	Listed	**Yes**
BAR-015	Sod House	Structural	Unknown	No
BAR-016	Elavgak House	Structural	Unknown	**Yes**
BAR-022	Kugok	Subsurface	Unknown	No
BAR-041	POW-M (DEW Line)	Structural	Eligible	No
BAR-046	Building 100	Structural	Eligible	No
BAR-047	Building 101	Structural	Not Eligible	No

BAR-053	LRRS Road System (DEW Line)	Structural	Eligible	No
BAR-055	NWS House 1	Structural	Eligible	No
BAR-056	NWS House 2	Structural	Eligible	No
BAR-057	NW House 3	Structural	Eligible	No
BAR-058	NWS Recreation Hall	Structural	Eligible	No
BAR-059	Old government building	Structural	Unknown	No
BAR-060	Browerville Ice Cellar	Subsurface	Unknown	**Yes**
BAR-061	NWS House Duplex B-4	Structural	Not Eligible	No
BAR-063	NWS Upper Atmosphere Facility	Structural	Not Eligible	No
BAR-065	NWS Office Building B-6	Structural	Not Eligible	No
BAR-066	Old Navy Bridge	Structural	Not Eligible	No
BAR-069	Cooper Is. Navy Station	Structural	Not Eligible	No
BAR-070	Cooper Is. 2	Subsurface	Eligible	No
BAR-073	Suvlu House	Structural	Not Eligible	No
BAR-074	Brower House	Structural	Not Eligible	No
BAR-075	NARL	Structural	Eligible	No
BAR-076	Building 250	Structural	Unknown	No
BAR-079	NARL Airstrip	Structural	Unknown	No
BAR-081	Building 133	Structural	Unknown	No
BAR-082	Building 134	Structural	Unknown	No
BAR-083	Building 130	Structural	Unknown	No
BAR-087	Grave	Subsurface	Unknown	No
BAR-101	Face-down burial (Uncle Foot)	Subsurface	Unknown	No
BAR-102	Nungasak House	Structural	Unknown	No
BAR-103	Yong House	Structural	Unknown	No
BAR-121	Seabee Core Test Well #1	Structural	Eligible (assumed)	No
BAR-123	Barrow Big Rig Test Well #1	Structural	Eligible (assumed)	No
BAR-129	South Barrow Test Well #1	Structural	Eligible (assumed)	No
BAR-138	BUECI Water Treatment Plant Utilidor	Structural	Unknown	No

Two more subsurface archaeological sites are also threatened by the continued erosion, the Esatkuat site (BAR-009) and the Ice Cellar in Browerville (BAR-060). At this time, these two sites have not had a determination of eligibility (DOE) for the NRHP completed. A DOE will need to be completed before any mitigation proposal is considered. The location of BAR-009 and BAR-060 are not within the revetment section, and the construction of a berm or raising Stephenson Street may protect the sites without further damage. However if the project is determined to have an adverse effect on BAR-009 and BAR-060, both sites will require a DOE to be completed prior to any further considerations.

Three paths forward for the project have been identified, the first is construction of four miles of berm, the second is the raising or protection of Stephenson Street, and the third is a combination of both plans. In addition to BAR-009, BAR-060, and BAR-002, the Browerville structure (BAR-007), the Elavgak House (BAR-016), and the Refuge Station (Brower Café) (BAR-012) are along the shoreline at locations where two different barriers are being suggested. Sites BAR-007, BAR-016, and BAR-012 have different NHPA standings, as seen previously in Table 1. The Elavgak House (BAR-016) has not had a DOE conducted, and will require it to be considered for eligibility before any mitigation strategy is implemented. The current undertaking will have no physical effect upon them at this time. A previous report written by Jensen (2015) also mentions that there is a presence of graves within the vicinity of the northwestern end of Browerville. These are not presently listed in the AHRS, and do not have a definite known position.

Conclusion

Under the current proposal, the Utqiaġvik Village Site (BAR-002) will continue to suffer erosion until the protection is completed. However, the proposed revetment barrier would have armor boulders resting against and upon beach side sections of the site, which may further complicate its protection. Additional discussion is needed to determine the appropriate mitigation strategy for the site. While the current proposal may not affect the other sites, including the Browerville structure (BAR-007), the Ice Cellar in Browerville (BAR-060), the Esatkuat site (BAR-009), the Elavgak House (BAR-016), and the Refuge Station (Brower Café) (BAR-012), mitigation may be required as the planning of the project develops. Selected mitigation strategies will depend on the method of remedy chosen to address the erosion, either a berm will be constructed or Stephenson Street will be raised.

The construction of the revetment along the bluff section will have an adverse effect upon the Utqiaġvik Village Site (BAR-002) with the proposed revetment material covering sections of the resource. Cultural materials eroding out of the bluff face below the Utqiaġvik Village Site may also be covered by rock or fill. Further consideration of the other previously identified five sites (BAR-007, BAR-060, BAR-009, BAR-016, and BAR-012) will have to be considered pending the implemented solution to the erosion. A Memorandum of Agreement is anticipated; please expect an invitation to participate per 36 CFR § 800.6(a) in the near future. The lead time required for awarding contracts and coordinating planning documents in advance of the actual field work for this undertaking is significant. The USACE has determined the proposed undertaking will have an **Adverse Effect** on local cultural resources, per 36 CFR § 800.5(d)(2) and seeks your concurrence on the finding of effect. If you have any questions about this project, please contact me by phone at 907.753.2640, or by email at joseph.e.sparaga@usace.army.mil.

Sincerely,

Joseph E. Sparaga
Archaeologist
Environmental Resources Section

Cc:
Charles Brower, President, Native Village of Barrow Iñupiat Traditional Government
Frederick Brower, Executive Director, Inupiat Community of the Arctic Slope
Rex Rock, Sr., President and CEO, Arctic Slope Regional Corporation
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Anne Jensen, Senior Scientist, UIC Science, LLC
Loyla T. Leavitt, City Clerk, City of Utqiaġvik
Vera Lincoln, Curator, Simon Paneak Memorial Museum
Fannie Akpik, Barrow Member, Commission on History, Language, and Culture

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