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Elim Hazard Impact Assessment

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Appendix A – Public Involvement
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Acronyms and Abbreviations

ABM	articulating block mat
ACS	American Community Survey
ADEC	Alaska Department of Environmental Conservation
AEB	Aleutians East Borough
AFI	air freezing index
ANVSA	Alaska Native Village Statistical Area
ATI	air thawing index
AVO	Alaska Volcano Observatory
DCRA	Division of Community and Regional Affairs
DHS&EM	Division of Homeland Security and Emergency Management
DOT&PF	Alaska Department of Transportation and Public Facilities
F	Fahrenheit
HDPE	high-density polyethylene
HDR	HDR Alaska, Inc.
HIA	hazard impact assessment
MHHW	mean higher high water
MHW	mean high water
MLLW	mean lower low water
MLW	mean low water
mm	millimeter
MOE	margin of error
MSL	mean sea level
NOAA	National Oceanic and Atmospheric Administration
PDO	Pacific Decadal Oscillation
PVC	polyvinyl chloride
REAA	Regional Education Attendance Area
RSLR	relative sea level rise
S&W	Shannon & Wilson
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WIS	Wave Information Studies

1. INTRODUCTION

The City of Elim recognizes that erosion and other climate change-related hazards are concerns and that they need to take action to minimize the impacts on the community. In support of these efforts, the City has hired HDR Alaska and subconsultant Shannon & Wilson (S&W) to perform a Hazard Impact Assessment (HIA) for Elim. The focus of this study is natural hazards, particularly those related to climate change such as erosion.

1.1 Public Involvement

To gain input into the plan, Laurie Cummings with HDR Alaska and Eric Anderson with S&W traveled to Elim to hold a community meeting where residents could share their concerns about climate change-related hazards. During their visit, they took sediment samples, visited previous erosion control measures, and observed various parts of the community. A second community meeting was held in December 2011 to discuss the results of the draft HIA. Information from the second community meeting was incorporated into the final HIA report. Copies of the public involvement materials are located in Appendix A.

1.2 Community Description

Section 1 Community Description information is from the Division of Community and Regional Affairs (DCRA) Community Database online at
http://www.commerce.state.ak.us/dca/commdb/CF_BLOCK.htm.

1.2.1 Location

Elim is located on the northwest shore of Norton Bay on the Seward Peninsula, approximately 96 miles east of Nome (Figure 1).

1.2.2 Demographics

According to the 2010 Census, the Elim Alaska Native Village Statistical Area (ANVSA) has a population of 330. This is a slight increase from the 2000 Census population of 313. The majority of the population (55%) is male, compared to 45 percent female. The median age of community residents is 23.8. The majority of the population is all or part Alaska Native[1].

There are 105 housing units in the community, of which 89 are occupied and 16 are vacant units. Of the 16 vacant units, 0 are for seasonal, recreational, or occasional use. The average household size is 3.71.

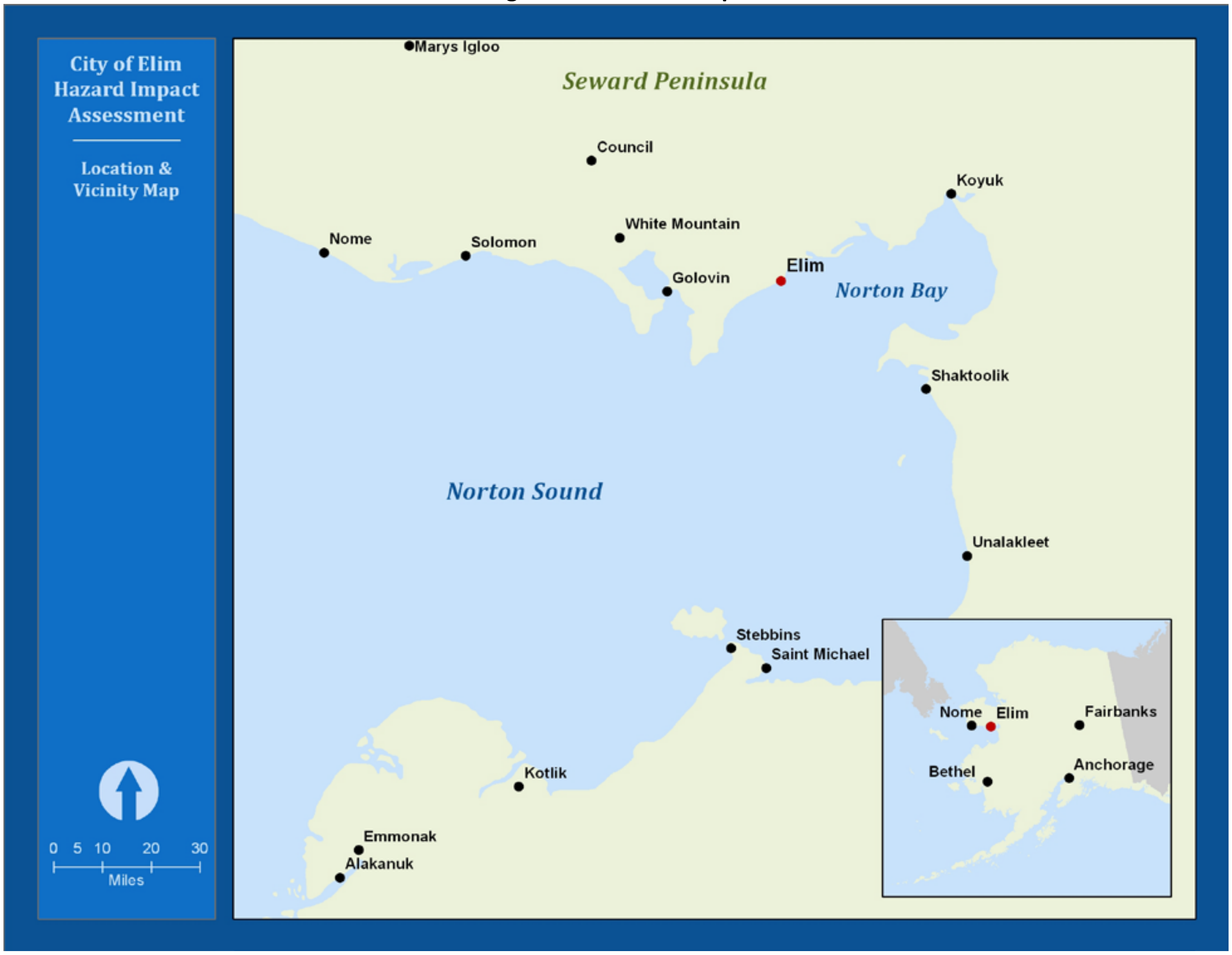
1.2.3 Economy

The economy of Elim is based on subsistence harvests, with cash employment limited to fishing, the city, and school. Residents rely on fish, seal, walrus, beluga whale, reindeer, moose, and home gardens for food. In 2010, 28 residents held commercial fishing permits.

The 2005–2009 American Community Survey (ACS) estimated 88[2] residents as employed. The ACS survey indicates that average median household income (in 2009 inflation-adjusted dollars) was $32,083, while the per capita income (in 2009 inflation-adjusted dollars) was $11,229. About 35.9 percent of all residents had incomes below the poverty level.

[1] The U.S. Census Bureau defines this category as American Indian and Alaska Native.
[2] ACS statistics are based on a sample and is subject to a margin of error (MOE).

Figure 1. Location Map



1.2.4 Climate

According to S&W, the nearest weather station with data that are suitable for use in this study is Nome (located approximately 95 miles from Elim). The average monthly summer temperature is approximately 40 to 60°F. The monthly average winter temperature is on the order of -5° to 15°F. The average annual precipitation is approximately 16.1 inches per year, with snowfall on the order of 60 inches.

1.2.5 Infrastructure

1.2.5.1 Water Infrastructure

According to the Source Area Assessment for Elim (ADEC 2004), the City of Elim water system is a Class A water system[3] that obtains water from Elim Creek at a location that is approximately 425 feet north of the Elim-Moses Point Road. The water system intake is composed of several perforated polyvinyl chloride (PVC) pipes that are placed below the bed of Elim Creek in gravelly soils. Water is pumped through a pumphouse and into an above-ground pipe and a water storage tank, where it enters the water distribution system. The residents indicated during the public meeting they believe the storage capacity of the tank is undersized relative to their needs. According to Mayor Kotongan, the existing

[3] A Class A system serves 25 or more people for a minimum of 6 months per year or has 15 or more year-round connections (ADEC 2002).

water storage tank is 211,000 gallons. According to the public meeting attendees, storm surge events can cause salt water to reach the water source. This often results in the water source being unusable for a few days at time. The actual duration of the water source being unusable varies with each event.

1.2.5.2 Wastewater Infrastructure

The city is served with a wastewater collection system that collects sewage and transfers the wastewater to four 5,000-gallon septic tanks. Wastewater from the septic tanks is discharged into Norton Sound under Alaska Department of Environmental Conservation (ADEC) wastewater permit 2003DB0096 through an offshore ocean outfall. The maximum permitted discharge rate is 21,000 gallons per day.

1.2.5.3 Electricity/Communication Infrastructure

The buildings in the community are served by mostly above-ground power and telephone lines. The poles observed in the community appear to be generally in good condition and relatively vertical. Diesel generators are used to provide power to the community.

1.2.5.4 Solid Waste Disposal

Solid waste is disposed at an ADEC-permitted (SW3A023-15) Class 3 landfill[4] located approximately 2.3 miles northeast of Elim along the Elim-Moses Point Road. In addition to solid waste, the landfill is permitted to receive septage. The village is also in the process of setting up a fee-based collection system for solid waste to limit human contact around the dump. According to the Region 10 Tribal Newsletter Alaska Edition prepared by the U.S. Environmental Protection Agency (2010), the community segregated solid and electrical (wires, computers, etc.) waste and this material was backhauled out of Elim by barge.

1.2.5.5 Fuel Storage Area

The fuel farm is located near the airport runway, approximately one-half mile from Elim. The relatively new fuel facility provides fuel storage for vehicles, power generation, and structures. Fuel (diesel and gasoline) stored at the facility is transferred from fixed pipe header close to the edge of the cliff face southeast of the teacher housing building. The 4-inch-diameter lines run approximately 10 to 20 feet from the top edge of the cliff to near the cemetery, where they bend inland and up to the fuel storage depot.

1.2.6 Buildings

Most of the buildings observed in the community appear to be constructed using post-and-pad techniques. A typical post-and-pad foundation is showed on Figure 2. Many of the homes have wooden skirts around the bottom that prevent air flow under the structure, similar to the school and the Elim Native Store, which is also shown in Figure 2.

Figure 2. Typical Post-and-Pad Foundation

Based on our analysis, we anticipate that the houses are founded on relatively shallow soils overlying bedrock. The presence of shallow bedrock in the eastern part of the community is confirmed in

[4] A Class 3 landfill is one that is more than 50 miles by road from a larger landfill or has no road access (ADEC 2011).

borings drilled by S&W and the Alaska Department of Transportation and Public Facilities (DOT&PF). Although permafrost is likely in the area, no permafrost stabilization techniques (such as insulated or passively refrigerated foundations) were observed in the community. This is likely as a result of being founded on thaw-stable bedrock.

During the first public meeting, several of the residents identified a "permafrost problem" associated with some of the housing. They indicated that this problem is generally an up-and-down movement, rather than a long-term settlement. As such, it appears likely that this movement is related to seasonal freezing and thawing of soils.

Also during the first public meeting, concerns were identified regarding rotting wood and mold problems in several of the houses, particularly in the bathroom areas. This problem may result from inadequate air exchange to circulate moist air away from the structure, poor vapor barriers, or inadequate insulation.

1.2.7 Transportation

Access to the community is generally via two transportation-related facilities:

- A State-owned 4,000-foot-long by 75-foot-wide gravel airstrip is available year-round and located on the western edge of Elim. Scheduled air service is generally available daily from Nome.
- A 9-mile-long gravel road connecting Elim to Moses Point to the northeast. The 4 miles of the road closest to Moses Point are generally located along the beach and we understand that this section has been washed out on several occasions.

In addition, Elim is serviced by barges that transport fuel and supplies. There is no formal dock facility in the community. Four-wheelers and pickups are the common modes of vehicular transport within the village. At the time of our visit, the road surfaces were generally in good condition with little sign of rutting. During the first public meeting, residents indicated that the roads are getting soft. Although not observed, this may be related to moisture accumulation resulting from the thawing of seasonally frozen soils in the road material. Drainage is another concern of the road system. Poor subsurface drainage across road alignments may result in buildup of water on the up hill side of the road in the fall. This could provide an additional moisture source into the road embankment, contributing to a softer road surface during the spring thaw.

There is a wooden bridge over Elim Creek approximately 200 feet from the edge of the water (see Figure 3). Suspended under the bridge are water and sewer lines. In addition to the bridge, the community has constructed a gravel road over Elim Creek approximately 30 feet down hill of the bridge. A large, oval, corrugated metal culvert, approximately 6 by 8 feet, has been placed to allow Elim Creek to pass under the embankment.

Figure 3. Wooden Bridge over Elim Creek

We understand that during winter months, aufeis[5] may be present in Elim Creek, resulting in water and ice approaching the elevation of the water and sewer lines. This condition would place a lateral pressure against the lines that may exceed design conditions and potentially result in rupture.

2. IDENTIFICATION AND DEFINITION OF HAZARDS

2.1 Climate Change

According to the State of Alaska's Alaska climate change strategy (State of Alaska 2011):

> "Climate change describes the variation in Earth's global and regional atmosphere over time. These changes are likely caused by a combination of natural processes and activities. The rise in the Earth's average surface temperature is known as global warming. Scientists attribute the accelerating rate of global warming to manmade greenhouse gas emissions.
>
> Global warming is currently impacting Alaska and will continue to impact it a number of ways. These impacts include melting polar ice, the retreat of glaciers, increasing storm intensity, wildfires, coastal flooding, droughts, crop failures, loss of habitat and threatened plant and animal species.
>
> Globally, 2005 was the warmest year on record (using records dating back to 1880) with a sustained period of warming in the arctic during 2000-2005[6]. Convincing evidence includes NASA satellite data that shows Arctic perennial sea ice decreasing by 9% per decade since 1979. Less ice means more open water-which means greater absorption of solar energy-which leads to increased warming in the ocean, and in turn accelerates more ice loss. This has led to a wide range of impacts in Alaska, including:
>
> - **Melting glaciers, rising sea levels, and flooding of coastal communities.** Warming of oceans and melting of land-based ice increases the volume of ocean water. Loss of sea-ice cover changes habitat for arctic species and leaves coastal communities more exposed to larger waves generated by severe storms.
> - **Thawing permafrost, increased storm severity,** and related infrastructure damage to roads, utility infrastructure, pipelines and buildings. Extremes in weather patterns, precipitation and rising sea levels will affect safe water sources in villages, and contributes to increased erosion along Alaska coasts and rivers and undermines Alaska boreal forests.
> - **Loss of the subsistence way of life** as animal habitat and migration patterns shift and as hunting and fishing become more dangerous with changing sea and river ice. Warming streams and increased silt from melting glaciers affect fish habitat. Boreal forests advance northward and to higher elevations, displacing tundra. Invasive species compete with native vegetation. Humans, animals and plants may be exposed to new infectious diseases as habitat changes.
> - **Forest fires and insect infestations** increasing in frequency and intensity. In the past decade, Alaska has witnessed a record loss of forests to fires and spruce bark beetles."

[5] Aufeis refers to the layered ice that forms from successive ground water flow during freezing temperatures. It is also called overflow or icing.

[6] The National Oceanic and Atmospheric Administration (NOAA) reports that 2010 tied 2005 as the warmest year on record (NOAA 2011).

S&W evaluated the temperature trends from data collected in Nome, the nearest identified weather station. Climate data recorded at the Nome Airport were obtained from the Alaska State Climate Center for the period of record (approximately 1908 to 2011). The Nome Airport was chosen due to its proximity to the site and the length of record. The Nome Airport is a first-order weather station[7]. A first-order weather station is part of a national automated climatological monitoring network, collecting additional parameters relative to the older airport weather monitoring systems used primarily for flight information and reporting special observations during rapidly changing conditions.

From the mean daily temperatures, S&W calculated annual air freezing (AFI) and thawing indices (ATI). The AFI is calculated by identifying the number of days in a year when the mean daily temperature is below freezing (32°Fahrenheit (F)). For each day, the difference between the mean daily temperature is subtracted from 32°F. The resulting numbers are then summed to give the AFI for that year. The ATI is the opposite of the AFI, as it looks at the days when the mean daily temperature is above freezing. Table 1 summarizes the calculations.

Table 1. Air Freezing and Air Thawing Index Trends

Period of Record	Air Freezing Index (AFI)	Air Thawing Index (ATI)
1908 – 2010	Mean: 4204 Trend: -4.9°F-days/yr	Mean: 2125 Trend: 3.1°F-days/yr
1908 – 1925	Mean: 4412	Mean: 1998
1926 – 1945	Not reported due to limited data set	
1946 – 1976	Mean: 4575	Mean: 2005
1977 – 2008	Mean: 3814	Mean: 2292

Note that there is a significant data gap in the data record between 1926 and 1945. As such, we have not included mean trend data from this period. In addition, June data from 2007 were not available and thus we removed 2007 from the ATI data set. In general, the temperature record was complete (greater than 98.5 percent), except as noted above. Where individual highs and lows were missing, they were estimated based on the previous and subsequent days.

The 1908–2010 data show a trend where the annual AFI is decreasing (winters are getting warmer) of approximately -4.9°F-days per year[8] and the ATI is increasing (summers are getting warmer) of approximately 3.1°F-days per year during the complete period of record.

It should be noted that if the dataset is divided into three categories, 1908 to 1925, 1946 to 1976, and 1977 to 2008, significantly different results can be seen. A data gap limits the evaluation from 1926 to 1945. These breaks in the data correspond to the start of the Pacific Decadal Oscillation (PDO). The PDO is a climate phenomenon that is characterized by changes in the northern Pacific Ocean, which impacts sea surface temperature, sea level, and wind patterns and impacts temperatures in the northern Pacific Ocean. The PDO switches between a warm or positive phase and a cool or negative index phase. According to the University of Washington (2011), each PDO phase during the 20th century lasted for approximately 20 to 30 years. The PDO was in a cool phase from 1890 to 1925 and 1945 to 1977, with warm phases from 1925 to 1945 and 1977 to 2008. Recent trends, since approximately 2006, show an increase in the AFI and a decrease in the ATI and may correspond to the PDO returning to the cool stage. In 2008, NASA's Jet Propulsion Laboratory announced that the PDO had shifted to its cool stage (NASA

[7] A first-order weather station is maintained professionally by the National Weather Service or the Federal Aviation Administration. They report multiple weather variables such as temperature, wind speed, and humidity several times each day.
[8] A decrease of 4.98°F-days per year means that days that have a mean temperature above freezing are, in general, 4.9°F colder than the previous year.

2008). As such, the magnitude of the climate change and climate information should be reviewed and interpreted considering the effects of the PDO.

2.2 Previous Soils Investigations

Elim is located within the physiographic province known as the Seward Peninsula (Wahrhaftig 1965). The Seward Peninsula is characterized as having broad, convex hills and flat divides 500 to 2,000 feet in elevation, sharp V-shaped valleys, isolated groups of glaciated mountains, coastal lowlands, and interior basins. The bedrock geology of the peninsula is given by Wharhaftig as being a biotite schist, gneiss, marble, and metavolcanic rocks. The entire peninsula is identified as a permafrost area.

The coastal area geology near Elim was mapped; the geological mapping indicates channel and overbank deposits (alluvium) near the Elim Creek drainage channel and sandy gravel beach deposits along the coast (Riehle et al. 1981). The rest of the area is identified as being composed of sedimentary, metamorphic, and igneous rocks. The report indicates that previous mapping indicated the composition of bedrock in the area as limestone and dolomite with lesser amounts of schist and slate and complexly folded and with marble outcrops. The report continues to state that many of the areas shown as bedrock are covered by thin, surficial deposits such as windblown silt, colluviums, and alluvium.

S&W conducted a geotechnical investigation in Elim for a proposed new High School in 1979. Given the elevation of the ground surface in the project area (~130 feet), S&W believes it was performed in an area that may now be part of the existing runway. In the test pits, S&W observed approximately 1 foot of tundra/organics overlying 1 to 2.5 feet of eolian silt. Underlying the silt, we observed weathered bedrock becoming more competent with depth ranging from 3 to 7.5 feet below the existing ground surface. The depth of our exploration ranged between 5 and 22 feet. S&W did not identify permafrost as part of their investigation.

2.3 Sediment Characteristics

During a site visit conducted from May 30 to June 1, 2011, S&W performed a cursory sediment analysis by collecting grab samples from two locations along the shoreline at Elim to characterize the type of sediments that exist at the site. The shoreline at Elim consists of extremely weathered rock cliffs/bluffs fronted by a sandy/cobble beach. Characterization of the sediments along the shorelines is important for assessing feasibility of potential shoreline protection methods as well as better understanding of the erosion processes. Table 2 shows the results of a preliminary grain size classification performed by S&W.

Table 2. Grain Size Classification

Sample	Median Grain Size (mm)	Classification	Characteristic Location
S1	9	Fine gravel	Beach
S2	21	Coarse/Fine gravel	Onshore adjacent to beach

3. IDENTIFICATION AND DEFINITION OF HAZARDS

The hazard identification for Elim is based on information in the 2010 State of Alaska Hazard Mitigation Plan, consultation with government agencies such as U.S. Geological Survey (USGS), Alaska Volcano Observatory (AVO), input from local residents, and documented past occurrences, The 2010 State of Alaska Hazard Mitigation Plan identifies hazard threats by region instead of by community. Elim is included in the Bering Straight Regional Education Attendance Area (REAA). The REAA covers a large area ranging from Gambell to the west, Shishmaref to the north, Koyuk/Unalaska to the east, and Stebbins to the south. Because of its size, not all the region information applied to Elim but it provides a starting point for the hazard identification process.

According to the State of Alaska Mitigation Plan, the following natural hazards are present in the Bering Strait REAA:

- Flood/Storm Surge
- Wildland fire
- Earthquake
- Severe Weather
- Ground failure
- Erosion
- Tsunami
- Snow avalanche
- Volcano

3.1 Flood/Storm Surge

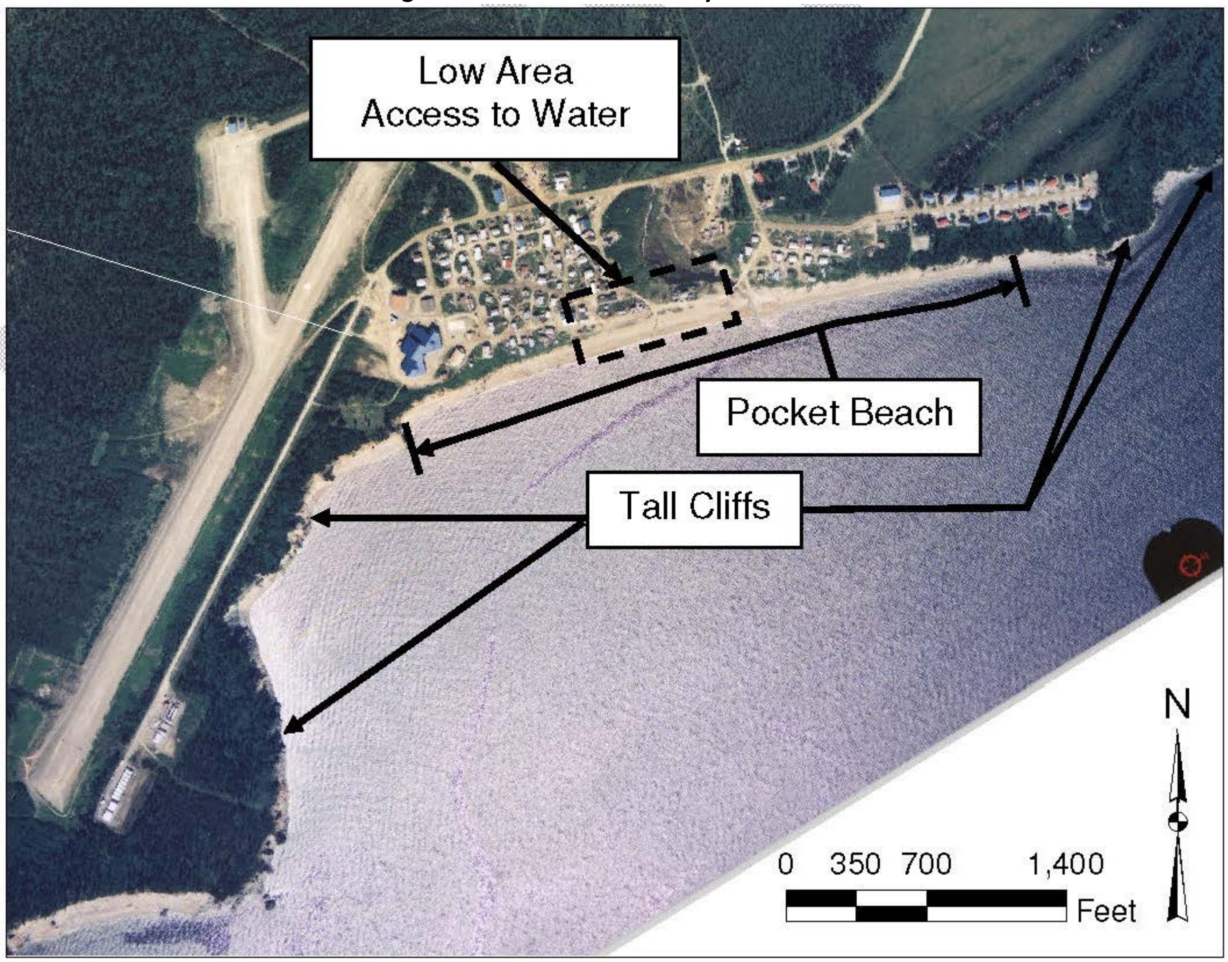
A flood is an overflowing of water onto land that is not usually submerged. Floods can result from many causes, including excessive rainfall, snowmelt, rising groundwater, and ice jams. Elim does not participate in the National Flood Insurance Program nor are there any mapped floodplains in the community. Community residents noted that flooding occurs mostly in the fall and spring (due to snowmelt). In Elim, the main cause of flooding appears to be storm surges.

Coastal rock cliffs, such as those along the Norton Sound shoreline, generally protect uplands from major storm waves and surge. Elim, however, is situated along a pocket beach[9] where the tall cliffs on both sides reduce in elevation, creating a natural area for residences to more easily access the water (Figure 4). Because of this, storm surge and waves are able to run up and cause damage to structures and dwellings of the community. According to the U.S. Army Corps of Engineers records, the worst flood of record is the October 1945 coastal storm (USACE 2007). The elevation of that flood was approximately 131 feet. The Corps of Engineers website indicated a High Water Elevation sign was installed at the 131.0 elevation, but this sign was not located during our site visit. Similar floods are said to have occurred in 1917 and in November 1974. Other major storm surges occurred in 1992, 2004, and 2005. Storm surge in Elim has even been reported in the national news. After a major storm in October 2004, *USA Today* reported:

> "The storm slammed Elim, about 90 miles east of Nome, causing erosion that exposed septic tanks and the city's main water line. It also took out the road to a popular subsistence fishing area, said city clerk Luther Nagaruk. Storms like Tuesday's hit the Norton Sound region every 15 or 20 years, he said. This one was worse than the biggest storm last year, but milder than one in 1974, he said."(*USA Today* 2004)

[9] A "pocket beach" is an isolated sandy or gravel beach, typically in a cove-like shape that occurs between rocky outcroppings.

Figure 4. Natural shoreline layout at Elim



A storm producing similar surge in Nome occurred almost exactly 1 year later in fall 2005. The USACE (2008) reported the 2005 storm damaged Elim's main access bridge, septic lines, and six subsistence-use cabins. It is clear that the ability for storm waves and surge to damage dwellings and key infrastructure, as well as erode/damage roadways, is a major coastal hazard at Elim.

The community has documented the occurrence of several surge events associated with storms. Photographs document surges on the order of 7 to 10 feet with the water surface near the elevation of the manhole lids for the septic tanks. The structures located near the cliff face can be subjected to flooding, wave action, salt spray, and other damaging impacts.

Flooding/storm surge has also impacted several structures near Elim Creek, resulting in flood damage. In addition, the surge was reported to overtop the Elim-Moses Point Road. If this road and the bridge are rendered unusable, as they appear to have been in the past, the eastern part of the village, including the new Head Start Building and approximately two dozen homes, will be isolated with potential loss of access to emergency services.

Photographs taken of the surge events show the water level near the deck level of the Elim Creek bridge. Logs and water partially submerged the utilities under the bridge. This condition can result in a rupture of the lines and loss of water and wastewater services for the eastern portion of the community.

Based on descriptions by community members, salt water can inundate Elim Creek near the water supply's intake piping. The presence of salt water near the intake may result in a loss of pumping capability for several days, depending on the duration of the surge event. During this time, the community has to rely on stored water in the city water tank. The tank may not have the capability to sustain the village for the required duration, resulting in a potential loss of drinking water for the community.

3.2 Wildland Fire

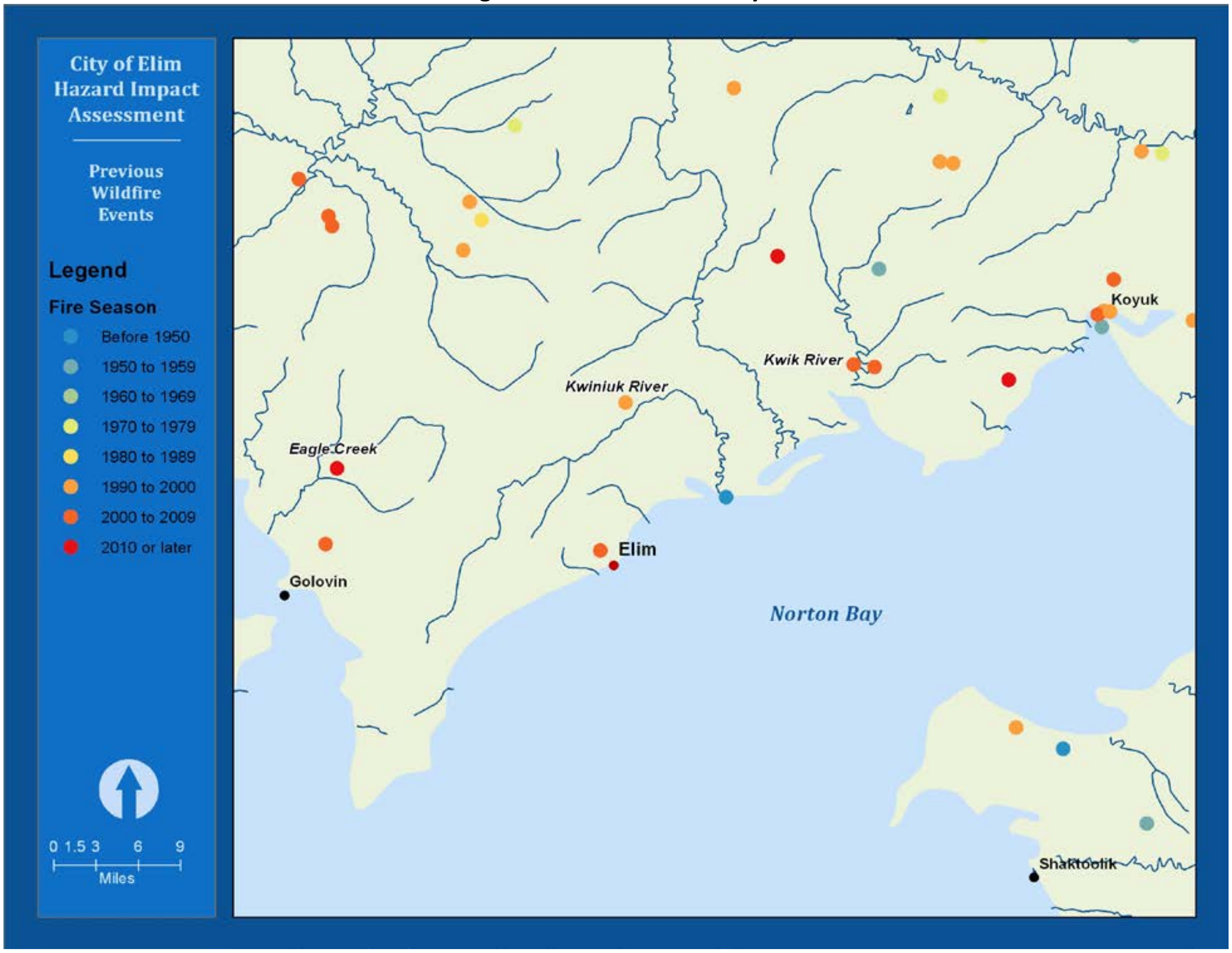
In general, a wildland fire is a fire that burns uncontrolled in a natural setting such as a grassland or forest. According to the State of Alaska Hazard Mitigation Plan, there are 600 to 800 wildland fires every year. Most of these are between the months of March and October.

Figure 5. Spruce Bark Beetle Killed Trees in Elim

Weather, topography, and fuel influence wildfire behavior. High temperatures with low humidity encourage fire activity, while low temperatures and high humidity inhibit fire activity. Topography directs air movement, which will influence fire behavior. Fuel will decide how much energy is given off by a fire, how fast it spreads, and how easily it will be contained. According to the State Hazard Mitigation Plan, Alaska has seen an increase in wildland fire risk in recent years because of climate trends, expansion of development into wildland areas, and the results of spruce bark beetle infestation. Spruce bark beetle larvae kill spruce trees by eating the area under the trees' bark. When the tree dies, it dries, making it very flammable.

Climate change can lead to an increase in wildland fires as earlier snowmelts lead to warmer springs (leading to a longer fire season) and warmer summers can result in lower soil moisture (Pew Center 1007). While Elim tends not to have high temperatures that encourage wildfires, there have been previous wildfires in the Elim area (see Figure 6). For example, in 2010, the Eagle Creek fire burned approximately 195 acres, the Kuiuktulik River fire burned approximately 1.4 acres, and the Kwik River fire burned approximately 13 acres (BLM N.d.)

Figure 6. Alaska Fire History



Source: Alaska Fire Service http://fire.ak.blm.gov/content/maps/aicc/Alaska_Fire_History.pdf

Many of the spruce trees near the community have been killed by spruce bark beetles and would provide fuel. If Elim gets less precipitation due to climate change, the surrounding area is likely to be more susceptible to wildland fires.

3.3 Earthquake

While Alaska is one of the most seismically active regions in the world, Elim is located in one of the least seismically active areas of the state. There are two known faults in the area: the Kigluaik fault and the Bendeleben fault. Elim is located approximately 45 miles southeast of the Bendeleben Fault.

The USGS has developed an earthquake mapping tool that calculates the probability of an earthquake of a particular size happening within 50-kilometer radius (approximately 30 miles). According to the tool, there is approximately a 10 to 12 percent probability that an earthquake with a magnitude greater than 6 or more will occur within 50 kilometers of Elim over a 50-year period (see Figure 7). The probability increases to 15 to 20 percent that an earthquake with a magnitude 6 or more will occur within a radius of approximately 30 miles of Elim over a 100-year period (see Figure 8). While an earthquake is possible in Elim, according to Peter Haussler with the USGS, Elim is located in one of the least seismically active parts of Alaska.

Figure 7. Probability of an Earthquake Greater than Magnitude 6.0 within 50 years and 50 Kilometers

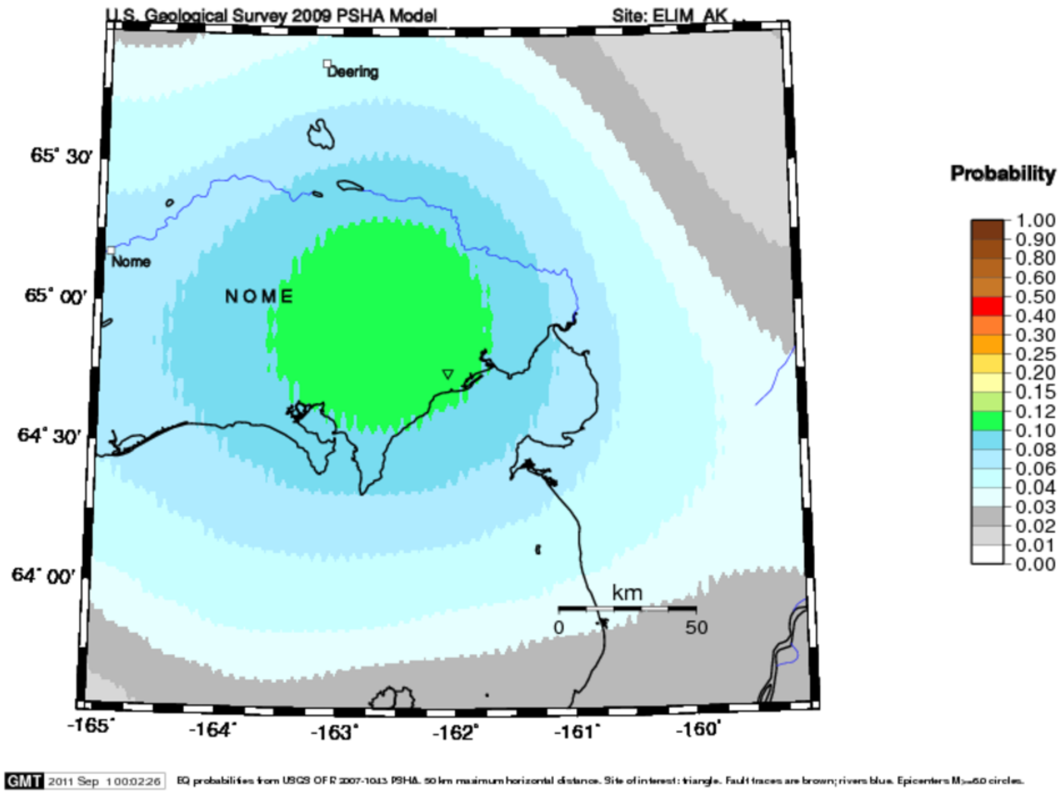
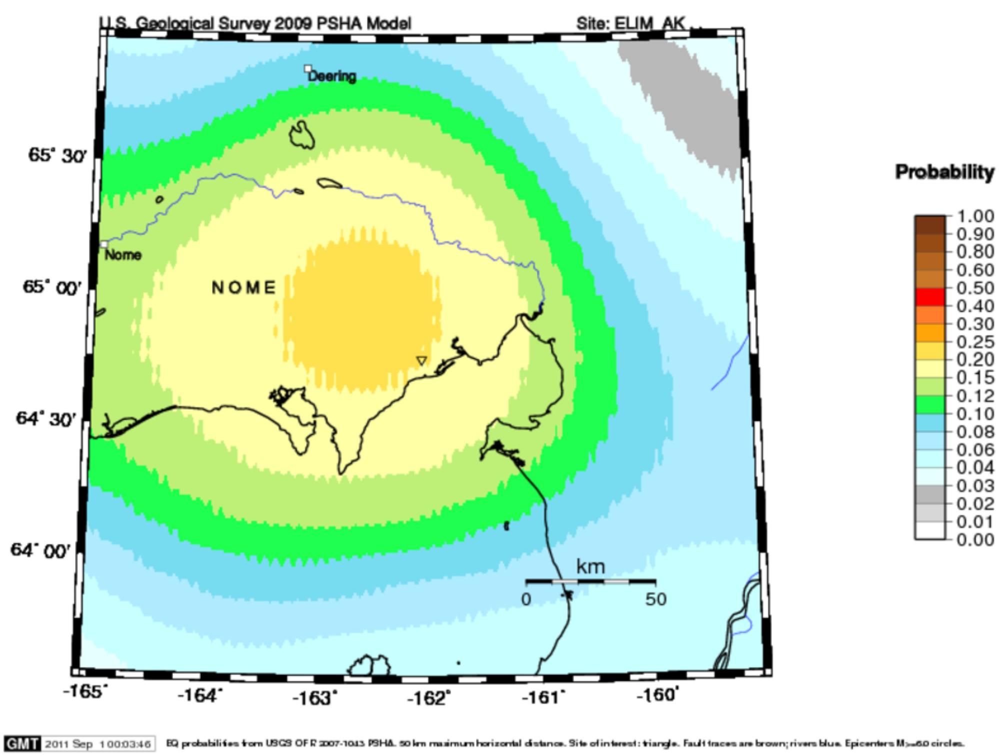


Figure 8. Probability of an Earthquake Greater than Magnitude 6.0 within 100 years and 50 Kilometers



An earthquake in the Elim area may cause localized slope failures. Liquefaction or localized lateral spreading may occur in areas near Elim Creek. Climate change is not anticipated to significantly impact earthquakes or the behavior of soil or rock as the result of a seismic event.

3.4 Severe Weather

Weather is determined by the interaction of the sun, the planet's atmosphere, moisture, and the structure of the planet. Certain combinations can produce severe weather events. For example, wind-driven waves can cause coastal flooding, while high winds and blowing snow can produce disorienting whiteout conditions. Extreme cold, beyond 40 degrees below zero, ice fog, and heavy snows are not uncommon in various areas of the state. There is no universal definition of severe weather. Severe weather is usually considered weather events that are worse than the typical events in the community. Elim residents indicate there have been extreme weather events in the past. For example, residents mentioned that strong winds have damaged power lines multiple times in the past.

3.5 Ground Failure

Ground failure is a general term that refers to landslide, liquefaction, lateral spreads,[10] and similar activities caused by shaking that influence the stability of the ground (USGS 2009). Ground failure mechanisms are generally limited to densification of loose to medium dense sands, in part relating to liquefaction, the potential for lateral spreading, and slope failure. The first two of these are associated with seismic events in saturated soils, primarily sands. As such, the applicability to Elim is anticipated to be limited to the area around Elim Creek. In addition, the acceleration generated by an International Building Code seismic event is going to be near the threshold for significant impacts due to liquefaction. As a result, large-scale damage due to liquefaction or lateral spreading in the Elim area is not anticipated. However, localized damage may still occur.

A failure along the rock slope can occur, either as a result of seismic action or due to weathering of the rock material. Based on review of aerial photography, we anticipate that the rock face generally has had only limited movement over the previous 40 years. However, caution and good engineering practice should be used when considering the placement of structures or infrastructure close to the edge.

The stability of the coastal rock face should be periodically monitored (once every 5 to 10 years) and assessed to identify potential areas where the weathering of the rock face may weaken the rock to the point where is becomes a stability concern. In general, the buildings have been set back far enough from the edge that they did not appear to be an immediate concern. However, the position of the fuel lines near the top of the cliff likely warrants periodic monitoring. Although there is some possibility for increasing the weathering on the rock face due to increasing number of freeze-thaw cycles or if there is an increase in the number or magnitude of storm events, in general, a significant short- to medium-term (less than 20 years) impact on the overall stability of the coastal rock face as a result of changing climate conditions is not anticipated.

3.6 Erosion

According to the USACE Alaska Baseline Assessment for Elim (2008), the community has identified that the primary erosion area is along the town front "with all beach sand eroded away leaving a rocky beach where a loss of 1 to 2 feet of shore has occurred over the past few years and there is an estimated need

[10] Lateral spreads refer to landslides that typically form on gentle slopes and have a quick fluid-like movement (USGS 2009).

to relocate homes in the next 10 to 20 years." This was confirmed by community residents during the first public meeting. Material may also be deposited, building the beach during smaller storms. Based on aerial photo review (see Section 3.6.1), there may be some indication that the size of the beach has been reduced over time. However, changes in the water surface elevation due to waves and tides, and lack of resolution in some of the earlier pictures to allow differentiation between cliff and beach in the photographs make it difficult to make a definitive statement regarding changes to the Elim coastline over time.

Based on field observations, it appears than several of these structures identified in the USACE report are located in areas with sand and gravel embankments and little exposed bedrock. It is not known whether this material is naturally placed alluvium, fill, or a combination. In addition, it was noted that in several areas, the vegetated turf (primarily grass) had slumped down the slope, potentially indicating erosion. However, we cannot determine at this time whether this is the result of the erosion of the rock face or the removal of the alluvial material on top of the rock.

The community of Elim relies on the beach as a place to store, launch, and receive small boats used for hunting, crabbing, fishing, transportation, and other uses. The loss of beach access would have a large impact on the community's ability to function. During recent storm events, the manholes to the wastewater septic tanks were exposed and potentially the tanks themselves exposed. If the tanks are damaged or leak during a storm event, it may result in negative health impacts for the community.

3.6.1 Erosion/Shoreline Retreat

Three potential causes of shoreline retreat were investigated for Elim: (1) climate warming, (2) wind-generated waves, and (3) relative sea-level rise. A growing concern for areas like Elim is the detrimental effects caused by changes in climate. The duration for which ice protects the shoreline from waves is steadily decreasing, allowing a longer seasonal period for waves to erode the shoreline. In addition, durations and/or areas of the soil that are frozen are diminishing. When these areas are no longer frozen they become more susceptible to erosion.

Relative sea level rise (RSLR) is the combination of eustatic (global) sea level rise and local land subsidence (or in some cases rise in land elevation). The National Oceanographic and Atmospheric Administration (NOAA) calculates RSLR from tide gauges having long-term records. Unfortunately, there are no gauges located along the western or arctic regions of Alaska. This limits quantification of the extent that sea-level rise contributes to shoreline retreat. The eustatic sea level rise ranges from 0.3 feet to more than 0.8 feet/century (NOAA 2001). This level of change would not contribute to any perceived shoreline retreat. Variations in RSLR along the peninsula and southern portion of Alaska are significant (+1.8 to -5.6 ft/century) and some of the highest in the United States (Figure 3.1). If significant subsidence occurs in the area of Elim, this could contribute to shoreline retreat.

Observations of shoreline retreat are generally performed by reviewing shoreline location either by survey or visually through comparison of aerial photographs. Using photographs to determine shoreline retreat can be inaccurate due to resolution of images, geo-referencing errors, surge/tide differences, and methodology of establishing the "shoreline." Aerial photographs, despite these challenges, can provide a good indication of shoreline morphology trends. Using surveys to determine shoreline retreat is often limited by lack of historical surveys unless a monitoring program has been established. Thus, aerial photography is the more common tool for determining shoreline retreat.

A preliminary assessment of shoreline morphology was performed by S&W to identify areas of significant erosion in the Elim area. To accomplish this, historical aerial photographs at approximately 10 year intervals from 1969, 1980, 1992, and 2004 were obtained. The 2004 aerial photography was the most recent available at the time the studies were being conducted. The photographs were imported into AutoCAD, where they were scaled and positioned based on common buildings in the photographs. The coastline, defined by the water line on each photo, was then traced and the distance between the lines measured at several locations shown in Figure 9. This type of analysis is intended to indicate gross patterns of coastal erosion and changes to the general shape of the coastline. The vegetation line was not used, as it would be a function of the erosion of the bedrock, not the beach. In addition, the resolution of the earlier photographs limits its interpretation between the vegetation line and the rock slope. Given the slope of the beach and tide fluctuations for the area, a significant amount of variability in the coastline should be expected through this analysis.

The results of these erosion studies are presented in Figure 9. The comparisons suggest apparent horizontal variations in the coastline of less than approximately 50 feet over 50 years. As shown in Figure 9, significant, obvious areas of systematic progressive erosion along the coastline or changes in the overall shape of the coastline were not identified. There may be a trend showing erosion is occurring along the beach near the village, but the uncertainties associated with the tides, waves, and other factors limit the ability to qualify or quantify a trend. In every time period (except 1980 to 1992), both erosion and accretion were reported, depending on the location. This is consistent with our expectations, given the presence of bedrock cliffs that tend to limit the amount of coastal erosion that can occur. Table 3 summarizes maximum shoreline retreats. These rates vary by location.

Beach widths are often cyclic in nature. Storm seasons will produce large waves, causing erosion and decreasing beach width. To offset this, during calmer periods (summertime, typically), gentle waves bring sand onshore and increase the beach width. In contrast to the cyclic nature of seasonal changes, random severe storms can cause significant erosion that may not be recovered through natural processes.

Major storms occurred in the fall of 2004 and 2005 at Elim. However, many of the larger storm events that have been documented or described in the public meeting occurred after 2004, and these more recent developments would not have been detected in the analysis. Therefore, the retreat rates in Table 3 do not include the impacts caused by these storms. However, based on the average shoreline retreat rate of 1 foot per year and aerial photographs taken after 2005, shoreline retreat at Elim is relatively moderate.

Figure 9. Shoreline Morphology Assessment

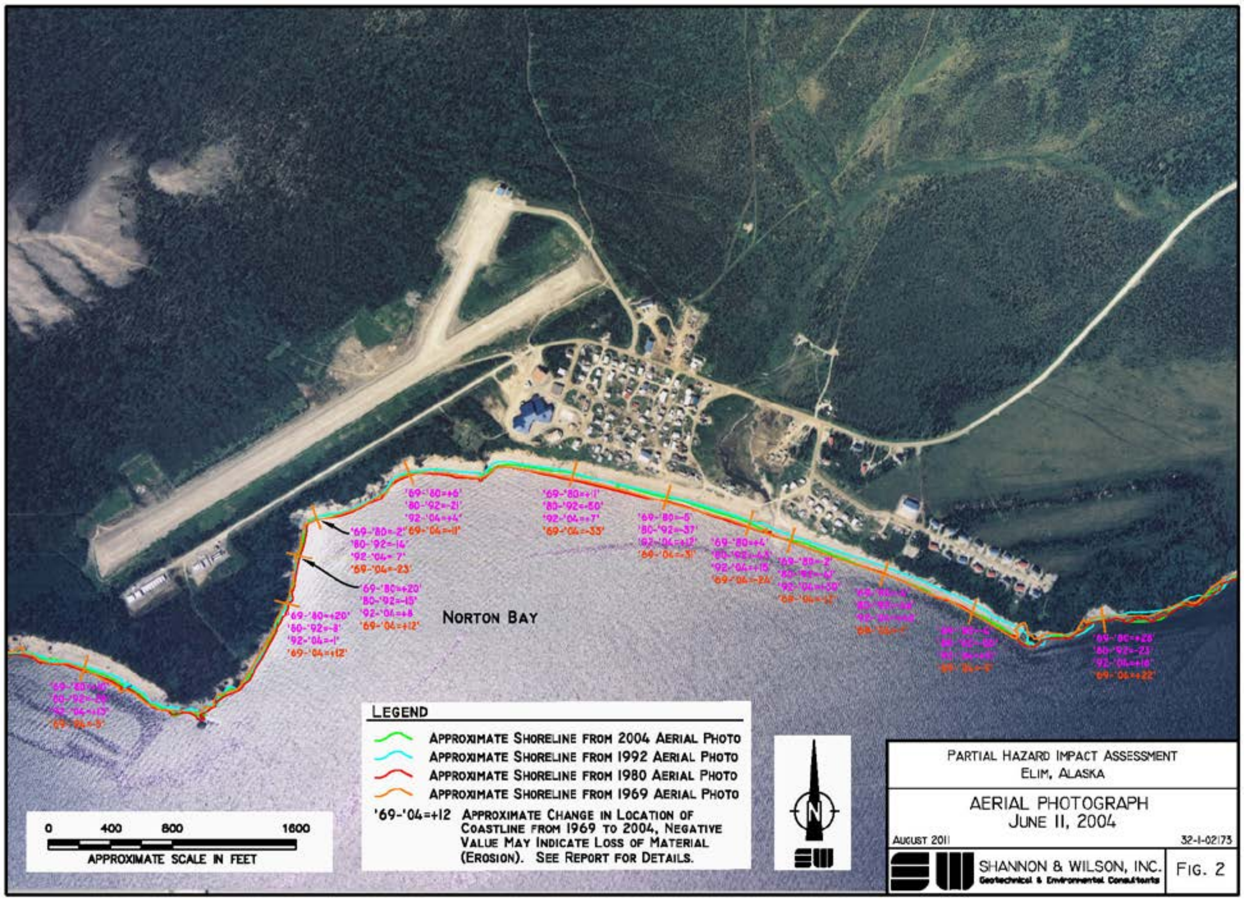


Table 3. Elim Shoreline Erosion Rates

Time Period	Maximum Shoreline Retreat	Maximum Retreat Rate
1969–1980	5 ft	<1 ft/yr
1980–1992	55 ft	14 ft/yr
1992–2004	7 ft	3 ft/yr
(Average) 1969 – 2004	33 ft	1 ft/yr

Regardless of the average rate of shoreline retreat, the rock in the cliffs along the beach appears to be extremely weathered and therefore breaks off easily. These rock pieces fall in to the surf zone and, over time, are ground down to help replenish the beach. If cliff pieces break off near dwellings, eventually structures will be at risk of undermining.

3.7 Hazards not profiled in the HIA

3.7.1 Tsunami

Paul Whitemore, Geophysicist in Charge of the West Coast/Alaska Tsunami Warning Center, indicated that Elim has a very low tsunami risk. As a result, tsunamis will not be discussed further in this HIA.

3.7.2 Snow Avalanche

According to the State Hazard Mitigation Plan, Elim has a low potential for a snow avalanche. As a result, snow avalanches will not be discussed further in this report.

3.7.3 Volcano

A volcano is an opening in the Earth's surface which magma (molten rock), ash, gases, and other volcanic material erupt. There are no volcanoes near Elim. Depending on winds, ash from a large eruption may impact Elim, but this is not considered a significant threat. Volcanoes will not be discussed further in this report.

3.8 Critical Facilities

Critical facilities are sites, structures, and infrastructure that are essential to the well-being of the community served by these systems. There is no universal definition of a critical facility, as facilities and their importance can vary in different communities. Laurie Cummings and Eric Anderson discussed what facilities would be important to the community with residents during the first public meeting. This initial list of critical facilities was reviewed with the community during the second public meeting. During the second meeting, it was decided that the Boys & Girls Club, library and Corporation building should be added to the list. The results are shown in Figure 10.

Figure 10. Critical Facilities

4. RECOMMENDATIONS

In order to document and develop actions to reduce the potential effects of hazards in Elim, several additional studies or actions are recommended. These actions may include additional data collection to document the need for funding prioritization, provide a basis for the design and evaluation of alternatives, or provide planning assistance to the City of Elim.

Table 4 summarizes the next steps recommended for the community as it seeks to better understand and cope with the potential effects of climate change and natural hazards. These projects are explained in greater detail in the subsequent sections of this chapter.

Table 4. Summary of Recommendations

Project	Hazard(s) Addressed	Possible Resources	Estimated Time Frame
Wildfire Fuel Removal	Wildfire	City of Elim, Alaska Fire Service	Ongoing
Periodic Monitoring of Cliff Face	Erosion/Storm Surge	City of Elim	Every five to 10 years

Monitoring and Documentation of the Rate of Beach Erosion	Erosion	City of Elim, DCCED	Ongoing
Protection of Wastewater Disposal System	Flooding/Storm Surge	City of Elim, Village Safe Water	5–20 years
Relocate the Water Source and Increase Storage Capacity	Flooding/Storm Surge	City of Elim, Village Safe Water	1–10 years
Wave/Surge Barrier	Flooding/Storm Surge	City of Elim, USACE	5–15 years
Culvert Evaluation	Flooding/Storm Surge	City of Elim, DOT&PF	1–2 years
Bridge Replacement	Flooding/Storm Surge	City of Elim, DOT&PF	1–5 years
Community Land Use Plan and Development Standards	All hazards	City of Elim, DCCED, U.S. Housing and Urban Development, Cold Climate Housing and Research Center	1–5 years
Setback Requirement	Flooding/Storm Surge/Erosion	City of Elim, DCCED	1–5 years
Moses Point	Flooding/Storm Surge/Erosion	City of Elim, DCCED, residents	1–5 years

4.1 Wildfire Fuel Removal

Three elements are needed for a wildfire to occur: oxygen, heat, and fuel. By minimizing the availability of fuel, the City of Elim can reduce their potential for a wildfire. For example, spruce bark beetle-killed trees are flammable, so removing the dead trees near all housing and other buildings reduces the chances of a house or building being burned in a fire. Another way to minimize fuel is by using non-combustible construction materials where possible. A firebreak would also help reduce the possibility of the wildfire spreading to the community. The Alaska Fire Service should be consulted to help identify the appropriate location and width of the firebreak.

4.2 Periodic Monitoring of the Cliff Face

Rocks in cliffs along the shoreline were found to be extremely weathered. Severe storms and/or ice impacts could further damage the cliffs, causing large pieces to detach and fall seaward. As a result, periodic geological surveys along the cliff face should be conducted. The surveys should be conducted by a professional engineer or geologist licensed in the State of Alaska. The survey would evaluate the folding, rock strength, and joint characteristics to identify areas of weakness. The purpose of the survey is to evaluate the stability of the slope and identify potential areas of concern in a timely manner such the slope can be stabilized or the impact of a failure, such as the presence of structures, fuel lines, or other infrastructure can be mitigated prior to a failure event. These evaluations should be performed on a periodic basis at least every 5 to 10 years.

The geological survey should be supplemented by a community-based monitoring program. After erosion events, the community should take photographs (of the cliff face and adjacent areas) and keep a log noting the dates of the photographs and a brief description of what they see and why they think it is happening. This log should be shared with the engineer/geologist conducting the geological survey.

4.3 Monitoring and Documenting the Rate of Beach Erosion

The use of the beach for launching, storing, and receiving small boats is an important component to the community. A review of aerial photography indicating a long-term trend in the width of the beach was inconclusive. Having a shoreline monitoring program to help identify erosion rates would provide valuable information about erosion in the community It is recommended that the community establish several benchmarks along the base of the cliffs and/or in upland areas above the beach, south of the town proper. These benchmarks should be constructed in a manner and in areas such that they will not experience damage or movement during storm events or sea ice when Norton Sound is frozen. Periodically during low tide, perhaps on the first of each month and after a storm event, a level survey should be conducted perpendicular to the shore between the benchmark and the low tide line. Over time, this will provide a record of erosional and depositional events and document long-term erosion of the beach.

4.4 Relocate the Water Source Area and Increase Storage Capacity

According to Mayor Kotongan, the current water source is located within a floodplain. The water source does not appear to be in a location that can provide the village with a continuous supply of drinkable water in the event of a large storm event. Community residents indicate this area can be inundated by salt water during storm surge events. Residents indicated that water is stored in the water tank to provide drinking water until the water source is no longer affected by the salt water. However, meeting attendees indicated the existing water tank is not large enough to meet their needs during storm surge events. CRW Engineering Group has developed a Sanitation Facilities Master Plan for the City of Elim which recommends the replacement of the water tank (CRW 2011). While the Sanitation Facilities Master Plan indicates the existing water source is sufficient to meet the community needs, Mayor Kotongan indicated that the community is still interested in relocating the water source. It is recommended that moving the water source to an area that is not vulnerable to storm surge be a long term goal of the community. In the short-term, replacing the water tank should provide the community with enough water to withstand periodic storm surge events. For more information on water and waste water system improvements, please see the Sanitation Facilities Master Plan.

4.5 Protection of Wastewater Disposal System

The exposure of manholes and wastewater septic tanks during storm events indicates that the system, as it currently exists, may not be adequate for long-term use. Damage to the wastewater system may result in a violation of wastewater discharge conditions of the wastewater permit and create a health concern, limiting the near-shore activities for a period of time.

After the major storm in 2005 that exposed the sewer tanks, the community re-covered the tanks and placed riprap on the slope seaward of the tanks. It is not known if the riprap is adequately sized to resist storm and ice forces. We recommend the protection be evaluated by a licensed engineer and appropriate riprap added to the existing system, if needed.

Alternatively, a temporary and demountable wave/surge barrier may be more appropriate. These are portable structures that can quickly be moved by a group of personnel or readily available equipment and placed prior to a storm for protection of landward structures. After the storm, the structures are removed and stored until needed again. These structures are generally significantly cheaper than permanent structures; however, they may not be as effective if not properly installed. An example of a temporary and demountable wave/surge barrier include a series of jersey barriers (hollow traffic barriers) filled with sand/water, geotextile tube/dam or a geotextile container (Figure 11). For more information on this type of structure, refer to DEFRA (2002).

Figure 11. Example of a Geotextile Container

It is recommended that a storm surge numerical model similar to that discussed above be performed to help determine an appropriate device and deployment plan. Strategic placing of the devices would be important, especially for some of the devices that are neutrally buoyant.

At this time, a permanent wave/surge barrier such as a seawall, bulkhead, quarry-stone riprap, etc. is not recommended for further study. This type of structure would likely be expensive (multi-million-dollar range). Most dwellings and key infrastructure (excluding roads) at risk could probably be relocated for significantly less cost. Prior to construction, a significant amount of data collection/gathering, alternatives analysis, design work, and permitting would need to be performed.

4.6 Bridge Replacement

Community residents indicate the bridge over Elim Creek is in need of replacement because it is subject to icing and flooding. According to Mayor Kotongan, the bridge was constructed of wood from a local source. Without strict quality control measures in place, which would be expected for commercially harvested and supplied lumber, the strength characteristics of the wood cannot be accurately ascertained. Furthermore, lumber that is used in outdoor bridge-type structures is typically pressure-treated to be more resilient to environmental effects. The pressure treating is especially important for when the bridge is exposed to moisture, salt, wind, and sun.

Photographs of the bridge show pronounced distortion in the railings. The distortion may also be evidenced in the bridge deck, as the traveling surface of the bridge appears to be warped. While these observations are not necessarily indicative of further distress or impending failure, the physical distortion may be cause for concern of the strength of the structure.

Community residents and photographs reveal water, ice, and/or debris reaching all the way up to the bridge stringers[11]. This creates a significant threat of damage to the bridge, as well as the possibility that the bridge could be washed out during an extreme flood/storm surge event. Additionally, flood water/storm surge overtopping the bridge could prevent people from using the bridge to cross Elim Creek.

Because the bridge includes water and sewer lines, damage or loss of the bridge could result in the loss of critical utilities for the community. In the current condition, not only does the bridge have zero

[11] A stringer is a part of a bridge that supports the bridge deck.

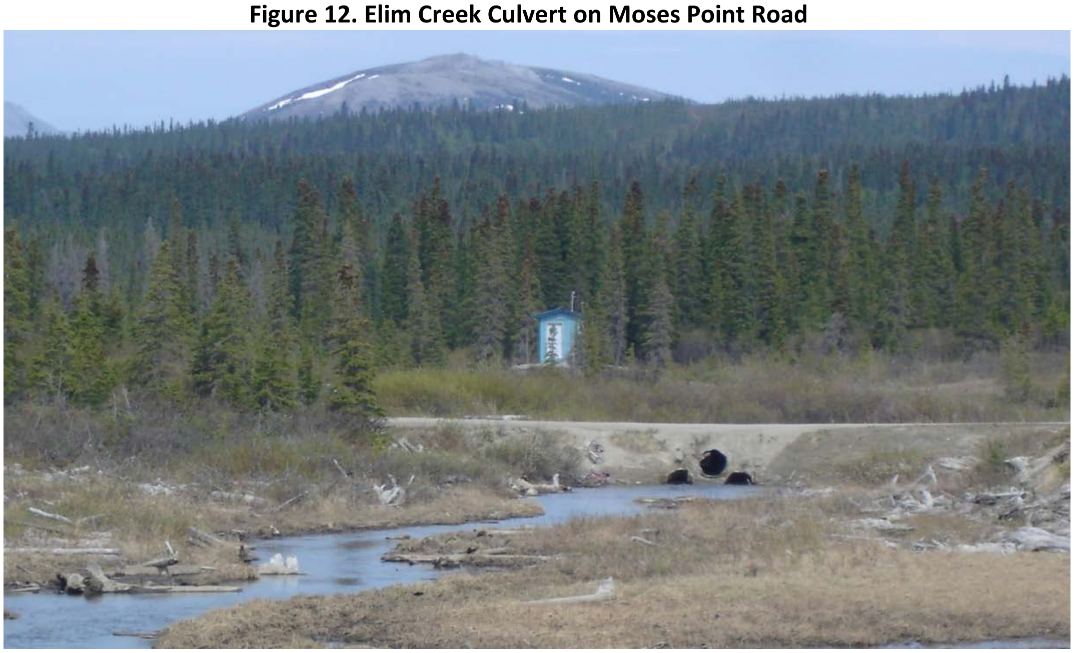
freeboard[12] above flood levels, but the utilities are suspended several feet below the low chord[13] of the structure. Typically when utility pipes are suspended from a bridge, they are placed in a location where they are protected by the bridge structure. In this case, the lines are suspended well below the structure and are thus particularly susceptible to forces caused by ice and water, and are more prone to rupture.

While the bridge has not been inspected by a qualified bridge engineer, based on the apparent condition, input from community residents, and the observed performance of the Elim foot bridge, a replacement bridge is recommended. A replacement bridge should have an elevated profile to allow for freeboard underneath the bridge, new materials of high quality for improved structural integrity, and a revised utility layout to better protect the water and sewer lines being conveyed across the stream.

4.7 Culvert Evaluation

Community residents indicated that culverts were installed based on what culverts were available to them at the time. As a result, some culverts may be undersized. Undersized culverts can lead to scouring and erosion issues. In addition, culverts can get plugged with debris and cause flooding. All culverts in Elim should be evaluated to determine if they are sized appropriately and to identify which ones need replacement. In particular, the size of the culverts along Elim Creek (see Figure 12) should be evaluated, both in terms of functioning in the winter with the potential presence of aufeis and during warmer months to evaluate whether they can transmit the flow of Elim Creek and handle potential storm surge. If these culverts are undersized, they may result in loss of support of the embankment and potential embankment failure. In addition, the base of the culvert needs to be placed at an elevation such that flow is contained within the culvert and does not pass underneath or beside the drainage structure.

Figure 12. Elim Creek Culvert on Moses Point Road



[12] Freeboard refers the vertical clearance between the low chord of the bridge and the water surface. Structures are often designed with a 2-foot minimum clearance above the design flood event to allow passage of ice and debris underneath the structure.
[13] The low chord is the lowest point of a bridge's structure.

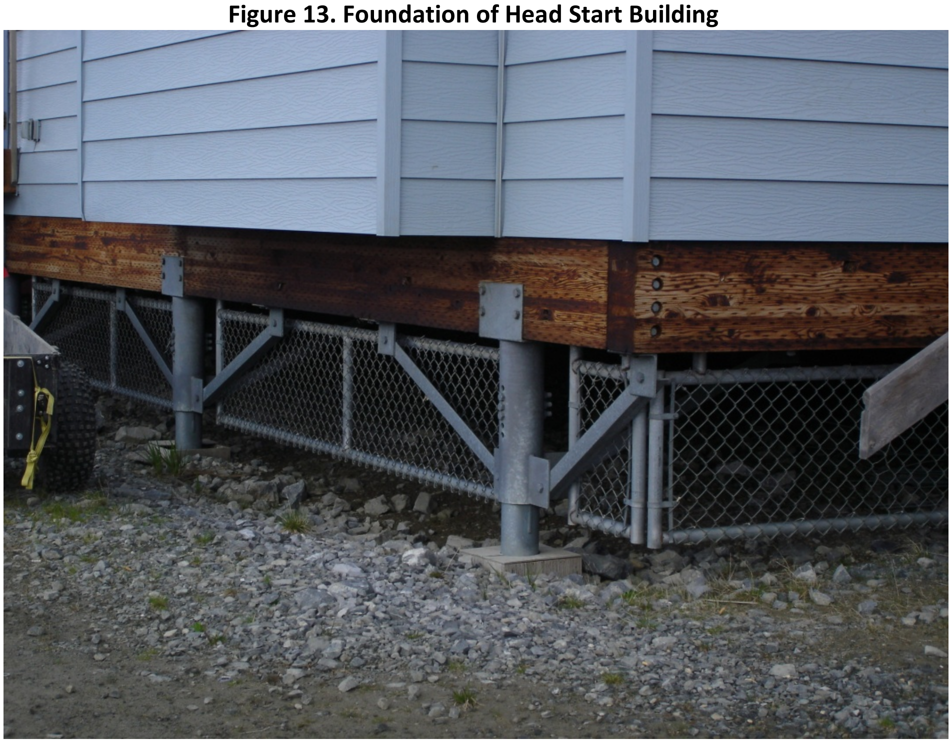
4.8 Community Land Use Plan and Development Standards

Developing a community land use plan to guide future development in Elim is recommended. The plan should identify preferred areas for new housing and other facilities that are not vulnerable to known hazards such as flooding/storm surge. The plan should also identify areas that should be protected from development. These areas should include known hazard areas and areas with subsistence resources.

Several community residents identified "permafrost problems" with some of the existing housing. Based on their description of the problem, it appears to be related to a seasonal freezing and thawing of soils rather than a melting of the underlying permafrost. The community should consider requiring building foundations that are appropriate for local soil conditions. For example, in places where the bedrock is near the surface (within 3 or 4 feet), building footings should be placed on the bedrock or a gravel pad to reduce future frost heaving problems (see Figure 13). The community should also consider requiring new buildings to grade around the structure so the water flows away from the building. Additional research should be conducted to ensure this activity would be allowed under current wetland and water body regulations and if any mitigation or permits would be required.

In addition, community residents indentified problems with rotting wood and mold in several houses, particularly in the bathroom area. Based on existing information, the exact cause of this is unknown, but it could be related to inadequate air exchange, poor vapor barriers, or inadequate insulation. The community should develop building standards to ensure new homes are built in a way that is appropriate for Elim's climate.

Figure 13. Foundation of Head Start Building



4.9 Setback Requirement

The City of Elim should establish a setback requirement preventing new development from being built too close to the shoreline or known flooding areas. All new buildings should be built behind the setback, reducing the need for storm surge and erosion control structures and minimizing damage from future events. Setback requirements tend to help new development more than existing development.

A setback requirement would need to include provisions that prevent a "taking." A "taking" is when the government takes private property for public use without compensation, either by the physical taking of the property or by restricting development in a way that leaves the property undevelopable. Potential ways to avoid a "taking" include having the local government purchase the property and allowing variances in cases where a property owner would be unable to develop their property.

The setback line can be measured from a variety of points, such as the first line of stable natural vegetation (also called the dune vegetation line) or the high tide line. The setback requirement would need to be adjusted if the shoreline continues to erode.

The setback distance should be set based on the erosion rate and consider the building type and expected lifetime of the structure. Larger, immobile buildings or those with longer life spans would require deeper setbacks than smaller buildings that could be moved. Basing the setback on the anticipated building lifetime assumes that by the time erosion approaches the building, the structure would be ready for replacement. The new building would then be built at a new setback.

With further data collection and analysis, storm surge numerical modeling can be performed to help establish a "set-back line" that can show potential risk of existing structures as well as provide guidelines for planning and development of new structures. Data collection/gathering would include nearshore bathymetric surveys, topographic surveys of the community, longer-term wind records at Elim, and elevation of approximate high water lines of past storms.

4.10 Moses Point

According to community residents, Moses Point is a seasonal fishing area that has been negatively impacted by flooding/storm surge in recent years. With sea levels being estimated to rise in the future, coastal areas like Moses Point are likely to be impacted worse during future flooding/storm surge events. Community residents should plan for periodic storm events and associated damage. One way of doing so is by making it possible to move any structures at Moses Point further inland when a storm is approaching or as the sea level rises.

Based on community input, an alternative access road between Moses Point and Elim should also be studied. The community reports that the existing road can be affected by storm surge resulting in residents using informal alternative routes. The community would like a formalized alternative access route that is not affected by storm surge.

The shoreline morphology study conducted as part of this HIA focused on the City of Elim. A shoreline morphology study in the Moses Point area would help identify whether this area is undergoing coastal erosion and at what rate.

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Appendix A

Public Involvement

Trip Report

To: File

From: Laurie Cummings

Subject: Elim Hazard Impact Assessment Community Visit #1

From May 30, 2011 to June 1, 2011, Laurie Cummings with HDR and Eric Anderson with Shannon & Wilson were in Elim to collect field information and to hold a public meeting for the Elim Hazard Impact Assessment project.

As part of our field activities, we collected information to develop a cross-section of the coast line, collected sediment samples, visited the water source area and walked throughout the community. Analysis of the information collected during our field investigation will be done at a later date. Approximately 200 photographs of the area were taken.

The community meeting was held on May 31st. During the meeting, notes were taken on the posters used during the meeting. These notes have been summarized and are attached to this trip report. These notes will be summarized for inclusion in the HIA report.

Meeting Notes

Subject: Hazard Impact Assessment	
Client: City of Elim	
Project: Elim HIA	Project No:
Meeting Date: May 31, 2011	In Attendance: See sign-in sheet
Notes by: Laurie Cummings	

Notes:

Natural Hazards in Elim
Community residents confirmed that the primary hazards in Elim are erosion, storm surge and extreme weather. Wildfires were initially identified as a rare/unlikely event but community residents indicate that wildfires are a possibility in Elim. Snowmelt caused flooding was also identified as a hazard. Earthquakes, volcanic events and tsunami are rare/unlikely hazards in Elim. The community did not identify any other natural hazards such as avalanches as being a concern.

Erosion

- Has occurred near cemetery/worse in area near graveyards
- Causes by storms
    - Most storms come from the south west, in 2004, the storm was from the south east. Most of the storms that cause the most problems are from the south east.
- The cliffs are wearing off
- Erosion is affecting water and sewer
    - Outfall pipe area wearing out
    - Exposed septic tanks need to be recovered
    - A seawall is needed near the sewage tanks
- On beach – used to have lots of sand, now less
    - Water pulling sand off – now have lots of gravel

Storm surge

- Storms have washed away the road between Iron Creek and Moses Point (approximately 13 miles)
- Have occurred in camps (18 miles up)
    - Some camps have drifted away
- High waves lead to salt water on transformers – sparks
- Lost at least 4 houses
- Storm surge is bad in town and camps
- Bridge acts like a dam – makes a lake in town

Flooding

- Flooding affects the water source
- Occurs almost every fall
- Occurs most springs but not the spring of 2011
    - Due to snowmelt
- City building floods in spring when snow melts

Extreme Weather

- Winds have affected power lines – downed, stretched, snapped
- Tilted poles so cables can't reach

Wildfire

- Trees have dried up due to bark beetles
- Trees dying in recent years
    - Community planning on building a firebreak up north
- Use trees for heat

Community Facilities

- A bigger community building in needed
    - It should be on ground level because the stairs are hard on the elders
    - Flooding is a concern
- Some residents are concerned about the area behind the community shop because of the potential for spills from oil drums, cans, tractors, etc. The drinking water comes from this area.
- Store – have separate warehouses
    - Mostly plywood in there
- Head start building is important so is the clinic and church
- AVEC tanks are leaking
- Have relatively new water and fuel tanks
- Teacher housing
- Power plant – near new tanks
- Concerned about homes expanding above water source
- Need bigger water tank because city is expanding

Housing

- Windows needed in older homes
- Some houses have mold
- Doors need to be fixed
- Putting air holes in building help
- Some areas have permafrost
- Houses move because the ground underneath shifts
- First homes were build on ground – newer homes have railing underneath
- In older homes, there are bathrooms rotting, mold, failing wax rings
- Most housing is occupied so no new houses for kids to stay in village
- No money to maintain housing
- Volunteers to a lot of the repair work
- Some houses need new furnaces
- Fuel and gas prices are going up
- Need better build homes – ones that fit in with the climate instead of prefab kits

Roads

- Getting soft
- No gravel base in most areas
- Some worse than others
- Need culverts – used what is available but that is often too short or has holes

Hazard Impact Assessment – Elim

Public Meeting #1 – Sign in Sheet

Name	Address/City/Zip	Phone	Email
Judith Daniels	PO Box 83, Elim Ak 99739	890-3737	IGAPCoordinator@gmail.com
Emily murray	PO Box 39407 Elim, Ak 99739	890-2351	murray.emily57@yahoo.com
Crystal Nanoff	P.O. Box 39009 Elim AK 99739	890-3441	cityofelim@yahoo.com
Ruth mow	Box 39075 Elim	890 1374	Moses ruthanne@yahoo.c
Russell Saccheus Sr.	Box 117 Elim AK 99739	890-6548	
Fredric Saccheus	Box 004 Elim AK 99739	890-3737	f-n-Beeb@hotmail.com
Stanton Nakarak	Box 114 Elim, AK 99739	880-1313	mxz600-Stan@hotmail.com
HARRY DANIELS	POB 87 ELIM		
Betty			
R			

Meeting Notes

Subject: Hazard Impact Assessment	
Client: City of Elim	
Project: Elim HIA	Project No:
Meeting Date: December 14, 2011	In Attendance: See sign-in sheet
Notes by: Laurie Cummings	

Notes:

The purpose of this meeting was to present the results of the draft Elim Hazard Impact Assessment (HIA).

The meeting began by presenting an overview of the natural hazards identified in Elim. The HIA identified the following natural hazards as likely to occur in Elim:

- Flood/Storm Surge
- Wildland fire
- Earthquake
- Ground Failure
- Erosion

While tsunamis, snow avalanches, and volcanoes could potentially occur in Elim, they were not considered likely and were not discussed in the CIA. The meeting attendees agreed with these findings.

Next, a map showing community identified critical facilities was presented. The community indicated that the Boys & Girls club, library and corporation building should be added to the list of critical facilities. They also indicated that the Eagle Cache Store is now called Johnny's Corner. The map and list of critical facilities in the HIA will need to be updated to reflect these changes.

Thirdly, the ten recommendations of the HIA were presented. Those recommendations are:

- Wildfire Fuel Removal
- Periodic Monitoring of the Cliff Face
- Monitoring and Documenting the Rate of Beach Erosion
- Relocate the Water Source Area or Increase Storage Capacity
- Protection of Wastewater Disposal System
- Bridge Replacement
- Culvert Evaluation
- Community Land Use Plan and Development Standards
- Setback Requirement
- Moses Point

Overall, the community agreed with all of the recommendations. The community would like a see a more formalized alternative access route between the community and Moses Point.

When there is storm surge in the area, the road can be dangerous. Currently, the community uses a short cut through a slough.

Other comments made by the community residents include:

- The roads are scheduled to be resurfaced in 2014
- The tanks near the school are a danger to children and should be addressed
- CRW recommends an intermediate pump station to increase water pressure on the east side of the village
- The weight of the snow can cause powerlines to droop low to the ground

Hazard Impact Assessment – Elim

Public Meeting #2 – Sign in Sheet

Name	Address/City/Zip	Phone	Email
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Emily Murray	Box 07	880-1065	
Stanton Nakarak	Box 114		
ED KOTONGAN	Box 58	890-4277	cityofelim@YAHOO.com
Ralph Saccheus	BOX 57	89-2519	
Carol J. Nagaruk	P.O.Box 31 Elim Ak 99739	890-2283	carolnagaruk@yahoo.com
Paul Nylin	P.O.Box 39032 Elim Ak 99739	880-7084	
CARLA R. IVANOFF	Box 118 Elim, AK 99739	(907)890-3551	carla-rose-ivanoff@hotmail.com
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Michael C. Murray	P.O. Box 39047 Elim, AK 99739	880-1049	firechiefmurray@yahoo.com
[illegible]	P.O.BOX 39072 Elim, AK	880-1001	
Joni Segock	Box 96 Elim, 99739	880 1072	
Raelene Keith	Box 44 Elim 99739	890-2012	
Tyler Ivanoff	Box 84 Elim Ak 99739	880-1360	tylerivanoff@gmail.com
Laverne Oshenfelter	Box 56 〃〃〃	880-1090	
Betty Segock	~~Box~~ 39045	890-2267	none

Hazard Impact Assessment – Elim

Public Meeting #2 – Sign in Sheet

Name	Address/City/Zip	Phone	Email
Desiree Davison	P.O. Box 106 Elim, AK 99739	907 880 1054	
Laurie Keith	Po Box 44	(907) 890-2269	
Amy Takak	P.O. Box 39014 Elim AK 99739	(907) 880-1013	
Loretta Nakarak	P.O. Box 64 Elim AK 99739	(907) 880-1097	
Paul Nagaruk	P.O. Box 71 Elim AK 99739	(907) 890-2283	
Fred Daniels	Box 104 Elim AK 99739	(907) 880-1071	

Appendix B

Coastal Support Memo

Memo

To: Laurie Cummings	
From: Ronny McPherson	Project: City of Elim HIA
cc: Dan Heilman, Lauren Augustin	
Date: 7/29/2011	Job No: 162096

RE: City of Elim Hazard Impact Assessment – Coastal Support

1. OBJECTIVE

The objective of this technical memorandum is to provide a desktop-level assessment of the potential coastal related hazards that affect the City of Elim. In addition, preliminary recommendations are provided for ways in to reduce the risk associated with potential coastal hazards. These tasks were performed in support of the hazard impact assessment being led by HDR's Anchorage office. Laurie Cummings served as HDR's overall project manager.

Climate change has been proposed to be a primary contributor to increased erosion in Alaska. Decreasing duration of ice coverage and ground freezing may cause the shoreline to be more susceptible to erosive waves during severe fall and winter storms. Alterations in freeze-thaw cycles can cause potential increases in weathering of rock faces. Erosion poses a significant hazard to many Alaskan coastal communities like the City of Elim where critical structures and homes are located relatively close to the shoreline.

As shown in Figure 1.1, the City of Elim is located on the northern shoreline of Norton Bay, the far north eastern portion of Norton Sound, approximately 94 miles east of Nome. An aerial of the City of Elim is shown in Figure 1.2.

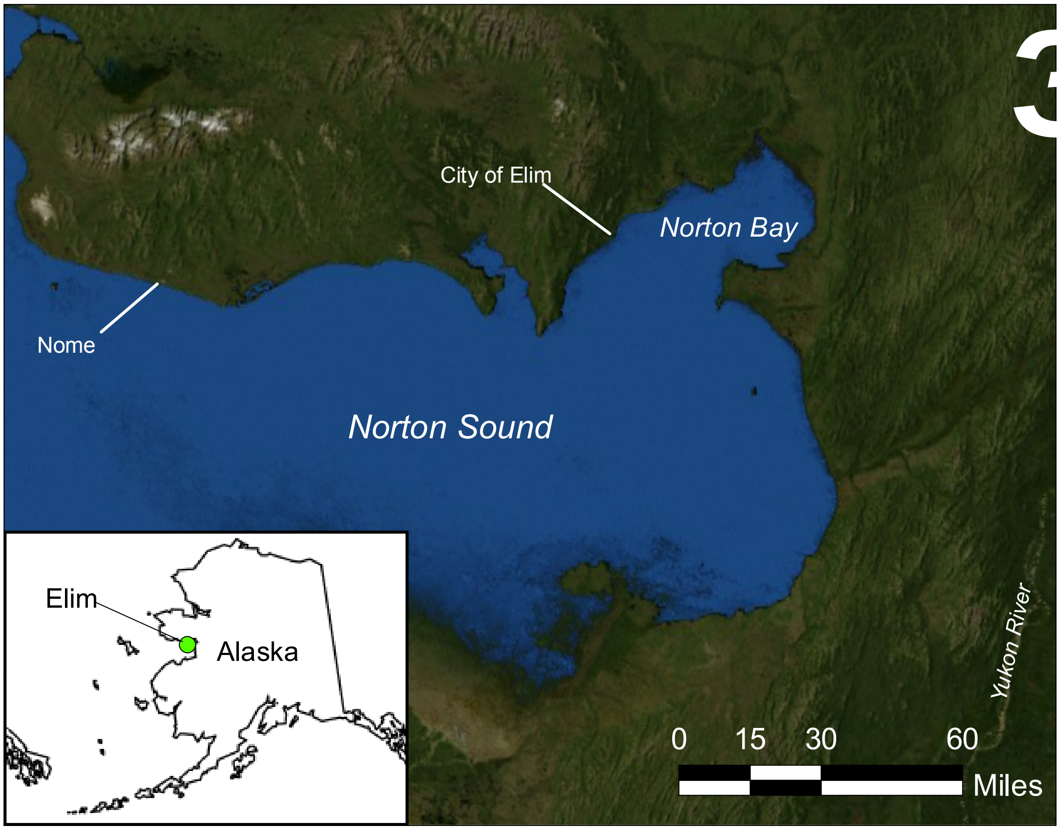


Figure 1.1 General location map.

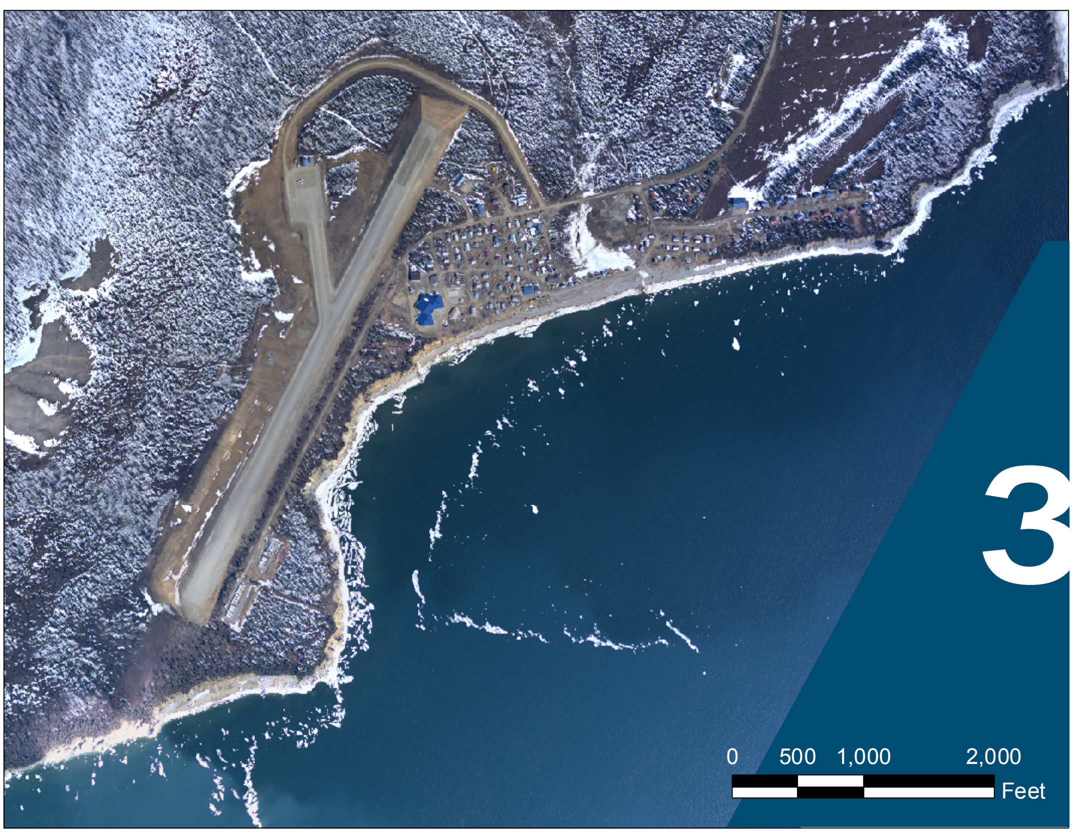


Figure 1.2 Aerial of the City of Elim.

2. METOCEAN AND GEOTECHNICAL CONDITIONS

Readily available meteorologic and oceanographic (metocean) data as well as geotechnical conditions were assessed to develop a cursory-level characterization of environmental conditions at the site. Figure 2.1 shows locations of several existing data collection stations established by the U.S. Army Corps of Engineers (USACE) and the National Oceanic and Atmospheric Administration (NOAA).

Figure 2.1 Location of gauges for data collection.

2.1. Wind

Characterizing wind is an important part of understanding the hazard posed by erosion and storm conditions. Extreme wind statistics for coastal areas within the United States are available from ASCE (2002). For the region surrounding Elim, wind speed is plotted as a function of return period in Figure 2.2. Both 20-minute average and 3-second gust wind speeds are shown for comparison. The 20-minute average duration wind speeds of 74 mph and 94 mph, which represent approximate 10-year and 100-year return periods, respectively, were applied for the wave analysis presented in Section 2.3.

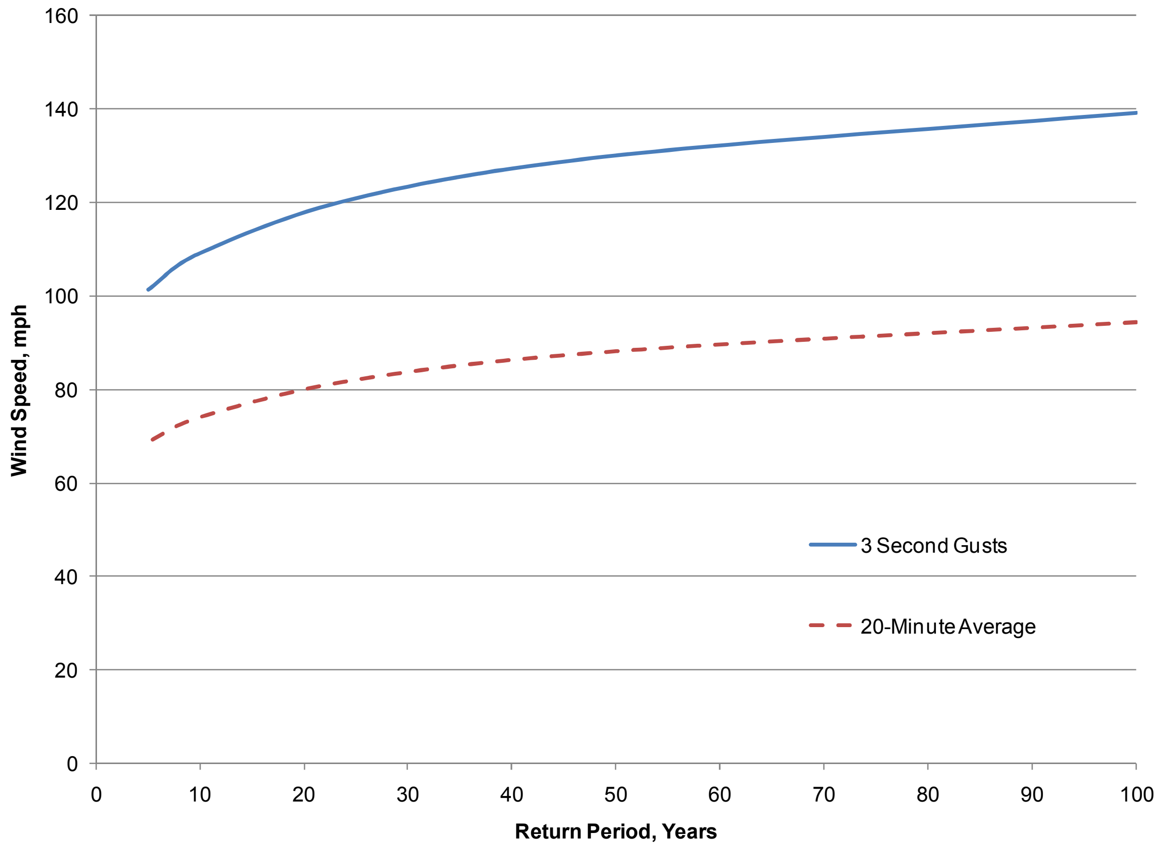


Figure 2.2 Extreme wind speed based on return period (ASCE 2002).

The nearest location having readily-available wind data is Nome, Norton Sound (NOAA 2011), which is approximately 94 miles west of Elim (Figure 2.1). Wind data from 2001 to 2011 were obtained for this location and are shown as a wind rose in Figure 2.3. Wind roses provide a graphical means of describing the intensity and direction of wind. The plot suggests that winds from southern directions are less frequent.

Because the Nome, Norton Sound gauge is nearly 100 miles away from Elim, it may not provide an accurate portrayal of the typical wind climate. To supplement the Nome, Norton Sound data, winds were obtained from the USACE Wave Information Studies (WIS) Hindcast Data (Tracy 2004). Note that hindcast data are calculated, not measured, as a substitute for actual measurements from data collection stations. Hindcast data are modeled based on historical regional meteorological records.

Figure 2.4 shows a wind rose from USACE WIS Station 82108 for 1985 to 2009; this station is approximately 25 miles southeast of Elim (Figure 2.1). The WIS wind rose, in general, shows greater occurrence of winds from the southern directions than reported for the Nome, Norton Sound gauge. However, it can be seen that the predominant winds are from the north to east directions, similar to the Nome, Norton Sound data. Differences in the wind roses may be attributed to the increased amount of land surrounding the WIS station or inaccuracies in the hindcast model.

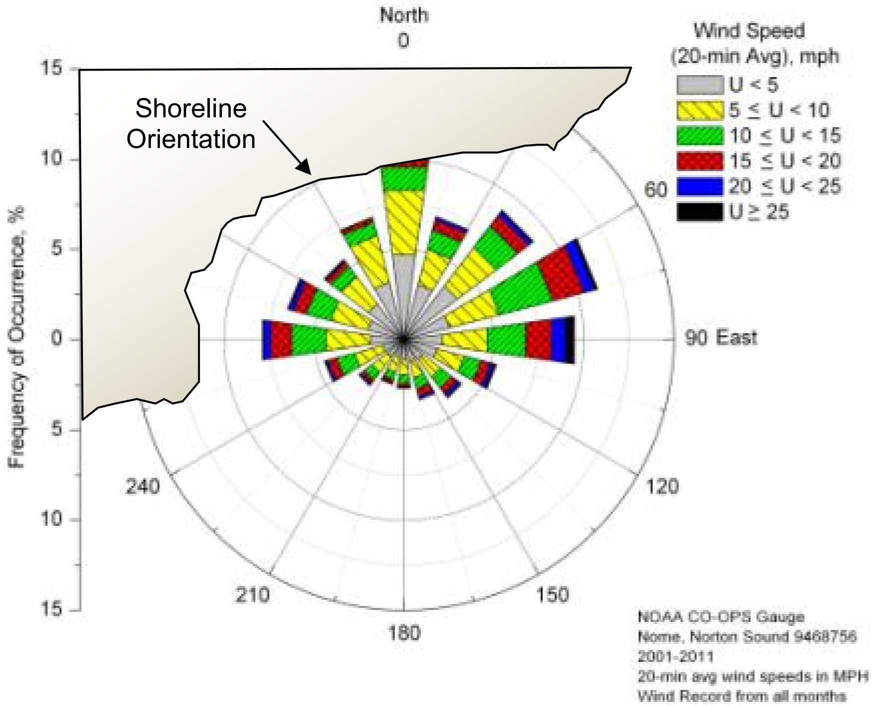


Figure 2.3 Wind rose showing direction, frequency, and magnitude of wind from Nome, Norton Sound NOAA Gauge (2001-2011)

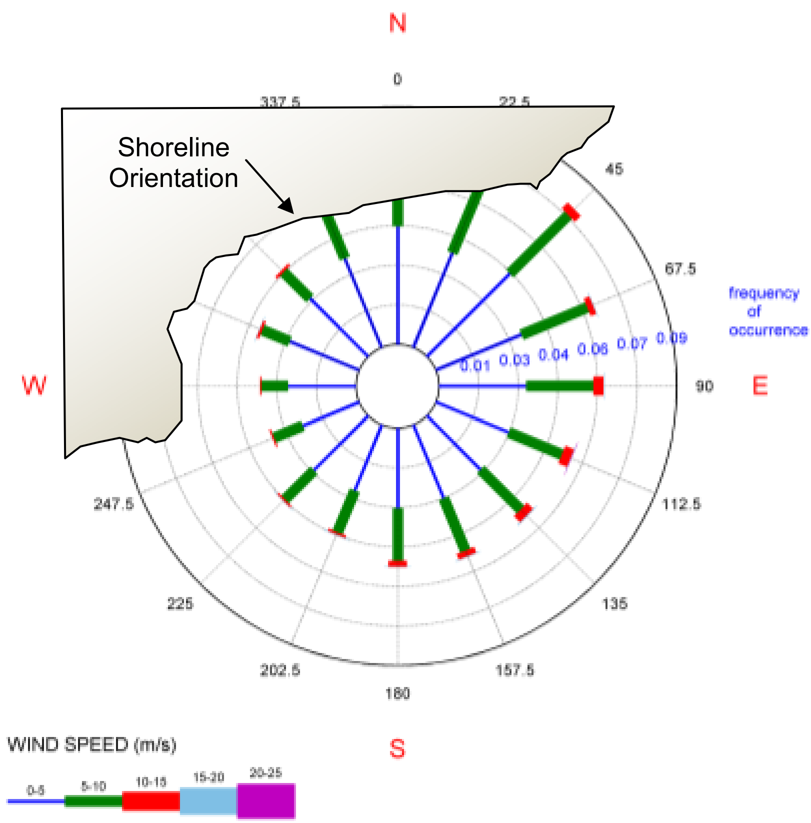


Figure 2.4 Wind rose for WIS Station 82108 (Tracy 2004).

From Figure 2.3 (and to some extent Figure 2.4), it can be seen that a significant percent of the time the wind comes from northern (upper) portion of the wind rose. The shoreline orientation at Elim is overlaid on Figures 2.3 to 2.5. Since Norton Bay is located to the southeast of the city, a majority of the wind produced has not historically contributed to waves affecting the shoreline. It can also be seen that onshore winds (winds blowing from sea) are in general stronger than offshore winds.

Shore-fast ice forms during the colder portions of the year in Norton Bay. During this time, the shoreline is protected from wave-induced erosion. Thus, winds that occur while there is shore-fast ice are not a concern for generalizing wave impacts at Elim. The same wind data collected at the Nome, Norton Sound NOAA gauge was filtered to remove months that historically have an average temperature lower than 32° F. Long-term temperature records at Nome, AK were gathered from the Alaska Climate Research Center. Based average monthly temperatures from 1971-2000, winds occurring between October and April were removed from the original dataset. Figure 2.5 shows a wind rose using wind data from the Nome, Norton Sound NOAA gauge during typically non-freezing months (May – September). For this filtered condition, note the predominance of winds from the west and north, neither of which are directions that would cause waves along the Elim shoreline.

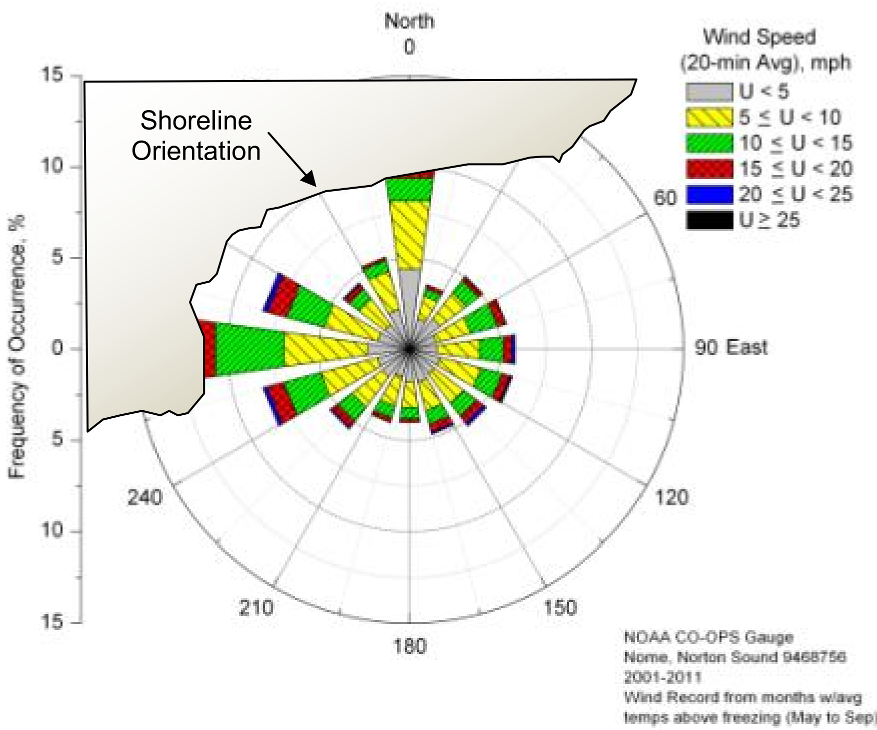


Figure 2.5. Wind rose showing direction, frequency, and magnitude of wind from Nome, Norton Sound NOAA Gauge during non-freezing months (2001-2011)

2.2. Water Level

Water level data were obtained from the NOAA station at Nome, Norton Sound from 2001 to 2011. The greater diurnal tide range[1] is approximately 1.5 ft. Figure 2.6 plots water level at Nome, Norton Sound as a percent of time exceeded. Note that tides remained below +5 ft MLLW approximately 99.5% of the time. Within this record, the water level exceeded +6 ft MLLW 101 times, with the extreme being +10.2 MLLW measured on September 23, 2005.

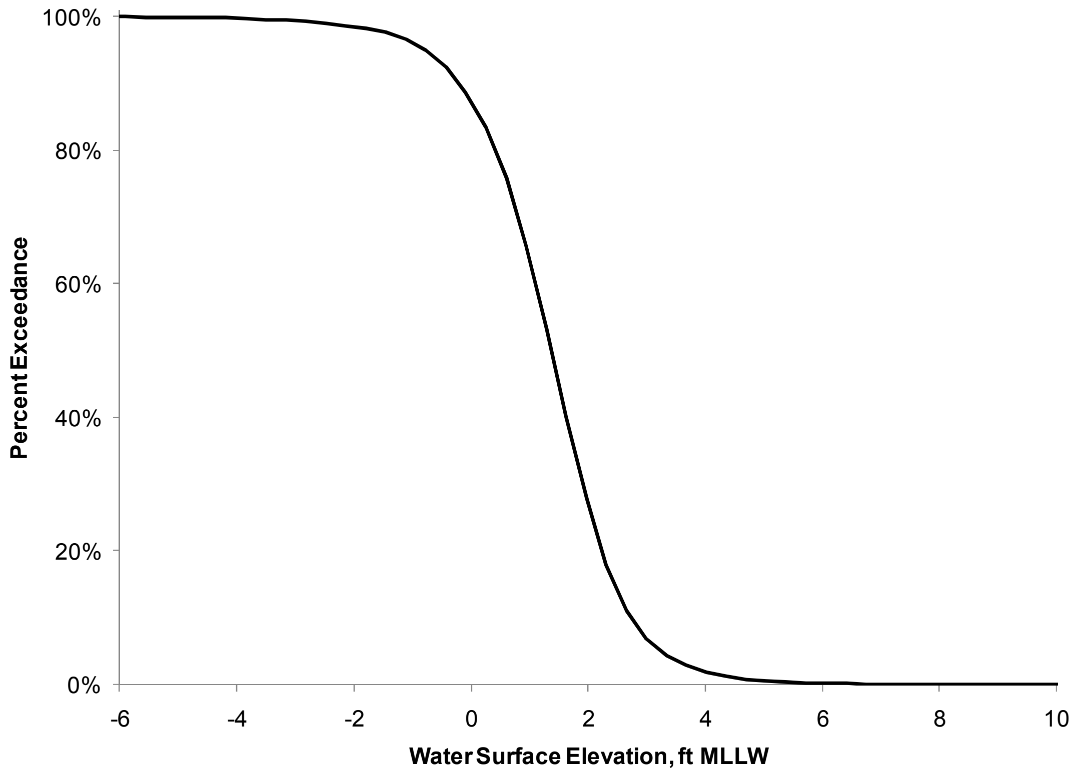


Figure 2.6 Water Level exceedance at Nome, Norton Sound

Figure 2.7 shows a time series of the water level recorded at Nome, Norton Sound from January 2004 to December 2004, a notorious storm surge year. The solid black line indicates the computed averaged trend of the data. Extreme low pressure storms traveling up the Bering Sea have been known to cause major storm surges in Nome. Based on anecdotal data (Section 3.2), it is believed similar storm surge conditions occur at Elim.

[1] Greater diurnal tide range is defined as the difference in the Mean Highest High Water (MHHW) and Mean Lowest Low Water (MLLW) tidal datums.

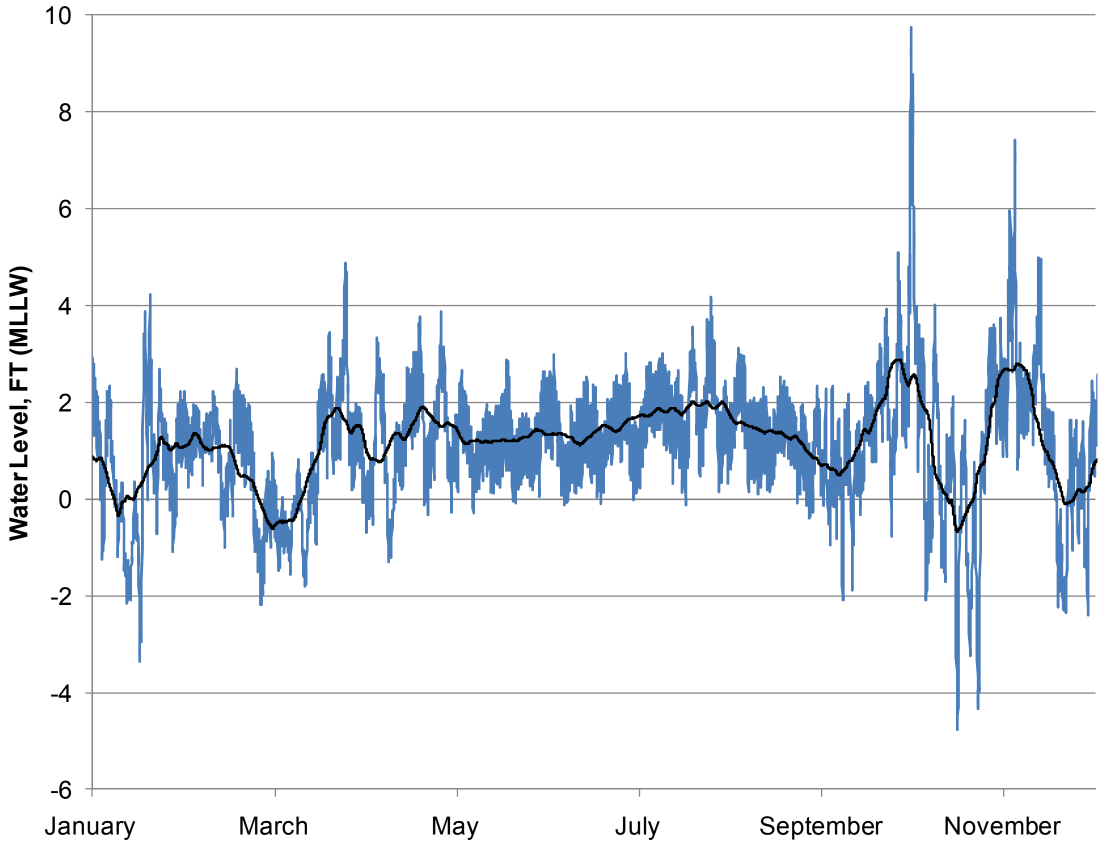


Figure 2.7 Water level recorded during 2004 at Nome, Norton Sound.

2.3. Waves

To calculate waves based on wind, there are several components to consider. The size of wind waves is a function of wind speed and duration, wind direction, water depth, and the distance across water that the wind blows (fetch). To conceptually quantify wave conditions at Elim, the available wind data (during non-freezing months) were coupled with representative basin geometry of Norton Bay, as measured from existing nautical charts and aerial photography. An analytical method for wind wave growth and prediction was then applied, resulting in a 10-year time series of representative wave conditions at Elim. This method accounted for wind speed, direction, and duration, as well as the geometry and bathymetry (underwater topography) of Norton Bay and followed wind-wave prediction techniques developed by the U.S. Army Corps of Engineers (USACE 2002). Figure 2.8 shows the predicted spectral significant wave height, H_{mo}, as a wave rose, where the direction of the wave origin is shown in the same meteorological convention as Figures 2.3.

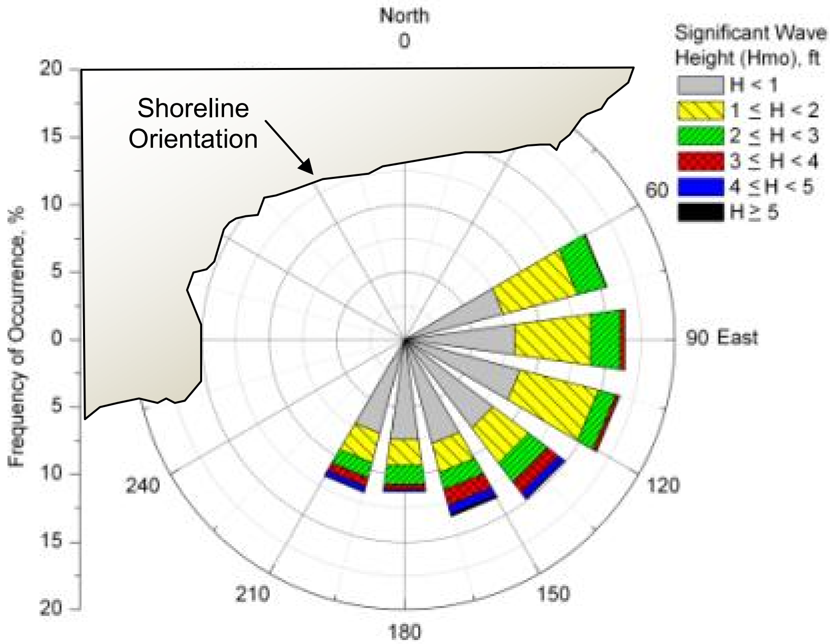


Figure 2.8. Wave rose showing direction, frequency, and magnitude of based on wind from Nome, Norton Sound Gauge during non-freezing months (2001-2011)

Waves are only shown in directions from the northeast to southwest (moving clockwise) because all other directions have zero fetch (no water). The larger fetch lengths (60 to 100 miles) from southern directions allow development of waves of 4 to 5 ft even with slower winds (less than 30 mph). Depending on the geotechnical conditions, water levels (surge), and nearshore bathymetry, waves of this size can cause erosion and other damage.

As mentioned earlier, wind at Nome may differ significantly from that at Elim, thus giving less accurate wave estimations. For comparison, wave rose data were obtained from WIS Station 82108 (Figure 2.9). Despite differences in frequency of wind between the Nome and WIS stations, the wave roses are relatively similar if the offshore directed winds are the WIS station are not considered.

Figure 2.10 shows extreme wave heights at WIS Station 82108 plotted against return period[2] based on data from 1954-2009. Based on the best fit line, the 10-year return period and 100-year return period significant wave heights are approximately 9.5 ft and 13 ft, respectively. The ten storms having the largest waves are listed in Table 2.1. Note that these wave heights are for open-ocean condition at the location of the WIS station. Nearshore wave heights are generally smaller because of the shallower water and influence of the ocean bottom on wave development.

[2] Return period indicates the probability of an event occurring in a given year. For example a 100 year return period indicates there is a 1% (or 1/100) chance of that event occurring in a single year. A 100 return period does **NOT** mean an event occurs only once every 100 years.

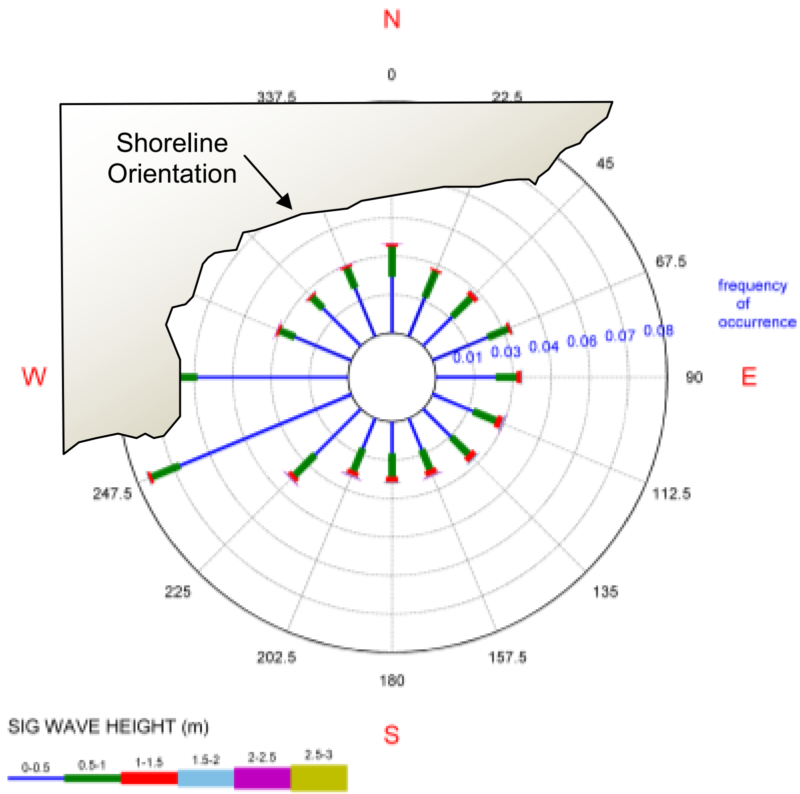


Figure 2.9 Wave rose for WIS Station 82108 (Tracy 2004).

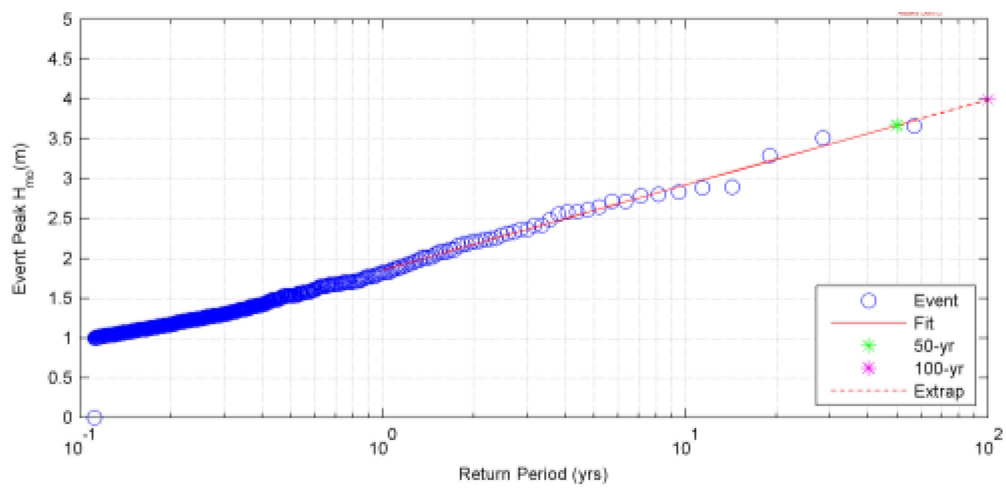


Figure 2.10 Extreme wave heights plotted against return period for WIS Station 82108 (Tracy 2004).

Table 2.1 Ten largest-wave events at WIS Station 82108 based on Peak H_{mo} (Tracy 2004).			
Event	**Date**	**Spectral Significant Wave Height, Hmo (ft)**	**Peak Wave Period, Tp (sec)**
1	10/4/1960	12.1	11.2
2	11/4/1978	11.5	7.6
3	11/15/1965	10.8	7.6
4	11/28/1970	9.5	9.2
5	10/15/1985	9.5	6.3
6	11/16/1989	9.2	6.3
7	11/16/1966	9.2	6.9
8	11/12/1965	9.2	6.3
9	11/9/2003	8.9	7.6
10	8/26/1975	8.9	8.4

2.4. Sediment Characteristics

During a site visit conducted from May 30 to June 1, 2011, Shannon & Wilson, Inc. performed a cursory sediment analysis by collecting grab samples from two locations along the shoreline at Elim to characterize the type of sediments that exist at the site. The shoreline at Elim consists of extremely weathered rock cliffs/bluffs fronted by a sandy/cobble beach. Characterization of the sediments along the shorelines is important for assessing feasibility of potential shoreline protection methods as well as better understanding of the erosion processes. Table 2.2 shows the results of a preliminary grain size classification performed by Shannon & Wilson, Inc.

Table 2.2 Grain Size Classification (Shannon & Wilson, Inc. 2011)			
Sample	**D_{50}, mm**	**Classification**	**Characteristic Location**
S1	9	Fine Gravel	Beach
S2	21	Course/Fine Gravel	Onshore adjacent to beach

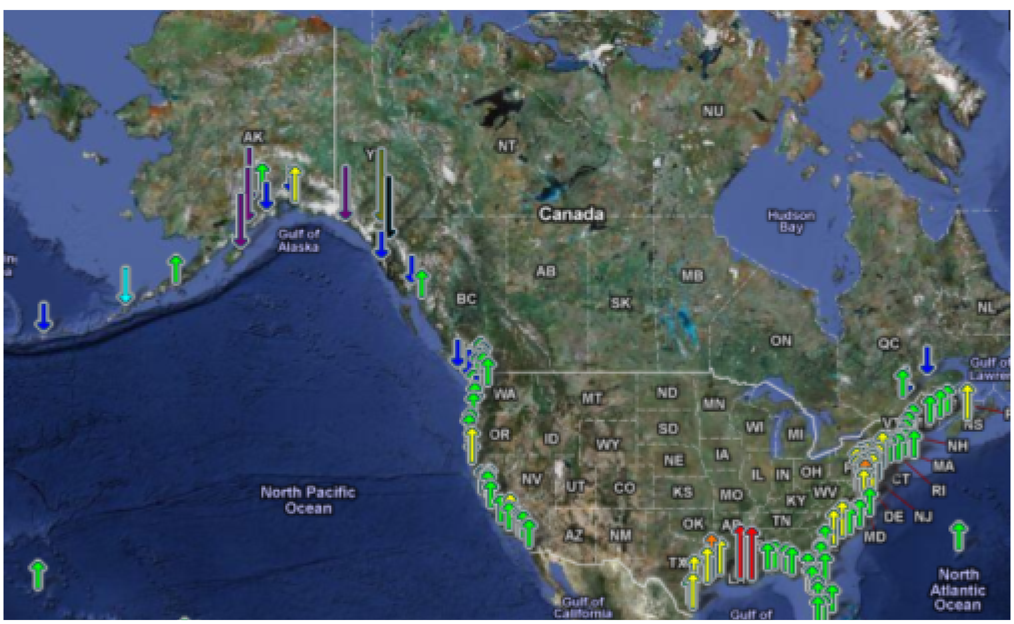
3. POTENTIAL COASTAL HAZARDS

During HDR's site visit to Elim, the community identified both erosion and storms as primary coastal hazards. These mechanisms were assessed in more detail to better understand their role as potential hazards and develop recommendations for counter measures.

3.1. Erosion/Shoreline Retreat

Three potential causes of shoreline retreat were investigated for Elim: (1) climate warming, (2) wind-generated waves, and (3) relative sea-level rise. A growing concern for areas like Elim, AK is the detrimental effects caused by changes in climate. The duration in which ice protects the shoreline from waves is steadily decreasing, allowing a longer seasonal period for waves to erode the shoreline. In addition, durations and/or areas of the soil that are frozen are diminishing. When these areas are no longer frozen they become more susceptible to erosion.

Relative sea level rise (RSLR) is the combination of eustatic (global) sea level rise and local land subsidence (or in some cases rise in land elevation). The National Oceanographic and Atmospheric Administration (NOAA) calculates RSLR from tide gauges having long-term records. Unfortunately, there are no gauges located along the western or arctic regions of Alaska. This limits quantification of the extent that sea-level rise contributes to shoreline retreat. The eustatic sea level rise ranges from 0.3 ft to more than 0.8 ft/century (NOAA 2001). This level of change would not contribute to any perceived shoreline retreat. Variations in RSLR along the peninsula and southern portion of Alaska are significant (+1.8 to -5.6 ft/century) and some of the highest in the United States (Figure 3.1). If significant subsidence occurs in the area of Elim, this could contribute to shoreline retreat.



Sea Level Trends
mm/yr (feet/century)

9 to 12 (3 to 4)	3 to 6 (1 to 2)	-3 to 0 (-1 to 0)	-9 to -6 (-3 to -2)	-15 to -12 (-5 to -4)
6 to 9 (2 to 3)	0 to 3 (0 to 1)	-6 to -3 (-2 to -1)	-12 to -9 (-4 to -3)	-18 to -15 (-6 to -5)

Figure 3.1 RSLR reported by NOAA Tides and Currents (NOAA 2011)

Observations of shoreline retreat are generally performed by reviewing shoreline location either by survey or visually through comparison of aerial photographs. Using photographs to determine shoreline retreat can have inaccuracy due to resolution of images, geo-referencing errors, surge/tide differences, and methodology of establishing the "shoreline." Aerial photographs, despite these challenges, can provide a good indication of shoreline morphology trends. Using surveys to determine shoreline retreat is often limited by lack of historical surveys unless a monitoring program has been established. Thus, aerial photography is the more common tool for determining shoreline retreat.

A preliminary assessment of shoreline morphology was performed by Shannon and Wilson, Inc. in 2004. A graphical excerpt of this assessment is shown in Figure 3.2. Shoreline positions are provided for 1969, 1980, 1992, and 2004. No obvious trend of shoreline retreat/sediment transport was discerned. In every time period (except 1980 to 1992), both erosion and accretion was reported depending on the location. Table 3.1 summarizes maximum shoreline retreats. These rates vary by location.

Table 3.1 Elim shoreline erosion rates (Shannon and Wilson 2004)

Time Period	Maximum Shoreline Retreat	Maximum Retreat Rate
1969-1980	5 ft	<1 ft/yr
1980-1992	55 ft	14 ft/yr
1992-2004	7 ft	3 ft/yr
(Average) 1969 – 2004	33 ft	1 ft/yr

Beach widths are often cyclic in nature. Storm seasons will produce large waves causing erosion and decreasing the beach width. To offset this, during calmer periods (summer time typically), gentle waves bring sand onshore and increase the beach width. In contrast to the cyclic nature of seasonal changes, random severe storms can cause significant erosion that may not be recovered through natural processes.

Major storms occurred in the fall of 2004 and 2005 at Elim. The shoreline position assessment was performed in June 2004. Therefore, the retreat rates in Table 3.1 do not include the impacts caused by these storms. However, based on the average shoreline retreat rate of 1 ft/yr and aerial photographs taken after 2005, shoreline retreat at Elim is relatively moderate.

Regardless of the average rate of shoreline retreat, the rock in the cliffs along the beach appears to be extremely weathered and therefore breaks off easily. These rock pieces fall in to the surf zone and, over time, are ground down to help replenish the beach. If cliff pieces break off near dwellings, eventually structures will be at risk of undermining.

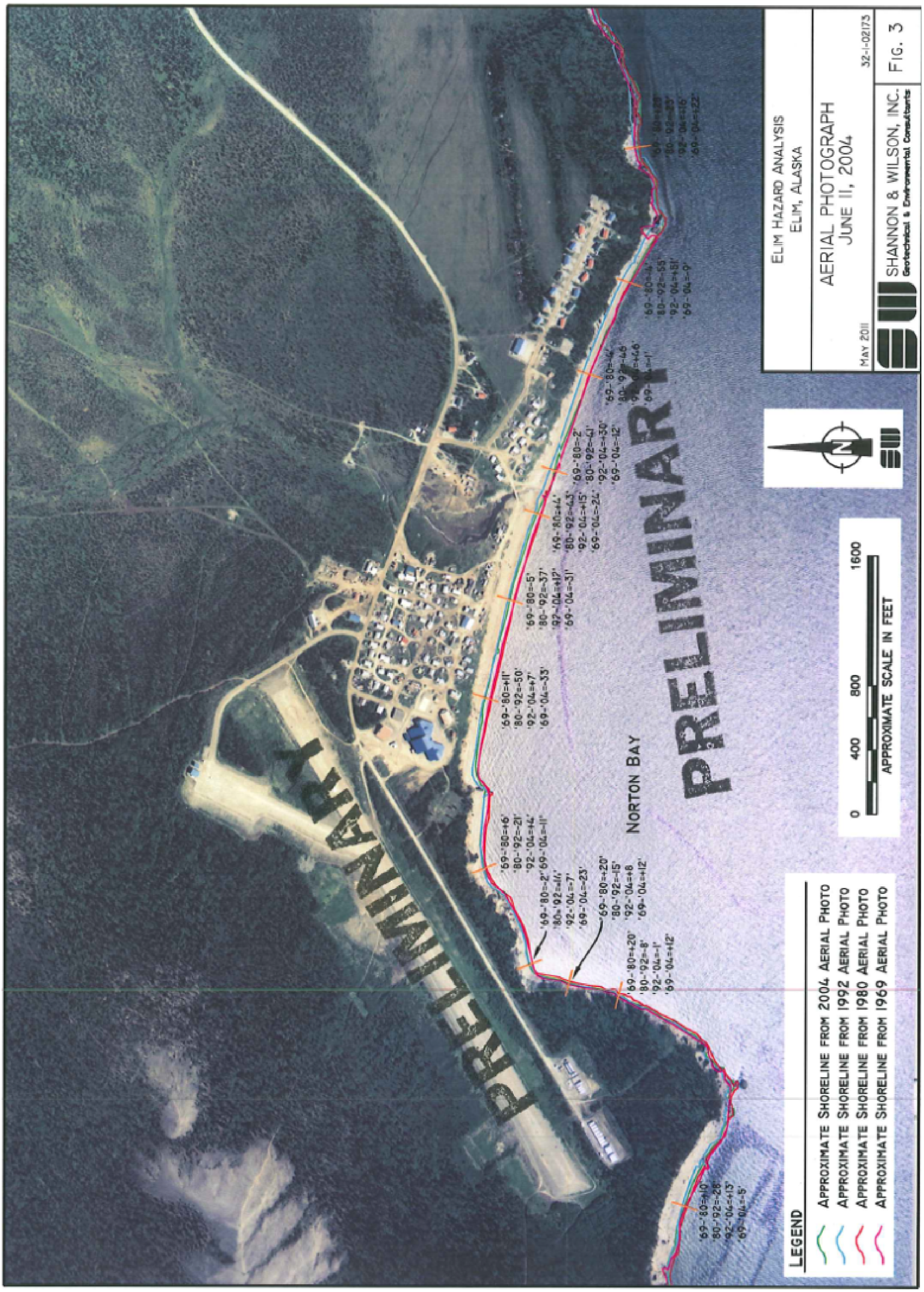


Figure 3.2. Preliminary shoreline morphology assessment (Shannon and Wilson, inc. 2004)

3.2. Storm Waves and Surge

Coastal rock cliffs, such as those along the Norton Sound shoreline, generally protect uplands from major storm waves and surge. Elim, however, is situated along a pocket beach[3] where the tall cliffs on both sides reduce in elevation, creating a natural area for residences to more easily access the water (Figure 3.3). Because of this, storm surge and waves are able to run up and cause damage to structures and dwellings of the community. Such occurrences have been reported anecdotally by the community and even reported in the national news. After a major storm in October 2004, USA Today reported:

> *"The storm slammed Elim, about 90 miles east of Nome, causing erosion that exposed septic tanks and the city's main water line. It also took out the road to a popular subsistence fishing area, said city clerk Luther Nagaruk. Storms like Tuesday's hit the Norton Sound region every 15 or 20 years, he said. This one was worse than the biggest storm last year, but milder than one in 1974, he said."*(USA Today 2004)

A storm producing similar surge in Nome occurred almost exactly 1 year later in the fall of 2005. The USACE (2008) reported the 2005 storm damaged Elim's main access bridge, septic lines, and damaged six subsistence-use cabins. It is clear that the ability for storm waves and surge to damage dwellings and key infrastructure, as well as erode/damage roadways, is a major coastal hazard at Elim.

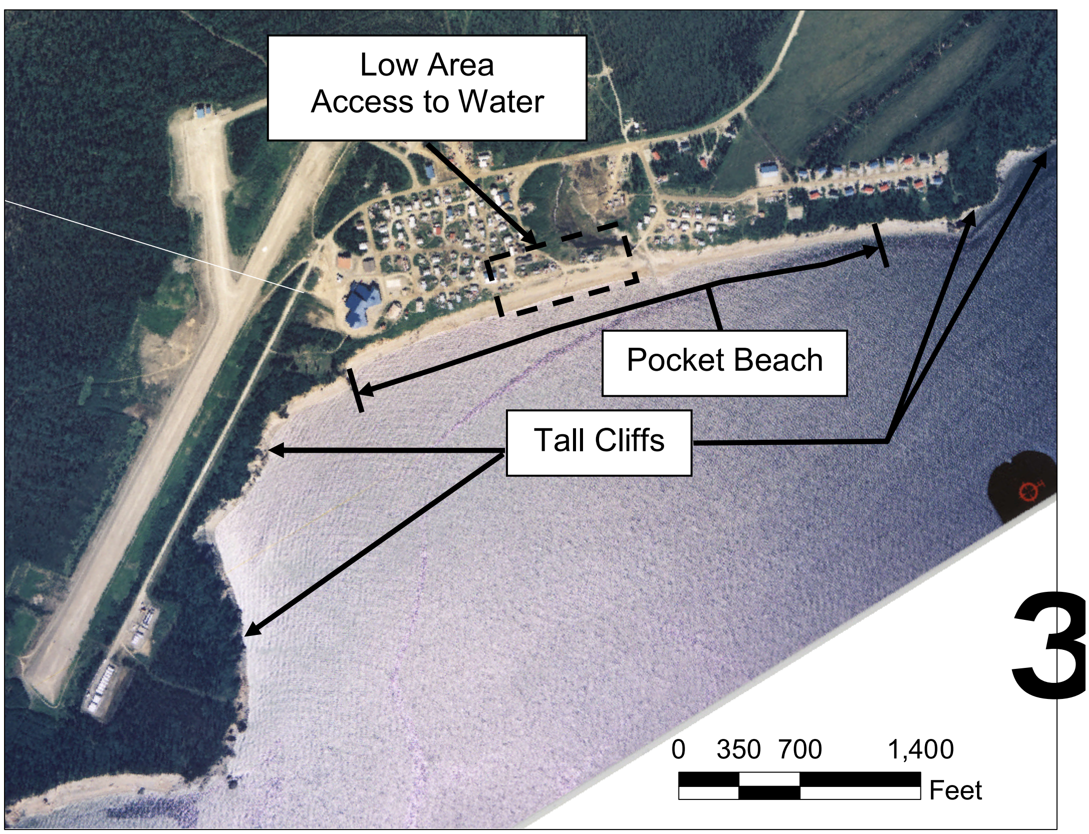


Figure 3.3 Natural shoreline layout at Elim.

[3] A "Pocket beach" is an isolated sandy or gravel beach, typically in a cove-like shape that occurs between rocky outcroppings.

4. SUMMARY AND RECOMMENDATIONS

This technical memorandum was developed to support a Hazard Impact Assessment for the City of Elim. It is clear that coastal hazards are a real risk to the community. The information compiled herein is the first step in quantifying coastal hazards at Elim so that engineering and planning solutions can be developed.

4.1. Summary

Available meteorologic and oceanographic data and existing site conditions were reviewed. A large amount of data that would be needed for a detailed alternatives analyses and design do not appear to exist. Based on the information available, shoreline retreat and erosion was assessed. It was found that the long-term average rate of shoreline retreat is relatively moderate at approximately 1 ft/yr. However, based on information from the local community, official reports, and historical metocean conditions it is clear that storm waves and surge periodically cause major damage to dwellings and key infrastructure, as well as erode/damage roadways.

4.2. Conclusions and Recommendations

The following is a list of recommendations for further actions based on available data and current understanding of coastal hazards at Elim:

- Shoreline Retreat: Averaged over the long-term, shoreline retreat is relatively moderate and may not require implementation of shoreline protection structures such as breakwaters, revetments, seawalls, etc. If shoreline retreat is considered a major concern for the community, a shoreline monitoring program should be established to better document/quantify episodic erosion from storms. The program should record the beach position by surveying annually and after storms to better determine risk and need for shoreline protection measures.
- Extreme Weathering of Rock Face: Rock in cliffs along the shoreline were found to be extremely weathered. Severe storms and/or ice impacts could further damage the cliffs, causing large pieces to detach and fall seaward. Based on available aerial photography, the long-term average rate of cliff erosion does not appear to be significant. If episodic sloughing off rock is a major concern for the community, the shoreline monitoring described above should include the cliffs. If dwellings and structures are in immediate risk, relocation/retreat and/or stabilization of the rock face(s) should be considered. Stabilization of the rock faces(s) should consider potential disruption of the natural littoral system.
- Storm Waves and Surge: Based on the available data, storms are considered to be the most damaging and imminent coastal hazard to the community. Several actions can be taken to address this hazard.

    - Establish Set-Back Line: With further data collection and analysis, storm surge numerical modeling can be performed to help establish a "set-back line" which can show potential risk of existing structures as well as provide guidelines for planning and development of new structures. Data collection/gathering would include nearshore bathymetric surveys, topographic surveys of the community, longer-term wind records at Elim, and elevation of approximate high water lines of past storms.
    - Temporary and Demountable Wave/Surge Barrier: Temporary and demountable wave/surge barriers are portable structures that can quickly be moved by a group of personnel or readily available equipment and placed prior to a storm for protection of landward structures. After the storm, the structures are removed and stored until

needed again. These structures are generally significantly cheaper than permanent structures; however, they may not be as effective if not properly installed. An example of a temporary and demountable wave/surge barrier is a series of hollow traffic barriers filled with sand/water. For more information on this type of structure refer to DEFRA (2002).

It is recommended that a similar storm surge numerical model as discussed above be performed to help determine an appropriate device and deployment plan. Strategic placing of the devices would be important, especially for some of the devices that are neutrally buoyant.

- Permanent Upland Wave/Surge Barrier: A permanent wave/surge barrier could consist of a variety of concepts such as a seawall, bulkhead, quarry-stone riprap, etc. This type of structure would likely be expensive (multi-million dollar). Most dwellings and key infrastructure (excluding roads) at risk could probably be relocated for significantly less cost. Prior to construction, a significant amount of data collection/gathering, alternatives analysis, design work, and permitting would need to be performed.

5. REFERENCES

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