Division of Geological & Geophysical Surveys

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ANNOTATED BIBLIOGRAPHY SERIES IN SUPPORT OF COASTAL COMMUNITY HAZARD PLANNING—NORTHWEST ALASKA

SHAKTOOLIK, ALASKA

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This annotated bibliography is part of a series created to facilitate access to documents useful for coastal geohazard evaluation and community planning in Northwest Alaska. Below is a comprehensive list of community-specific information sources, each with full bibliographic information and an informative-style annotation that highlights content pertaining to the community of Shaktoolik, Alaska. For a detailed description of the preparation and scope of this resource, please refer to this bibliography series' foreword. Any notable errors and/or omissions may be reported to the Coastal Hazards Program manager at the Alaska Division of Geological & Geophysical Surveys (DGGS).

Alaska Department of Commerce, Community & Economic Development (DCCED), accessed 2011, Division of Community & Regional Affairs (DCRA) Community Profiles [website]: State of Alaska Department of Commerce, Community & Economic Development.

http://www.commerce.state.ak.us/dca/profiles/profile-maps.htm

The community profile maps include five maps created between 1980 and 2004. The 1980 map overlays an aerial photograph and indicates major salmon and herring fishing areas; known herring spawning areas; information about mammal, fish, birds, and vegetation; and flood data. The 1996 map shows the location of buildings and utilities. Three maps were completed in 2004. The first map, based on a June 27, 2004, aerial photograph, indicates the flood plain and location of buildings for the western part of the village. The second map provides the same information for the eastern part of the village, and the third map provides an overview of area uses in and near the community. The 1980 map indicates that most buildings are located at an elevation of 28 to 30 feet, while the 2004 maps indicate most buildings are located at an elevation between 18 and 20 feet.

Alaska Department of Environmental Conservation (ADEC), 1974, Aerial photographs of Alaskan coastal communities [photographs]: Alaska State Historical Library, file no. 0488PCA.

This file at the Alaska Historical Library includes three aerial photographs of Shaktoolik taken on June 26, 1974. The photos indicate that approximately 14 buildings had been constructed at the current village site.

Alaska Department of Natural Resources, Division of Coastal and Ocean Management (DCOM), December 2010, State of Alaska Coastal Impact Assistance Program December 2010 amendment: Department of Natural Resources, Juneau, Alaska, 40 p.

The 2010 Coastal Impact Assistance Program (CIAP) document is an amendment to the 2008 program document. The report outlines the CIAP funding distribution throughout Alaska. For 2010 Alaska received $37,085,568.48 and distributed the funds as follows: Municipality of Anchorage, 16.23%; Bristol Bay Borough, 0.08%; Kenai Peninsula Borough, 7.00%; Kodiak Island Borough, 8.62%; Lake and Peninsula Borough, 4.07%; Matanuska–Susitna Borough, 3.70%; North Slope Borough, 32.57%; and Northwest Arctic Borough, 27.73%. The goal of the CIAP plan is to protect Alaska's coastal areas through wise management of resource development. This goal is to be accomplished through projects that will lead to development of effective mitigation strategies and efficient and responsible resource management, minimizing impacts of natural hazards on coastal areas, and funding projects that address the CIAP goal and meet immediate needs.

Alaska Department of Natural Resources Division of Coastal and Ocean Management (DCOM), accessed February 2011, Alaska coastal management program [website]: Alaska Department of Natural Resources Division of Coastal and Ocean Management.

http://alaskacoast.state.ak.us/Explore/Tour.html

This website outlines the Alaska Coastal Management Plans for each coastal district. It provides stewardship plans "to ensure a healthy and vibrant Alaskan coast that efficiently sustains long-term economic and environmental productivity."

Alaska Village Electric Cooperative, 2008, Application for renewable energy fund grant, Alaska Energy Authority—Shaktoolik, Alaska, wind generation construction: Alaska Energy Authority.

This application to the Alaska Energy Authority for two Northwind 100kW wind turbines. During 2007 at the Shaktoolik power plant, 809,700 kWh of energy was generated using 58,600 gallons of diesel fuel. Shaktoolik is considered to have a high-value, Class 4 wind generation potential. The two generators would supply more than 540,000 kWh of electricity each year, which would supply half the power currently used in the community.

Azelton, Mary, *of* U.S. Army Corps of Engineers, July 2010, Memorandum for the record—Trip report, site investigation at Shaktoolik, Alaska, 27 July 2010: U.S. Army Corps of Engineers, Hydraulics Hydrology Section, 7 p.

This memorandum states that the purpose of the Corps' July 2010 visit to Shaktoolik, Alaska, was to become familiarized with the area to facilitate completion of a flood inundation study for the community. Observations were made and noted in this document, pertaining to general physical characteristics of the shoreline. The tidal datum will be available based on benchmarks placed by John Oswald and Associates. Photographs of the site are included in the memorandum.

Blier, Warren, Stanley Keefe, Wilson A. Shaffer, and Sung C. Kim, December 1997, Storm surges in the region of western Alaska: Monthly Weather Review, vol. 125 p. 3094–3108.

The authors describe the relationship between storm surges in Alaska and extratropical cyclones. They have identified Norton Sound and the Bering Sea as the two regions most vulnerable to cyclone-linked coastal flooding. A statistical storm-surge model was developed to provide advanced warning to coastal villages; however, the author highlights that a more accurate model would be necessary to utilize this warning system as a hazard mitigation strategy. The installation of storm-surge gauges would also be required for this warning system to be used successfully.

Bloom, David T., ed., August 2008, Shaktoolik airport 2005 Bering Sea storm permanent repairs: Alaska Deparment of Transportation & Public Facilities, A.K.S.A.S. no. 62932, 8 p.

This report summarizes the restoration project to the Shaktoolik airport after storm surge damage in 2005. Construction designs and directions include expected delineating borrow sites, and repairing airport access roads and the airport.

Brazo, Gary M., Harold R. Livingston, Daniel R. Pavey, and Paul W. Misterek, eds., *of* Northern Region Technical Services Geology, May 1996, Geotechnical report, Shaktoolik airport runway relocation: Alaska Department of Transportation & Public Facilities, state project no. 64759, 43 p.

This is the geotechnical report for the proposed relocation of the Shaktoolik airport to the north end of the Shaktoolik spit. The report consists of recommendations and soils testing reports for the area of interest.

Brazo, Gary M., Harold R. Livingston, Monte K. Weaver, and Paul W. Misterek, eds., *of* Northern Region Engineering Services Geology, October 1992, Geotechnical report, Shaktoolik airport: Alaska Department of Transportation & Public Facilities, state project no. 64759, 30 p.

This is the geotechnical report for suggested improvements to the Shaktoolik airport, located adjacent to the local fish plant. This report describes the fieldwork completed to add technical information to the 1980 geotechnical report and to document the anticipation of any problems with proposed repair designs, the laboratory testing done post fieldwork, and all geotechnical recommendations to the project.

Brower, W.A., Jr., R.G. Baldwin, R.G. Williams, J.L. Wise, and L.D. Leslie, 1988, Climatic atlas of the outer continental shelf waters and coastal regions of Alaska: National Oceanic and Atmospheric Administration, U.S. Department of the Interior Minerals Management Service, U.S. Department of Defense Naval Oceanography Command Detachment, vol. 2, Bering Sea, 519 p.

Storm surges consist of waves that can last from a few minutes to a few days, resulting from atmospheric weather conditions. The height of the storm surge depends on characteristics of a storm (wind speed, direction, length of fetch, latitude direction, and speed of storm) as well as topography of shore and bathymetry offshore. Shallow water bodies experience greater ranges of surges. Height of storm surge is less if the sea floor has a steep rather than shallow slope.

Waters of the Bering Sea provide a long fetch for development of storm waves. With exception of the Shaktoolik River mouth, which is low relief and marshy, east Norton Sound is generally rugged due to proximity to the Nulato Hills. Norton Sound is shallow with a gently sloping sea floor that is very favorable to development of storm surges. Wind directions that develop storm surges are limited to west–southwest to west. A 1985 model showed that the November 1974 storm produced the highest surge in Norton Bay (more than 3 meters). Eleven of 12 storm surges in Unalakleet were in the fall. Sea ice and shorefast ice limit development of storm surges.

Cacchione, David A., and David E. Drake, 1979, Sediment transport in Norton Sound, Alaska: U.S. Geological Survey Open File Report 79-1555, 88 p.

This report is an investigation of sediment dynamics in Norton Sound and the northern Bering Sea. The major topic of the research was sediment movement and hydrodynamic stresses that occur in the Sound and their relationship to Bering Sea ocean dynamics. Other studies have found sediment accumulation from the Yukon River inconsistent with the rate of supply. The modes of transport for this loss of materials are discussed in the report. This study attempts to provide a description of the bottom transport of sediments, pollutants, nutrients, and other particulate matter, as well as identify hazardous sea floor conditions in Norton Sound.

Chapman, Raymond S., Sung-Chan Kim, and David J. Mark, *for* U.S. Army Corps of Engineers, Alaska District, 2009, Storm damage and flooding evaluation—Storm-induced water level prediction study for the western coast of Alaska: Vicksburg, Mississippi, U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, 92 p.

Technical assistance was provided by the U.S. Army Engineer Research and Development Center, Coastal & Hydraulics Laboratory, in assessing storm-generated regional water levels and currents at selected sites of ongoing and potential COE projects along the western coast of Alaska. The purpose of this study was to develop frequency-of-occurrence relationships for storm-generated water levels at 17 communities along the western coast of Alaska. Storm wind, pressure, ice, and surge data were generated for each of the areas, and the bathymetry was updated. Fifty-two storm event simulations were performed and a database of water levels versus return period was developed for each site.

Cold Climate Housing Research Center, Inc., 2010, Sustainable northern communities [website]: Cold Climate Housing Research Center, Inc., Fairbanks, Alaska.

http://www.cchrc.org/sustainable-northern-communities

The Cold Climate Housing Research Center is a nonprofit in Fairbanks with the goal of constructing energy-efficient, sustainable housing for rural Alaska. It is currently working with the communities of Anaktuvuk Pass, Newtok/Metarvik, Point Lay, and Nuiqsut.

The 2009 demonstration house project in Anaktuvuk Pass involved construction of an energy-efficient home. The home was constructed with a light steel frame sprayed with a soy-based polyurethane R-60 insulation and covered on the inside with a plywood skin. A sod roof and earth banking are used on the outside. Energy consumption is estimated to be 110 gallons of fuel oil per year, and the home uses both solar and wind power. The cost of the house, including shipping, was less than $150,000. Students from Illisagvik College in Barrow built the house in four weeks.

Denali Commission, March 2011, Road and waterfront project selections, fiscal year 2006–2011: Denali Commission, 9 p.

This report contains an overview of all of the funding dispersed by the Denali Commission Transportation Program from 2006–2011. The document is organized by partner agency/project and includes a description of the project status. Shaktoolik had funds of $1 million for the planned development of an evacuation route in 2009, but the funds were cancelled.

Drake, D.E., D.A. Cacchione, R.D. Muench, and C.H. Nelson, 1980, Sediment transport in Norton Sound, Alaska: Marine Geology, vol. 36, p. 97–126.

This study examines the suspended sediment and ocean circulation of the northeastern part of the Bering Sea shelf. The authors describe the fate of sediment delivered by the Yukon River to the southwestern corner of Norton Sound and the importance of storm events in Norton Sound associated with erosion and sediment transport. Landsat images were also used to inspect the distribution of sediments and regional circulation in the Sound.

Ecology and Environment, Inc., *for* the City of Shaktoolik, the Native Village of Shaktoolik IRA Council, and the Alaska Department of Military and Veterans Affairs, Division of Homeland Security and Emergency Management, January 2010, Emergency operations plan: Shaktoolik, Alaska: Ecology and Environment, Inc.

The Emergency Operations Plan describes how the city, IRA, and Native Corporation will cooperate to mange emergencies, including their participation in the incident command system. The plan describes procedures for mitigation and prevention, preparedness, response, and recovery. The plan outlines specific responsibilities of local, state, and federal agencies and organizations. Specific hazards that may result in an emergency include fires, adverse ice conditions, flooding and erosion, extreme weather, earthquakes, tsunamis, hazardous material releases, and terrorism. The plan specifies training that is needed for members of the incident command system and exercises the community should complete, including "tabletop" and full-scale exercises. Appendices include a memorandum of understanding to implement the plan, forms, and guides.

Ecology and Environment, Inc., *for* the City of Shaktoolik, the Native Village of Shaktoolik IRA Council, and the Alaska Department of Military & Veterans Affairs, Division of Homeland Security & Emergency Management, February 2010, Continuity of operations plan—Shaktoolik, Alaska: Ecology and Environment, Inc.

The Continuity of Operations Plan addresses how the community will provide essential services to Shaktoolik residents during response to severe weather, natural or manmade hazards, or malevolent attack. This plan covers all facilities, vehicles, and buildings operated by the city, tribe, or the Shaktoolik Native Corporation. The plan lists essential functions, responsible persons, and actions that will be taken to maintain these functions. Three scenarios are covered by the plan: A single building, a catastrophic event that affects the entire community, and a pandemic influenza outbreak. The youth camp, located 8 miles across the Tagoomenik River, has been designated as an alternate facility with five permanent structures that could be used for shelter.

Ecology and Environment, Inc., *for* the City of Shaktoolik, the Native Village of Shaktoolik IRA Council, and the Alaska Department of Military & Veterans Affairs, Division of Homeland Security & Emergency Management, February 2010, Evacuation plan—Shaktoolik, Alaska: Ecology and Environment, Inc.

A joint resolution by the City of Shaktoolik, the Native Village of Shaktoolik, and the Shaktoolik Native Corporation outline cooperation among the three entities to support the emergency evacuation plan. The City and IRA Council share responsibilities for emergency preparedness, administrative, response, and recovery responsibilities. The plan specifies that elderly, small children with at least one parent, and individuals with medical needs will be given priority for evacuation. The Incident Commander (Mayor), with guidance from the Unified Command (representatives of the city, tribe, and corporation) decides whether to issue a decision for residents to remain at home (shelter-in-place), evacuate residents to a location within the community, or evacuate residents to areas outside of Shaktoolik. Evacuations may apply to certain parts of the community or the entire village. Evacuation locations include the school (for elderly, families with small children, and people with special needs), the Youth Camp (for youth located outside the community; accessible by boat), and the National Guard Armory (for others). Evacuation orders will be given on the VHF radio, by telephone, through house-to-house notifications, and through television and radio announcements. The plan describes five levels of preparedness. Appendices include checklists, procedures, and a sample evacuation order.

Giddings, James Louis, 1964, The archeology of Cape Denbigh: Providence, Rhode Island, Brown University Press, 331 p. 73 plates.

This book is the compilation of the excavations of archaeological sites on Cape Denbigh, Alaska. The excavation sites are explained in great detail, including diagrams and photographs of items collected. Three major cultural phases of the western Arctic are defined, including the Denbigh Flint complex, the Norton culture, and the Nukleet culture. This book supports the theory of continuity in cultures of the Bering Strait region.

Gologergen, Sterling, March 2009, Trip report, travel to Shaktoolik March 17–18, 2009: Kawerak, Inc., 1 p.

The purpose of travel was to talk to the 2009 Annual Membership Meeting for the IRA, requested by IRA President Simon Bekoalak. An update was given regarding the community's efforts with erosion/mitigation issues. A report of work done at the local level by the Shaktoolik Mitigation/Erosion Committee was also provided. The community still needs to decide whether or not they are willing to relocate. Meeting notes are provided.

Gray, Glenn, *for* the Community of Shaktoolik, December 2011, Shaktoolik planning project situation assessment—Public review draft: Juneau, Alaska, Glenn Gray & Associates in association with Kawerak, Inc., 55 p.

This report is an assessment of current natural hazards, and evacuation and emergency options and alternatives for the village of Shaktoolik, Alaska. Coastal storms and flooding are identified as threats to the community. This report provides a compilation of recommendations regarding the threats, including additional investigation by the U.S. Army Corps of Engineers. The investigation would include design analysis for structural protection, which could include, but is not limited to, an articulated concrete mat for protection of the community's oil tanks. Other erosion control techniques might include beach nourishment, berm construction, or beach grass planting. Also mentioned is Shaktoolik's consideration for emergency evacuation plans, which will include an evacuation road and shelter for use during high-water events. Relocation has been discussed as an alternative, but has not been studied formally.

Gray, Glenn, *for* the Community of Shaktoolik, 2010, Summary of door-to-door survey: Glenn Gray & Associates in association with Kawerak, Inc.

As part of the Shaktoolik planning process, Glenn Gray & Associates conducted a door-to-door survey of Shaktoolik residents to obtain input about the growing concern about the threats of natural hazards. Kawerak, Inc., funded the Shaktoolik Planning Project in coordination with a series of natural hazard studies that will be completed by the U.S. Army Corps of Engineers. Survey participants provided information about natural hazards, environmental changes, and suggestions for short- and long-term actions the community should take. Sixty-three people, from 55 of the estimated 59 occupied housing units, participated in the survey.

Major Issues: The survey began with an open-ended question about the major problems facing Shaktoolik. Most of the responses to this question identified fall storms, erosion, and the difficulties evacuating the community as the most pressing issues. Some people identified unemployment and improvements to housing and community infrastructure as important issues.

Natural Hazards: The second part of the survey asked participants about natural hazards. Many residents said storm intensity and surges have increased during the past 5–7 years. They said storms have pushed the line of driftwood close to the homes, and the flats on the east side of the village have flooded in recent years as far as one can see.

Regarding erosion, most people indicated the old village site was eroding the most, especially near the airstrip and the area of the Tagoomenik River locally known as "first bend." Survey participants also indicated erosion was occurring at the current village site and up the rivers.

One person believed erosion of a point between the old village and the foothills may have increased erosive forces at the old and new village sites.

Sediments eroded in one area will be deposited (accreted) in another. While most of the people interviewed did not know of areas of accretion, a few people indicated that coastal processes are constantly changing and that sediments have accreted near the mouth of the Shaktoolik River and appear to be deposited in the marine waters directly offshore of the community.

Many of those surveyed were not aware of areas with melting permafrost, but a number of residents related detailed observations. Specific areas identified include the shoreline on the north side of Cape Denbigh, areas

of the tundra, and riverbanks. A number of people said that lakes have been drying up because thawing soils have allowed them to drain.

Responses to Hazards: Most of the residents surveyed had suggestions for short- and long-term responses to natural hazards. People identified evacuation planning as a short-term priority as well as construction of an evacuation road. In addition, some residents recommended the community complete a planning process to evaluate future options.

Many people recommended erosion protection efforts for the community, including construction of a seawall or strategic efforts to protect the fuel tanks and the school. Seventeen people said they would prefer to remain in the community, but some of them believed remaining at the current site was not a realistic long-term solution.

More than half of the survey participants said they believed relocation would be necessary in the long run. Many people identified the foothills as a preferred relocation site, and some said it would be possible to construct a boat harbor using local rock. Others, however, did not support a move to the foothills, citing a lack of a boat harbor and distance from fish and wildlife resources. A few people recommended relocation to a site upriver or to a location towards Cape Denbigh.

Environmental Changes: The last survey question asked residents about what environmental changes they have observed. While some residents could not think of anything, others provided a wide variety of details about environmental changes, including increased severity of storms, flooding in the flats, later and milder winters, earlier springs, and melting permafrost.

In addition to climate-change-related observations, many residents noted new species have arrived in the area, and changes have occurred to the numbers and distribution of existing species. Residents reported observing fewer ducks and geese and reduced numbers of certain fish such as herring, chum salmon, and king salmon. Increased numbers of crows, ravens, and seagulls were reported. New species observed in the area include killer whales, blow fish, and insects. A number of people reported changes in the condition of species, such as reduced blubber in seals, thinner fish, and deformed birds.

Hartig, Larry, *of* Alaska Department of Environmental Conservation & Governor's Climate Change Sub-Cabinet, October 2010, State of Alaska and State/Federal Executive Roundtable Activities Regarding the Arctic [presentation]: Anchorage, Alaska, Northern Waters Task Force, 53 p.

http://housemajority.org/coms/anw/pdfs/26/NWTF_Powerpoint_Hartig_01Oct10.pdf

This is a powerpoint presentation about the state and federal executive roundtable activities regarding the Arctic. The discussion includes hazards associated with declining Arctic sea ice extent, melting of permafrost, storm surges, and coastal erosion. Thirty-one villages are identified as imminently threatened: Barrow, Kivalina, Selawik, Allakaket, Hughes, Huslia, Shishmaref, Deering, Teller, Koyukuk, Nulato, Golovin, Shaktoolik, Unalakleet, Saint Michael, Kotlik, McGrath, Emmonak, Alakanuk, Chevak, Newtok, Nunapitchuk, Lime Village, Eyak (Cordova), Napakiak, Akiak, Chefornak, Kwigillingok, Dillingham, Clark's Point, and Port Heiden. Specific photos and engineering initiatives for four communitites are discussed, including: Kivalina, Shishmaref, Unalakleet, and Newtok.

Hopkins, David M., and Giddings, James Louis, Jr., June 1953, Geological background of the Iyatayet archeological site, Cape Denbigh, Alaska: U.S. Geological Survey and University of Pennsylvania, Smithsonian Miscellaneous Collections, vol. 121, no. 11, 33 p.

This report is a geological review of the Iyatayet Valley on the northwest coast of Cape Denbigh. The report includes reference to archeological occupations throughout the proposed geological sequences correlated with climatic fluctuations throughout the region.

Immediate Action Workgroup (IAWG), Michael Black and Patricia Opheen, eds., March 2009, Recommendations to the Governor's Subcabinet on Climate Change: Immediate Action Workgroup, 162 p.

This report provides 2009 recommendations from the Immediate Action Workgroup (IAWG) to the Alaska Governor's Subcabinet on Climate Change. Information presented in the report for Shaktoolik is summarized below.

- *Priority Communities: Shaktoolik was included in the list of "communities in peril" that were the focus of the report, along with Newtok, Shishmaref, Kivalina, Koyukuk, and Unalakleet.*

- *Community Planning: The report recommended community planning be conducted to address threats from storm surges, erosion, and battering of logs against structures during storms.*
- *Emergency Planning: State funding ($400,000) and federal funding ($125,000) were provided to prepare Emergency Operations, Community Evacuation, and Hazard Mitigation plans and for training. The community identified cabins along the evacuation route that could be used in an emergency.*
- *Evacuation Road: The community requested $500,000 from the State of Alaska for road design. Kawerak, Inc., and the Denali Commission completed a reconnaissance study.*
- *Shelter: Shaktoolik is investigating the feasibility of developing an emergency shelter in the community.*
- *Funding: The report recommends Shaktoolik request Congress add it to the Section 117 Alaska Coastal Erosion Program. The report states Shaktoolik has been allocated $16.6 million between 1988 and 2012 for public infrastructure. Shaktoolik is eligible for funds from the Alaska Climate Change Impact Mitigation Program.*
- *Mapping: The DNR Division of Geological & Geophysical Surveys has funding to complete hazards mapping.*
- *Coordination: The Alaska Department of Transportation & Public Facilities received state funding to work with the Army Corps of Engineers and the Department of Commerce, Community & Economic Development to identify existing data and missing information. Site surveys, material source investigations, hazard mapping, geotechnical and environmental studies, and permitting studies need to be completed. The IAG recommended a phased and coordinated approach among the communities of Shishmaref, Kivalina, Shaktoolik, and Unalakleet.*
- *Obstacles: The report found that because there is no definite timeline or authorities for erosion control and relocation, it is difficult to coordinate and focus resources.*

Immediate Action Workgroup (IAWG), Michael Black and Patricia Opheen, eds., 2008, Recommendations report to the Governor's Subcabinet on Climate Change: Immediate Action Workgroup, 86 p.

This report provides recommendations to the Alaska Governor's Subcabinet on Climate Change. The Immediate Action Workgroup (IAW) reports to this subcabinet. This report includes community profiles and immediate actions. The report identified immediate priorities for Shaktoolik including a preliminary relocation site assessment, an evacuation road, geologic mapping, and completion of emergency plans and training. Five specific projects were identified in the report:

1. *Emergency Plans: Completion of training and Emergency Operations, Community Evacuation, and Hazard Mitigation Plans.*
2. *Evacuation Road: Completion of a reconnaissance study for an evacuation road.*
3. *Cabins: Identify cabins that should be built along the evacuation road for emergency housing and a 30kw generator.*
4. *Relocation Site: Completion of a preliminary site relocation assessment.*
5. *Relocation Plan: Form a local planning committee to complete a relocation plan (tribe, city, school, village corporation, and Kawerak).*

Johnson, Walter R., and Zygmunt Kowalik, April 1986, Modeling of storm surges in the Bering Sea and Norton Sound: Journal of Geophysical Research, vol. 91, no. C4, p. 5119–5128.

Based on the results of a numerical model used to examine sea level, currents, and ice distribution during Bering Sea storm events, the authors suggest that the presence of land-fast ice in Norton Sound has a measurable effect on the size and onshore arrival time of storm-surge events. Both land-fast and pack ice are included as parameters in the model runs. The model is validated using observations and measurements from the February 1982, March 1982, and November 1974 storm events and reproduces observations of sea ice redistribution during these storm events.

Kawerak, Inc., *for* the Village of Shaktoolik and the Bering Strait Development Council, June 2007, Shaktoolik local economic development plan, 2006–2011: Village of Shaktoolik and the Bering Strait Development Council, 48 p.

This plan identifies the following top 10 economic development priorities:

1. *Land expansion and site control.*
2. *Evacuation route/gravel site upgrade.*
3. *Erosion control.*

4. *Multi-purpose building.*
5. *New housing development.*
6. *Bulk fuel tank farm.*
7. *Environment–subsistence–wildlife conservation.*
8. *Water system upgrade.*
9. *Shaktoolik boat harbor.*
10. *Community roads upgrade.*

The community vision is to use cultural values and natural resources to augment future growth and welfare. Three goals have been established to reach this vision:

1. *Ensure financial stability and employment by building infrastructure for community growth.*
2. *Raise the standard of living by expanding community services, education, and culturally appropriate healthy lifestyles.*
3. *Preserve the culture by developing natural resources while protecting and enhancing the environment.*

Kawerak Transportation Program and Rodney P. Kinney Associates, Inc., *for* Native Village of Shaktoolik, December 2008, Shaktoolik evacuation road project route reconnaissance report: Shaktoolik, Alaska, Native Village of Shaktoolik, 15 p.

The Denali Commission, Bureau of Indian Affairs (BIA) Indian Reservation Roads (IRR) Program and Kawerak, Inc., allocated funds to work on this project. The evacuation road would cost an estimated $33,398,822. It would be 14 feet wide with turnouts and extend from the village south to the foothills. The party responsible for maintaining the evacuation road will be either the City of Shaktoolik or the Native Village of Shaktoolik.

As a result of meetings with the IRA, the new proposed route differs from the routes evaluated in the 2007 scoping report completed by the same author. The main purpose of the road is to provide an evacuation route during an emergency, but it would also be used for access to a gravel source and for subsistence hunting and fishing. The reconnaissance report splits the road into the following segments.

- *Segment 1 (4.2 miles): From north of the school to the south of the former village site where the Tagoomenik River is close to Norton Sound. Raise the first 4.1 miles of the road, straighten alignment, install culverts, repair washed-out sections, resurface with crushed aggregate, install armoring, and apply dust treatment. An estimated 2,000 feet of road will need to be armored with riprap, and some of this segment will need to be raised.*
- *Segment 2 (5.7 miles): From Segment 1, this segment heads southeast for 2.7 miles and then south along Beeson Slough for another 3 miles. Culverts will need to be placed in this section.*
- *Segment 3 (4.7 miles): From Segment 2, this segment follows higher ground along Beeson Slough for 3.3 miles where it travels west to end at an existing gravel source at Norton Sound. Culverts will need to be installed in this section.*

Right-of-way easements would be needed for all three segments except the in-town portion of Segment 1. Shaktoolik's spit is composed of course, granular sand and gravel, and its elevation ranges from sea level to about 30 feet above sea level.

Additional investigations will be needed to determine if there are areas of permafrost, what sections will need to be armored, wetlands delineations, archeological field investigations, an environmental site assessment, investigation to the extent of the material source, and where culverts need to be placed. None of the segments are anticipated to have high environmental impacts, and the costs for constructing each segment are assumed to be equal.

Kinney, Thomas C.; Rohn D. Abbott, ed., *of* Shannon & Wilson, Inc. *for* Ellerbe Alaska, Inc., March 1981, Summary of geotechnical recommendations for proposed runway and access road stabilization, Shaktoolik, Alaska: Fairbanks, Alaska, Ellerbe Alaska, Inc., 12 p.

This is the original geotechnical report for improvements to the Shaktoolik airport located adjacent to the local fish plant. The suggested improvements included lengthening the runway, building a taxiway and parking apron, and reconstructing the airport access road. Many of the subsurface materials explorations consisted of clean sands or rounded aggregates, which are unsuitable for airport traffic, because of the ease of slipping and

rutting. Materials would have to be mixed from multiple sites and crushed to become suitable. This report was based on a materials investigation by the State of Alaska; the author did not visit the site or examine samples.

Magdanz, James S., Sandra Tahbone, Austin Ahmasuk, David S. Koster, and Brian L. Davis, *of* Alaska Department of Fish & Game Division of Subsistence, August 2007, Customary trade and barter in fish in the Seward Peninsula area, Alaska: Juneau, Alaska, Alaska Department of Fish & Game, Technical Paper no. 328, 126 p.

This regional field study, conducted in 2005, includes a section on Shaktoolik. Only three of the 13 households that attended a public meeting agreed to participate in the survey. In response, the study was expanded to include a focus group of elders. The participants in this study discussed trade for fish throughout their lifetimes.

Mason, Owen K., and James W. Jordan, 2002, Minimal late Holocene sea level rise in the Chukchi Sea—Arctic insensitivity to global change?: Global and Planetary Changes, vol. 32, p. 13–23.

In this article, Mason and Jordan outline the apparent disconnect between late Holocene global sea level rise and the moderate sea level rise observed in Northwest Alaska. Radiocarbon ages taken from peat and storm deposits in Seward Peninsula lagoons allowed for the reconstruction of a sea level curve spanning the last 6,000 years. The results indicate that sea level in northwestern Alaska has risen an average 0.3 mm per year compared to the global average of 1–2 mm per year. The authors suggest several hypotheses for these differing rates including cold sea surface temperatures (limited steric expansion), geoid variation and/or the development of permafrost. Although observed rates of sea level rise are moderate for the Chukchi Sea, the article cautions that the response of northern Alaska's coasts to future global climate change remains uncertain and requires continued investigation.

McCaleb, David L,. ed,. 1998, Construction plans for Shaktoolik airport relocation: Alaska Department of Transportation & Public Facilities, A.I.P. no. 3-02-0401-01/64759, 22 p.

This report is the construction design for the airport relocation project from the Shaktoolik airport on the east side of the Shaktoolik spit to the north middle region. The project was completed after four years in 2003 by Tidemark Corporation.

Michels, Denise, March 2006, Senate Committee on Commerce, Science, and Transportation Subcommittee on Disaster Prevention and Prediction Hearing on "Winter Storms" [electronic]: American Geosciences Institute, Government Affairs Program, Alexandria, VA.

http://www.agiweb.org/gap/legis109/wind_hearings.html

Testimony of Mayor Michaels addresses threats to western Alaska from winter storms. The hazards discussed include storm surges and ice override. The Great Bering Sea storm of 1974 resulted in a storm surge in Nome 12 feet above mean lower low water. An ice override event resulted in a pileup of 30–40 feet. Another ice override event in 1980 reached a height of 20–25 feet. An October 2002 storm resulted in 14 foot seas at high tide in Kivalina and Shishmaref. A September 2005 storm eroded 25–30 feet of beach in Kivalina. Winter storms are occurring more frequently, and because of a later freeze up, they are doing more damage.

Native Village and City of Shaktoolik, WHPacific, and Bechtol Planning and Development, October 2009, Community of Shaktoolik, Alaska, local multi-hazard mitigation plan: Shaktoolik IRA Council and the City of Shaktoolik, Alaska, 84 p.

This plan characterizes risks of hazards to the community and recommends mitigation efforts to reduce or eliminate long-term risk to human life and property from hazards. It must be updated every 5 years and resubmitted to FEMA. The plan includes a community overview, a capability assessment, a risk assessment, and a mitigation strategy. Hazards present in the community include flooding (high), erosion (medium), severe weather (high), wildfire (low), and earthquakes (medium). Coastal flooding occurs in late summer and fall, and large western storms can cause wave run-up as high as 30 feet. Storm surges result from strong winds and low atmospheric pressure. The report notes that state disaster declarations included the community in 2004 and 2005. The mitigation strategy includes the following recommendations: Complete evacuation road design and engineering (high), request Congress add the community to the Alaska Control Erosion Program (high), complete hazard mapping (high), elevate or relocate flood-prone structures (medium), investigate benefits of joining the national flood insurance program (high), shoreline protection projects to protect tank farms and utilities (high), protect water source (high), mark navigable waterways for evacuation (high), public education (high), implement "storm-ready" program (high), conduct weather awareness activities (high), public

awareness about NOAA weather radio (high), encourage weather-resistant buildings (medium), promote Fire Wise building design (high), join Alaska Fire Wise program (high), develop local building codes for fire safety (medium), enhance awareness of fire risk (high), encourage mitigation measures around buildings (high), identify critical buildings for earthquake hazards (high), assess vulnerabilities for buildings (medium), and implement nonstructural mitigation projects for earthquakes (high).

Ray, Dorothy Jean, 1975, The Eskimos of the Bering Straits, 1650–1898: Seattle, Washington, University of Washington Press, 305 p.

The author summarizes research from early voyages to the Bering Strait and Norton Sound region of Alaska, and other written sources. Shaktoolik and the Cape Denbigh area are mentioned occasionally. Captain Cook made contact with indigenous people at Cape Denbigh on September 11, 1778. The Unalit people occupied the area before the Malemiut people migrated to the area from Kotzebue Sound, primarily from the Kobuk River and Buckland River areas.

The author speculates that the migration of the Malemiut had not begun by 1782 because written references to the pronunciation of Shaktoolik used the Unaluk rather than the Malemiut pronunciation. During 1839, Shaktoolik was the only Malemiut village in Norton Sound, but by the 1840s Malemiut people were habitated in Unalakleet and St. Michael. The author states that it was likely Shaktoolik was abandoned by the time it was occupied by the Malemiuts. The Russian fort in St. Michael was established in 1833, and a supply post at the mouth of the Unalakleet River was established in 1838. A smallpox epidemic reached Norton Sound in 1838. The author reports that berry picking began the first week of August near Shaktoolik, and the best cranberry and blackberry grounds were located near the ocean.

Rodney P. Kinney Associates, Inc., and Kawerak Transportation Program, *for* Shaktoolik IRA Council, March 2007, Shaktoolik long-range transportation plan: Shaktoolik, Alaska, Shaktoolik IRA Council, Indian reservation roads program no. E04435-SHAKTOOLIK, 15 p.

This plan describes transportation priorities for Shaktoolik including funding priorities of the Bureau of Indian Affairs (BIA) Indian Reservation Roads (IRR) Program. When this plan was written, the IRR program included 2.5 miles of road with about 247 miles of road planned to be submitted. The plan prioritized nine projects:

1. *Upgrade community streets ($3 million)*
2. *Construct proposed subsistence and economic routes ($980 million)*
3. *Build a road to the Foothills and Swallow for material access, subsistence access, and evacuation purposes ($64 million)*
4. *Construct roads in the new townsite ($40 million)*
5. *Rehabilitate existing 13 miles of Foothills Road ($26 million)*
6. *Construct/upgrade harbors, ports, barge landings, and breakwaters ($7 million)*
7. *Construct/upgrade boat landings ($750,000)*
8. *Construct snow fencing along community routes ($200,000/mile),*
9. *Provide signage and staking for winter routes ($100,000/mile)*

The City of Shaktoolik only has authority for lands inside its boundaries, so roads outside of city limits must be approved by the federal, state, or private landowner. The City of Shaktoolik is responsible for road maintenance in the municipal boundaries, and the Alaska Department of Transportation & Public Facilities is responsible for maintaining the road to the airport. The Shaktoolik IRA will be responsible for maintaining any future roads constructed under the IRR program.

The plan includes a complete list of traditional routes in section 4.1 and a map of these routes in section 4.2. Proposed locations for future marine facilities are identified in section 4.2. For safety purposes, the plan recommends marking winter routes with tripods every 100–500 feet, depending on the location of the route.

Appendix E of the plan includes the scoping report for Shaktoolik Main Street Rehabilitation and Evacuation Road Project. The scoping report states that the road to the former village site is eroding and insufficient for evacuation during a high-water event. Two alignments have been evaluated for an evacuation road. Both alignments include an initial 1.5 mile segment that begins south of the existing village and would involve two bridges across the Tagoomenik River.

Alternative A would continue 11.7 miles due east to the Nulato Hills, and would involve a 3.5 mile segment due north to a 350 foot tall hill. The 14-foot-wide single-lane road would have turnouts. The initial estimated costs for the evacuation road are between $20.7 million (Alternative B) and $37.9 million (Alternative A).

Rosales, Jon, January 2011, Shaktoolik's very existence is in jeopardy [electronic]: Alaska Dispatch.

http://www.alaskadispatch.com/article/shaktooliks-very-existence-jeopardy

This article discusses the potential disasters to Shaktoolik and reasons for current controversy over legislation. Historic knowledge of this area was of predictable and calm waters, which was a reason for settlement; however, in recent years, storms have become more intense and sea ice less extensive. Although the American Clean Energy and Securty Act of 2009 passed, some senators contiue to argue that climate protection is too expensive, will affect employment, and otherwise hurt the economy.

Russell Cox, Sally, *of* Alaska Division of Community & Regional Affairs (DCRA), 2011, Alaska climate change impact mitigation program [powerpoint]: Anchorage, Alaska, Division of Community & Regional Affairs, 28 p.

This is a powerpoint presentation about the Alaska Climate Change Impact Mitigation Program (ACCIMP) presented by Sally Cox, a planner with the Alaska Division of Community & Regional Affairs. Communities that have been identified for community planning grants under this program are Kivalina, Shishmaref, Koyukuk, Unalakleet, Shaktoolik, and Newtok.

Sallenger, Asbury H., Jr., 1983, Measurements of debris-line elevations and beach profiles following a major storm—Northern Bering Sea coast of Alaska: U.S. Geological Survey Open-File Report 83-394, 12 p.

This report involved field surveys in Norton Sound of the debris line caused by the 1974 storm. The debris line is the result of the highest storm surge (still water level during a storm) and wave run-up. Two of the survey locations are near the existing and former Shaktoolik village site. The report found that the highest debris line in Norton Sound (5 meters) was in eastern Norton Sound, and the lowest debris line was in Norton Bay.

Sallenger, Asbury H., Jr., and John R. Dingler, September 1978, Coastal processes and morphology of the Bering Sea coast of Alaska: U.S. Geological Survey, Menlo Park, CA, Research Unit No. 431, 66 p.

The research outlined in this paper was done in order to characterize the regional physical environment of the Bering Sea coast of Alaska in order to prepare for potential oil and gas development and subsequent hazards to infrastructure and environment. The net direction of longshore transport, coastal morphology, and reconnaissance-based beach morphology and sediment characteristics were used as indicators. Measurements were taken along the Bering Sea coast of debris-line elevations that were reached during the 1974 Bering Sea storm. Coastal change was measured near Nome during 1976 and 1977 using nearshore coastal profiling and aerial photography. Wave characteristics and sea-level variations were also measured in order to check the validity of the wave model used. The specific objective of the research was to develop a coastal set-back line beyond which petroleum development would not occur.

Thomas, D., 1982, The role of local fish and wildlife resources in the community of Shaktoolik, Alaska: Alaska Department of Fish & Game Division of Subsistence.

The Alaska Department of Fish & Game completed this study in anticipation of state and federal oil and gas leasing in Norton Sound. Prior to this study, little data existed on subsistence use by the community. The City Council approved this research project, although they had concerns that information could attract sport hunters and that documentation of illegal harvests could be used against residents. The author conducted the research for the study September–December 1980. The methodology included informal discussions, formal interviews, observations, diet calendars, mapping, and a literature review. While the author had subsistence users indicate where they obtained resources on maps, those maps were not included in the final study. The study found that most residents followed a yearly cycle of subsistence activities and that sharing of subsistence foods was important. Most subsistence activities occur in the spring, summer, and fall, and commercial fishing is the dominant activity in the summer for most households. Species harvested include beluga whales, seals (ugruk, ringed, and spotted), birds (ducks, geese, and cranes), eggs (seagull, waterfowl, and murres), salmon (king, dog, pink, and silver salmon), other fish (trout, herring, herring eggs, tomcod, lingcod, wolf fish, rockfish, cigarfish), and shellfish (crabs, mussels, and clams). The study also includes information about flooding and ice hazards.

U.S. Army Corps of Engineers, October 2011, Shaktoolik Coastal Flooding Analysis: U.S. Army Corps of Engineers, Alaska District, 73 p.

From introduction: "The purpose of this report is to identify the likelihood and severity of coastal flooding, and to update the erosion map presented in the 2009 Alaska Baseline Erosion Study for the community of Shaktoolik, Alaska. Coastal flooding results from the combination of wave, surge, and runup. The 'old site', approximately 3 miles south of the current community site, endured several storms that resulted in flooding and damage to the community. The extent of erosion at the "old site" was one of the factors that prompted the community to relocate to its current site in 1974. This report has been prepared to assist the community of Shaktoolik in future planning, studies, and projects. The results of this report were reviewed by the U.S. Army Corps of Engineers, Alaska District, Coastal and Hydraulics Laboratory (CHL), residents of Shaktoolik, Kawerak Corporation, and the Denali Commission."

U.S. Army Corps of Engineers, accessed 2011, Civil works floodplain management services [website]: U.S. Army Corps of Engineers, Alaska District.

http://www.poa.usace.army.mil/en/cw/fld_haz/floodplain_index.htm

This website provides flood-hazard data for communities throughout Alaska. A link is provided to a flood-hazard-specific bibliography, maintained by the U.S. Army Corps of Engineers. The flood record database states that wave run-up extends to 30 feet elevation on the Norton Sound side of Shaktoolik. Flooding is considerably less on the Shaktoolik River side.

U.S. Army Corps of Engineers, 2009, Continuing authorities project fact sheet [preliminary]: U.S. Army Corps of Engineers, Alaska District.

This fact sheet was completed under authority of Section 103 of the Rivers and Harbors Act to investigate interest of the federal government in reducing storm-related damage to public facilities in Shaktoolik. The village was designated a priority action community in the March 2009 Alaska Baseline Erosion Assessment Study. Portions of the sand spit south of town flooded during storm surges in 2004 and 2005. The report identified the following concerns:

- *The south tank farm operated by the Shaktoolik Native Corporation is threatened by erosion that could result in environmental damage.*
- *AVEC's north tank farm is also threatened by erosion.*
- *The First Bend of the Tagoomenik River is threatened by erosion, which could breach the spit and make the community an island, preventing evacuation to high ground and access to subsistence resources.*
- *Erosion near First Bend would threaten the community's fresh water source.*
- *The driftwood line in front of the community could cause structural damage during a storm.*
- *The septic tank for the school is subject to erosion.*
- *Sewer lines serving residences are also subject to erosion.*

The fact sheet states that, typically, severe wave occurrences move sediments offshore and move them back to the beach during periods of calmer weather. In addition to storm surges, ice contributes to erosion. The report predicts that later sea ice formation will increase occurrence of high-energy waves that narrow and steepen the beach.

Using aerial photographs from 1980, 1994, and 2004, the Corps measured erosion rates in front of buildings in Shaktoolik and each 1,000 foot increment for the 5,000 feet northwest and the 9,000 feet to the southeast of the community. Between 1980 and 1994, the trend was for the beach to remain stable or grow in some areas. During the period 1994 and 2004, the beach eroded. While it is unknown whether the future trends will result in accretion or erosion, for the purpose of this analysis the Corps assumed that the recent rates of erosion will continue. The Corps divided the area around Shaktoolik into three sections, and it predicted that erosion rates will be between 1 and 3 feet per year (see explanation under the Alaska Baseline Erosion Assessment above for more details). The aerial photographs did not cover the First Bend area, so the Corps assumed the erosion rate would be 3 feet, the same as section 3. The fact sheet includes an estimate that future erosion damages would be $7.8 million for the next 15 years.

The study considered five alternatives for protecting Shaktoolik's shoreline: Rock revetment, articulated concrete map, groin fields (jetties), beach nourishment, and relocation of structures. The Corps recommended 260 feet of articulated concrete mat (concrete blocks connected by cable) to protect the south fuel tank. The estimated cost of this option is $3.3 million (with an estimated life of 15 years), as opposed to a rock revetment, which would cost $6 million.

The fact sheet mentions the Corps was asked, at a public meeting in the community, to evaluate protection measures for First Bend. The fact sheet states that the current intake structure for the water supply could be relocated "at a substantial savings compared with structurally protecting the potential breach area" (p. 8).

The fact sheet ends by clarifying that the recommendations could be modified at higher levels and that a feasibility study would need to be conducted.

U.S. Army Corps of Engineers, March 2009, Study findings and technical report—Alaska baseline erosion assessment: Elmendorf Air Force Base, Alaska, U.S. Army Corps of Engineers, Alaska District, 68 p.

http://www.poa.usace.army.mil/AKE/Home.html

This report presents the results of the Alaska Baseline Erosion Assessment, which found that Shaktoolik is one of 26 Alaska communities designated as Priority Action Communities. This designation indicates an immediate need for action, which includes either an evaluation of potential solutions or continuing efforts to manage erosion. Priority Action Communities have reported serious erosion that threatens community viability. Appendix F of this report includes a detailed erosion assessment for Shaktoolik. The assessment found that Shaktoolik experiences both coastal erosion from Norton Sound and riverine erosion from the Tagoomenik River. It states the community is vulnerable to future storm damage in the next 10 years due to erosion of natural protection. Erosion could cause isolation of the community and loss of its water source if the spit erodes south of the village.

The report identified Shaktoolik as a target community for continuation of existing Corps of Engineers studies. The Corps is investigating erosion at Shaktoolik under funding from the Baseline Erosion Assessment, the Hurricane and Storm Damage Reduction program, and section 103 of the 1962 Rivers and Harbor Act. The report states that the community's long-term goal is to relocate, and the next step is to complete planning and design efforts for a 14.6 mile road to the relocation site.

Appendix H of the assessment discusses three expedient coastal protection measures appropriate for Alaska considering locally available materials and the ability for a locally mobilized work force.

- *Geotextile sandbags, composed of either polyester or polypropylene, filled with sand or gravel. These bags are placed on top of a filter fabric, overlapped and extended below MLLW. This alternative requires annual maintenance and may not be suitable to areas subject to damage from ice ride-up.*
- *Beach nourishment involves replacement of sediments eroded from a beach with material at least as coarse as the eroded materials. Materials can be placed from onshore sources or dredged from offshore sources. Wider beaches reduce damage from storms, and erosion of the new materials to areas offshore will reduce the number of large waves reaching shore. Beach nourishment efforts will need to be continued periodically, depending on the rate of erosion of the new material.*
- *Modified geotextile wrap-around revetments involve filling large sheets of fabric and wrapping them around into an enclosed structure. The layers are sewn together. While this technique has not been used in Alaska, it has had success in other areas.*

This appendix describes coastal processes including sediment transport and water levels. The report identifies characteristics of a shoreline protection project: Strength (ability to withstand wave force), flexibility (ability to settle without failing), and protection from undermining of materials in front of the structure (toe protection) and along the sides of the structure. In most circumstances, structures with gentle slopes and high porosity (drainage) will receive less damage from toe scour. A beach or structure with a gentle slope and rough service will receive less run-up than a steep slope with a smooth surface.

The detailed erosion assessment for Shaktoolik (Appendix F) identifies storms coming from the south, storm surges, and sea-ice conditions as the major erosive forces. Major storms in 2003, 2004, and 2005 resulted in considerable coastal erosion, and the airport at the former village site to the south is "just a few hundred feet from erosion advancing from Tagoomenik River. It is reported that most of Shaktoolik lies within the 100-year floodplain" (p. 2).

The assessment identified six categories of damage: Land, residential structures, commercial structures, public structures, infrastructure, and environmental hazards. The erosion assessment estimates that Shaktoolik is losing about 0.88 acres (38,300 square feet) of land each year with a total expected loss of 44.84 acres during the next 50 years. The assessment estimated damage for three sections of the community:

- *Section 1 (9,600 foot area fronting the community): This section is eroding at a rate of 2 feet per year. Next 50-year loss is estimated to be 23.42 acres.*

- *Section 2 (3,900 foot area south of section 1): This area is eroding at a rate of 1 foot per year. Next 50-year loss is estimated to be 3.86 acres.*
- *Section 3 (4,700 foot area south of section 2): This area is eroding at a rate of 3 feet per year. Next 50-year loss is estimated to be 17.56 acres.*

The erosion assessment states that 14 outbuildings and 18 residences are at risk in the present community site including: Three commercial structures (two tank farms and retail store), four public buildings (including school and its septic system), 5,000 feet of roads, 1,400 feet of sewer lines, 275,000 gallons of bulk fuel storage capacity, 848,000 gallons of water storage and 10,000 feet of water lines, and the power plant. The southern tank farm would need decommissioning in the next 10 years, and the northern tank farm would need decommissioning in 11–30 years. Potential environmental consequences would occur from eroding sewer lines, and erosion of possible soil contamination at the tank farms. An estimated $23 million in future costs would result from damages stemming from erosion.

The assessment identifies potential responses to continued erosion including structural and non-structural solutions. Structural solutions include building a 4,500 foot revetment in front of the community ($29.2 million), constructing a 3,350 foot revetment near First Bend to protect the water supply ($18.6 million), constructing a "groin field" to trap sand on the beach ($30.8 million), and beach nourishment ($36.5 million). Nonstructural solutions include relocation of threatened buildings and infrastructure (including water intake area), construction of an evacuation road, and village relocation.

U.S. Government Accountability Office (GAO), June 2009, Report to congressional requestors—Alaska Native villages, limited progress has been made on relocating villages threatened by flooding and erosion: U.S. General Accountability Office Report GAO-040895T, 53 p.

http://www.gao.gov/products/GAO-09-551

This report updates a December 2003 report. The report recommends Congress consider: (1) Directing the Corps to conduct a flooding assessment in Alaska, (2) amending legislation to allow 64 additional villages to be eligible for grants under the Housing and Community Development Act, and (3) designating a lead federal agency to work with a lead state agency to coordinate relocation efforts. The report found that most of the 12 villages considering relocation have made limited progress, except for Newtok.

The 2009 report added Shaktoolik to the 2003 list of villages in immediate danger (Kivalina, Shishmaref, Newtok, and Koyukuk). It found that Kivalina, Shaktoolik, and Shishmaref would likely need to be relocated concurrently.

The document reports that Shaktoolik officials have located a potential site near Christmas Mountain, about 8.5 miles northeast of the current community. It states that this site would start as an evacuation destination, and that the feasibility of constructing an evacuation road to the site is being investigated.

Since 2003, a number of efforts have been initiated. In 2004, the Corps was given authority to initiate an erosion control project at full federal expense, but this authority was repealed in March 2009. The Corps conducted an Alaska erosion baseline study, and it completed the Alaska Village Technical Assistance Program Assessment in 2006. An October 11, 2007, congressional field hearing in Anchorage identified the following obstacles faced by federal agencies and villages: Inability of many villages to meet criteria for federal assistance, high cost of protection and relocation projects, and the lack of scientific erosion data for sound decision making.

The report states that some officials fear erosion control projects in Shaktoolik, Shishmaref, and Kivalina could slow the progress toward relocation because of a false sense of security. The seawalls are expected to protect the villages for 15 years, and up to 25 years if maintained.

The report found that the lack of a lead federal agency is an impediment to relocating the villages most threatened. The State of Alaska in 2008 designated the Department of Commerce, Community & Economic Development as the lead state coordinating agency for relocation assistance. A $13.6 million state appropriation was made for FY09. The report summarizes grant programs available for communities facing erosion and flooding.

U.S. Government Accounting Office (GAO), 2003 [2004], Alaska Native villages—Most are affected by flooding and erosion, but few qualify for federal assistance: U.S. General Accounting Office Report GAO-04-142, 82 p.

http://www.gao.gov/products/GAO-04-142

This study was conducted to provide recommendations to Congress that would improve how state and federal agencies respond to flooding and erosion in Alaska. This was done by:

1. *Determining the extent to which these villages were affected.*
2. *Identifying federal and state flooding and erosion programs.*
3. *Determining the current status of efforts to respond to flooding and erosion in nine villages.*
4. *Identifying alternatives that Congress may wish to consider when providing assistance for flooding and erosion (see "Highlights" section).*

The recommendations provide alternatives to current actions taken during flooding and erosion responses by including federal agencies and the Denali Commission. The adoption of policies by the Denali Commission would guide investments in infrastructure for Alaska Native villages affected by flooding and erosion. Shaktoolik was recognized as one of the 184 Alaska Native Villages facing imminent flooding and erosion threats.

VanHorn, Steve, August 1980, Memorandum to Danial D. Urbach, P.E., Shaktoolik airport rield reconnaissance: State of Alaska (SOA), 3 p.

This memorandum explains a reconnaissance trip to the Shaktoolik Airport taken by Steve Van Horn, Airport Engineer, on July 31, 1980. The condition of the site is explained for preparation for fieldwork later that year.

VanHorn, Steve, November 1980, Memorandum to Dan Pavey, Shaktoolik materials investigation: State of Alaska, 4 p.

This memorandum explains, in detail, the fieldwork completed by Steve Van Horn, Airport Engineer, from September 15–18, 1980, for the Shaktoolik airport materials investigation. The results from the fieldwork are discussed as well as all activities required to complete the work.

Vaught, Douglas, November 2008, Shaktoolik, Alaska wind resource report: V3 Energy, LLC, 20 p.

This study found that Shaktoolik has good potential for development of wind energy. The community is rated as a high Class 4 category for wind generation. Wind speed data were collected over a one-year period.

Waller, Roger M., 1958, Ground-water reconnaissance of Koyuk and Shaktoolik villages, Alaska: Alaska Department of Health Section of Sanitation and Engineering, no. 7, 10 p.

This document is a report on ground-water potential as drinking water for the communities of Koyuk and Shaktoolik, Alaska. A geologic review is also included for the region. The ground-water potential is examined based on physical characteristics of the general area.

Wise, James L., Albert L. Comiskey, and Richard Becker, 1981, Storm surge climatology and forecasting in Alaska: Anchorage, Alaska, Arctic Environmental Information and Data Center, University of Alaska, 26 p.

This project investigated the climatology of storm surges and refined procedures for storm-surge forecasting. Storm data for 90 storms since 1954 were used in the study. Intense atmospheric low-pressure systems with strong winds onshore or along the shore create storm surges. Winds can develop over several hundred miles of open water (fetch). Gently sloping nearshore areas and sufficient fetch are needed for storm surges. The study found that ice cover generally dampens waves, but 3-foot storm surges have occurred when there were 3 feet of ice. The upper limit of storm surges is generally 12 feet.

The Chukchi Sea is one of the areas in Alaska conducive to storm surges. Most storm surges in this area occur in the autumn. The study estimated that a 10.6 foot storm surge could be expected once every 100 years.

Young, C., and C. Lewis, 1996, Shaktoolik feasibility study for a fish and reindeer processing facility: Fairbanks, Alaska, University of Alaska Fairbanks.

This study was conducted to determine the feasibility of constructing a fish and reindeer processing facility. An upgraded facility would cost between $1.5 and $1.8 million with an annual estimated operating cost of $588,000. The report concluded that the facility would not be feasible as planned and engineered. The facility could be profitable, however, if grants were available to reduce start-up costs and if a value-added product was developed in addition to processing fish and reindeer. Regarding natural hazards, the report states that the fall of 1993 storm damaged the overhead rail, dock, and diking of the existing processing plant. The embankment in front of the facility was repaired to prevent further erosion.