Technical Memorandum

Date:	February 1, 2013	**W.O.#:**	879301
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From:	Mel Langdon		
Project:	Noatak Airport		
Subject:	Noatak Riverbank Erosion Assessment		

1 INTRODUCTION

Cumulative riverbank erosion in the vicinity of the Noatak Airport and apron over the past 60 years has caused the loss of approximately 430 horizontal feet, leaving only approximately 160 horizontal feet between the top of bank and the southeast edge of the apron. An erosion study conducted in 2003 by R&M Consultants, Inc. (“R&M study”), prepared for the Alaska Native Health Consortium (ANTHC) (R&M, 2003), projected maximum erosion extent that would impact the apron by 2010, and by 2020, extend into the runway. Active erosion has been observed since 2003, but the full extent of the R&M study projection has not been realized.

The Alaska Department of Transportation and Public Facilities (DOT&PF) is evaluating the need to relocate the Noatak Airport. This Noatak Riverbank Erosion Assessment Technical Memorandum is meant to supplement DOT&PF’s evaluation by summarizing erosion issues using previous reports in the vicinity of the runway, evaluating the environmental factors that are still valid today, and highlighting erosion factors for consideration in the future. This memorandum also discusses road settling issues on Pit Road, the access road parallel to the runway, and how it may be related to riverbank erosion.

2 BACKGROUND

2.1 Overview

The airport and Village of Noatak are located on the west bank of the Noatak River (Figure 1), about 25 miles east of the Chukchi Sea coast, 55 miles north of Kotzebue and 70 miles north of the Arctic Circle. The Noatak River rises in the Brooks Range, and flows west for about 80 miles before turning south and entering the Mission Lowlands, a broad forested floodplain where the Village of Noatak is located.

In the vicinity of the Noatak Airport, the Noatak River is a split channel river, with two channels referred to as the East and West channels. The West Channel separates from the East Channel about 1 mile upstream of the airport (Figure 2). Local knowledge indicates that the main river channel migrated from the west to the east side of the river within the past three decades (Mobley, 2006). An appendix to the 1992 Environmental Assessment for runway extension and apron expansion includes a 1992 letter stating that water levels drop rapidly during the spring in the channel of the Noatak adjacent to the village, no longer allowing barge traffic. This may be reflective of the change in the dominant flow channel. The R&M study indicated that the change in the dominant flow channel, from the West Channel to the East Channel, occurred sometime between 1998 and 2002. The 2006 aerial imagery (Figure 2) indicates that the upstream bifurcation point between the East and West channels continues to exist and the East Channel is the dominant flow channel.

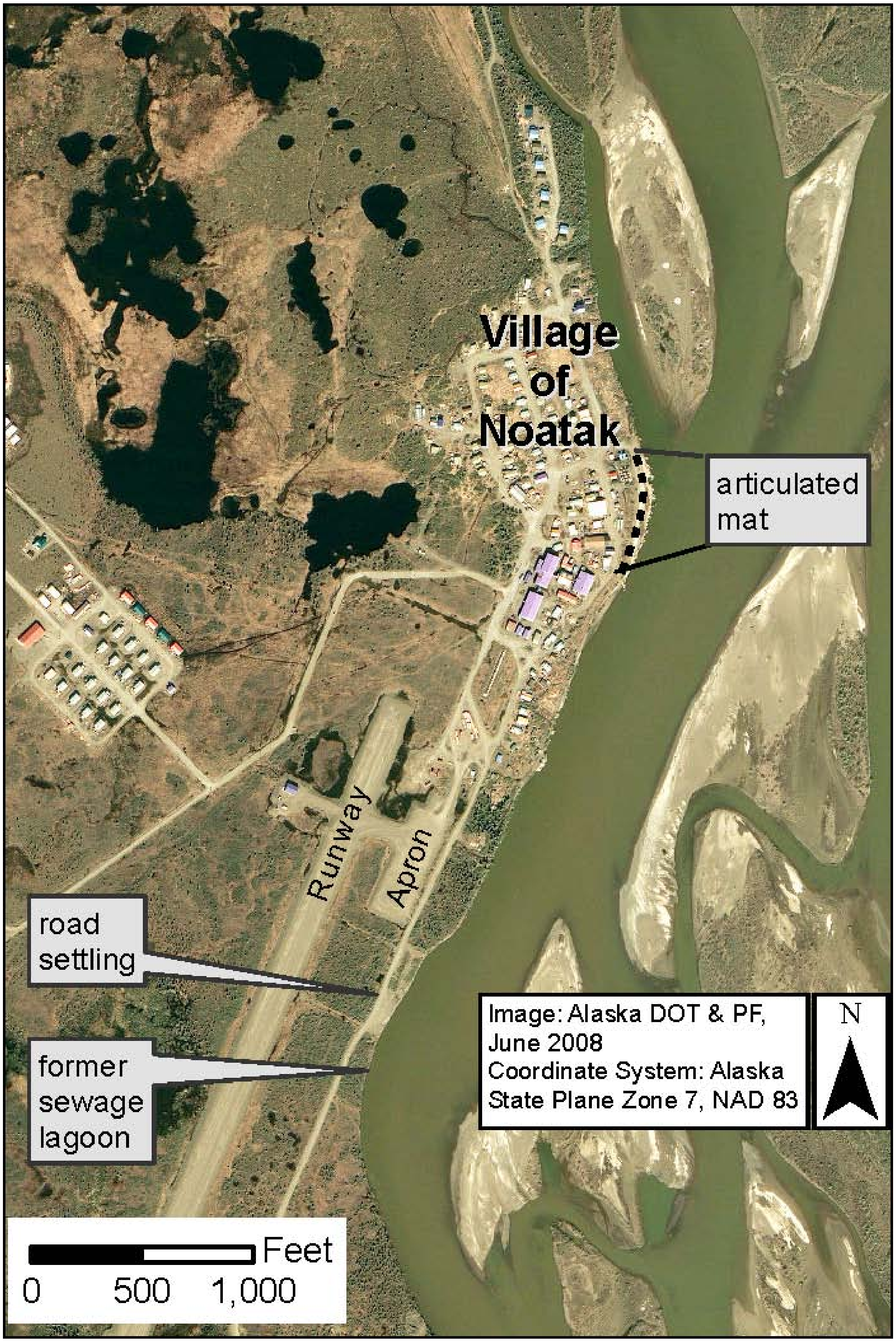


Figure 1: Study Area Features

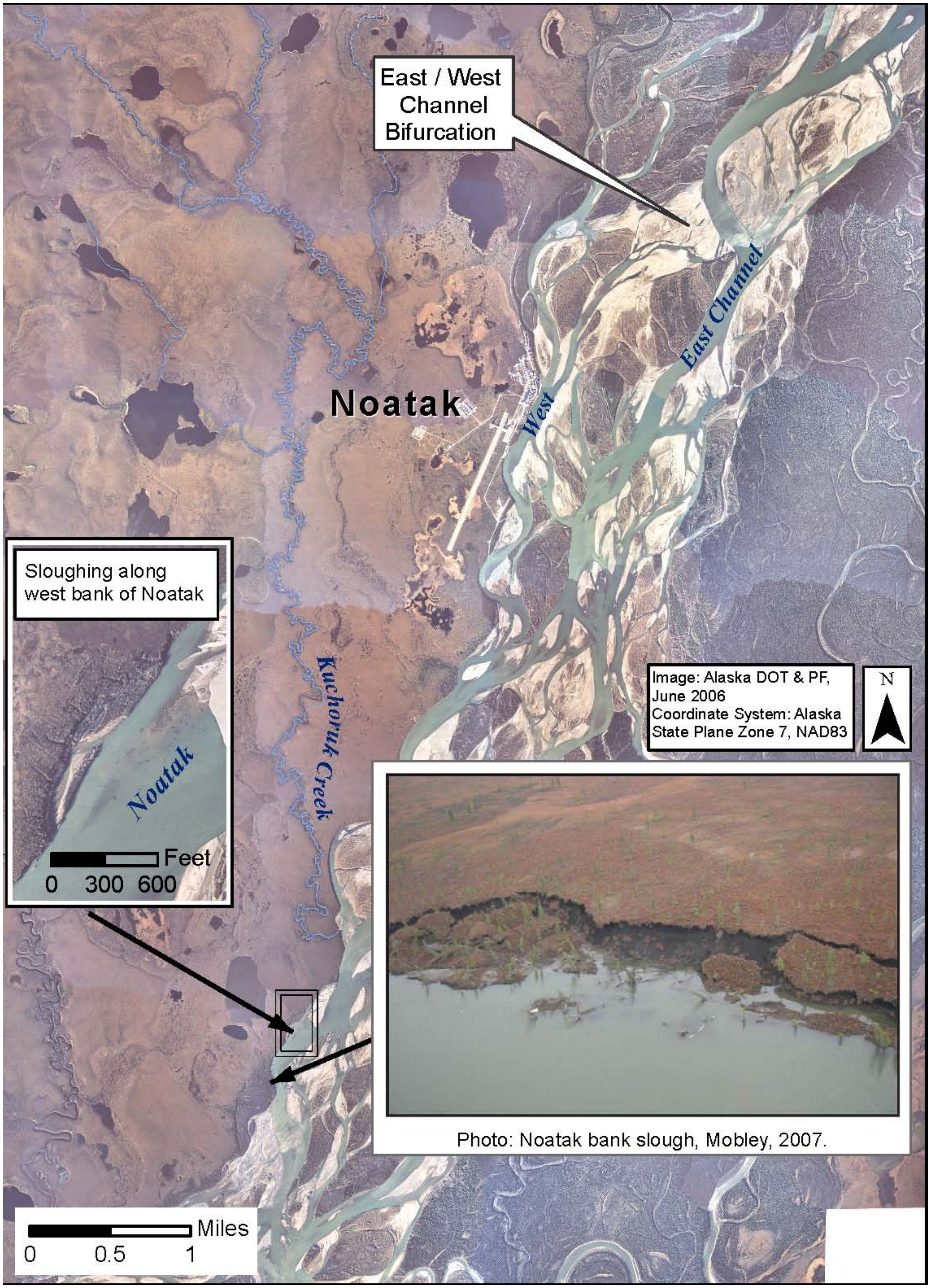


Figure 2: River Setting

Bank erosion has occurred along upstream and downstream portions of the Noatak River. Numerous incidents of erosion have been documented in the mountainous upper main stem of the Noatak River (Swanson, 2012). In the more lowland setting, within 15 miles upstream of the Village of Noatak, erosion has been observed on the west bank over the past 10 years (Kirk, 2013). In addition, approximately 75 to 100 horizontal feet of bank erosion on the west bank has been observed approximately 4 miles downriver from the airport (inset, Figure 2). The incidents of erosion on the west bank, even with the dominant flow not in this channel, are indicative of the westward migration of the river in general and may also reflect other erosion processes described in a following section.

2.2 Previous Studies

1. Erosion in the Vicinity of the Village. As early as 1976, *the "Environmental Considerations for Community Development"* prepared by the Alaska Department of Community and Economic Development Division of Community and Regional Affairs (DCRA) delineated active bank erosion starting about 400 feet upriver from the north end of the runway and extending approximately 800 lineal feet further up river. In 1981, 1,500 lineal feet of articulated concrete mat was installed in this area. This mat has been successful in stemming erosion of the bank above it, but portions of the mat have been undercut by the river and the mat is degrading in other areas.

2. Erosion in the Vicinity of the Airport. Based on aerial photo overlays for 1972 and 2000 in the R&M study, as much as 430 horizontal feet of erosion occurred along a 2,500-foot stretch of the west bank near the airport and former sewage lagoon. A DOT&PF Northern Region trip report dated September 21, 1978, included a photo that showed the sewage lagoon was intact. The R&M study indicated that the sewage lagoon was breached in 1984. The 1992 Environmental Assessment (EA) for runway extension and apron expansion describes westward migration of the river, facilitated by the presence of ice-rich silt that is eroded away more easily than gravel. An appendix to this EA includes a September 1991 memo indicating that the sewage lagoon had been washed out since a previous visit. These observations indicate progressive erosive activity over the 1978 to 2000 time period, averaging 20 feet per year.

3. Quantitative Documentation of Flow Regime. A 2002 U.S. Army Corps of Engineers (USACE) study (USACE, 2002) reported that the East Channel is the dominant low-flow channel (estimating that it carried about two-thirds of the river flow in September 2001, a relatively low-flow period) and probably is also the dominant high flow channel. This study indicates that the East Channel appears to be increasing in depth and capturing an increasing share of the flow and that the current planform favors this trend, because flow into the West Channel takes a perpendicular bend, increasing the potential that the West Channel will fill and have reduced capacity over time. The report observed that the West Channel does convey flow, particularly during high water events. This study estimated maximum bank erosion rates of up to 20 feet per year in some locations.

4. Erosion Rates Defined and Erosion Extents Projected. The R&M study discussed the relative flows in the East and West channels, as above. The study also evaluated potential erosion effects from further flow bifurcation just upstream of the village around an island that has experienced erosion. The R&M study identified historic bank locations from a series of aerial photos from 1952 through 2000 and for six discrete cross-sections, including two across the runway and apron areas of the airport. The study delineated potential maximum extents of erosion to occur by 2010, 2020, and 2050. By 2010, the projected maximum erosion would

extend into the apron and, by 2020, into the runway. For two cross sections in the airport area, the study estimated a maximum rate of erosion of 60 feet per year.

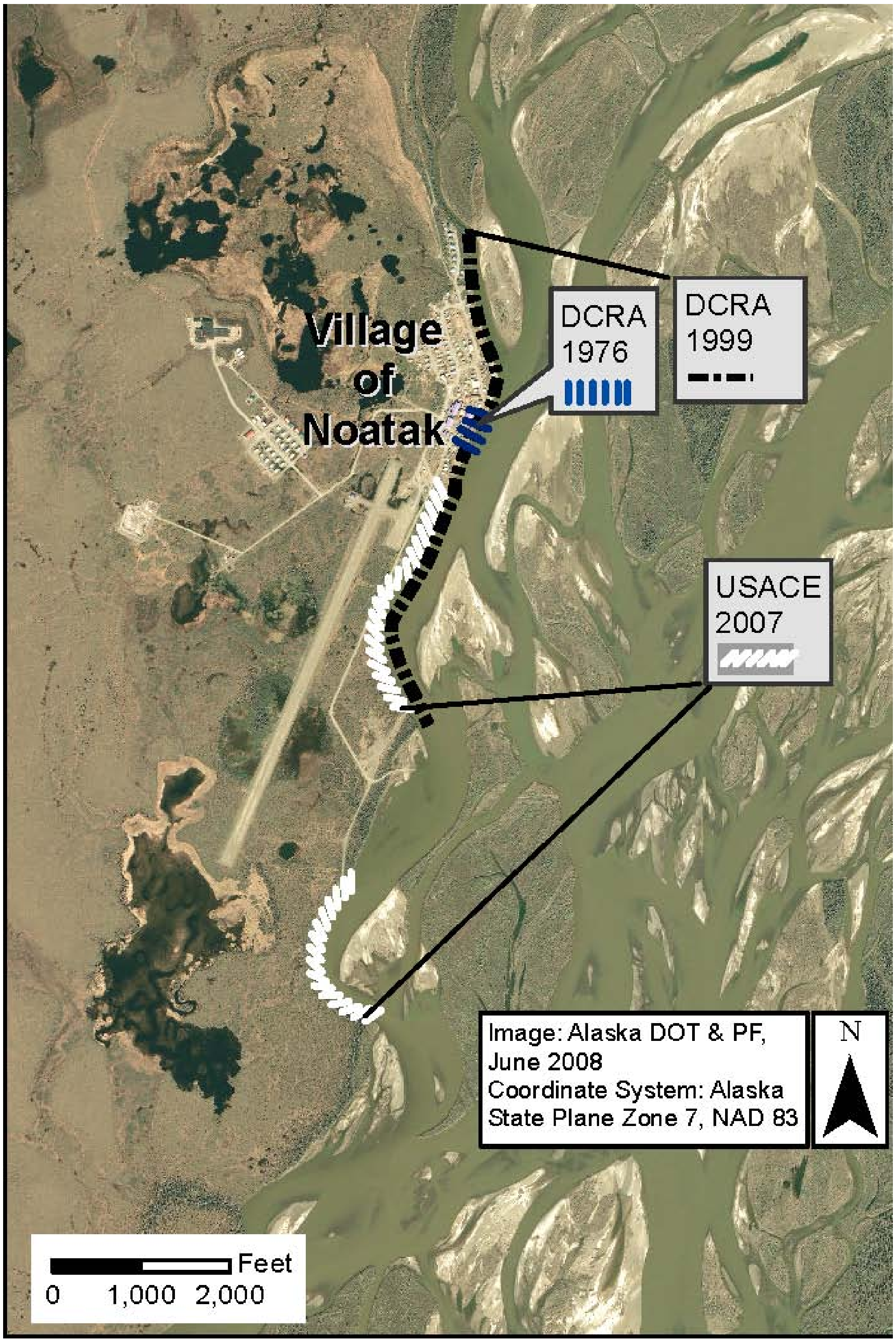


Figure 3: Areas of Erosion

5. Current Areas Subject to Erosion. Areas depicted on maps prepared by two agencies (DCRA, 1999 and USACE, 2007) in the past 13 years are shown on Figure 3. Erosion is more apparent in areas of high, steep banks, than along the area adjacent to the airport apron. The *Alaska Baseline Erosion Assessment* (USACE, 2009) rated Noatak as a "Monitor Conditions Community," having significant impacts related to erosion, in which taking action to prevent a problem from becoming worse would be prudent.

3 EROSION OBSERVATIONS AT NOATAK 2003 - 2012

1. Aerial photographs were obtained by DOT&PF for 2000, 2005, 2006, 2007, 2008, and 2011 and are shown in Figure 4. Because of varying water levels at the time of the photos, the absolute extent of erosion is not measurable at the level of detail in the aerial photos. However, between 2000 and 2005, it appears that about 80 horizontal feet have been lost, corresponding with erosion observed in May-June, 2004.

2. May-June 2004. Erosion was observed southeast of the airport apron during spring break-up. The environmental coordinator for the Village of Noatak notified DOT&PF that there was high water and active erosion on May 28, 2004. DOT&PF staff made a field visit on June 11th and estimated that the edge of Pit Road at the southeast corner of the apron was 125 feet from the riverbank.

3. August 2006. During a reconnaissance visit to assess gravel sources for a new runway (HDL, 2006), the hydrologist observed that significant permafrost was evident on the west mainland bank of the Noatak River, with active erosion present. The study *stated "The exposure of the massive ice at the cut bank and resulting erosion will likely continue whether or not the river geometry continues to direct energy toward the cut bank."*

Figure 4: Aerial Photography 2000 to 2011

4. August 2012. Significant erosion occurred southeast of the airport apron during a very rainy late summer period.

   - A DOT&PF sketch based on GPS coordinates collected on August 1, 2012, site visit and aerial imagery (Figure 6), indicates the distance from the southeast corner of the apron to the riverbank is now about 125 feet. Photos from that site visit (Figure 5) illustrate the bank height and the extent of erosion along the bank. DOT&PF personnel note that active erosion was occurring at Point C shown in Figure 6 and that erosion had occurred both up and downriver from Point C, as illustrated by the red line ("2012 anticipated shoreline") in Figure 6. The actual location of Point C may be somewhat closer to the river than shown on this figure, due to cloud cover interfering with the GPS satellite signal (Dianoski, 2013). Assuming Point C is only half the distance from the river edge than shown on Figure 3 and comparing this with the 2006 edge of bank, it appears that 20 to 30 horizontal feet had been lost.
   - DOT&PF's contract airport maintenance staff in Noatak described the erosion as occurring over several weeks, losing about a foot a day (Kirk, 2013). He described high water all summer and an eddy effect against the bank during the active erosion. The maintenance staff also observed sinkholes next to Pit Road, between the road and the runway. During the summer rain, runoff from the road entered the sinkholes but didn't fill them, apparently because water was seeping out. Seepage from the riverbank face on the other side of the Pit Road from the sinkholes was observed. This may indicate that there is direct seepage from the subsurface to the face of the riverbank.

Figure 5: Bank Erosion August 2012 Orange cones set along east side of Pit Road. (Left) looking upriver from Point C (Right) looking downriver from Point B

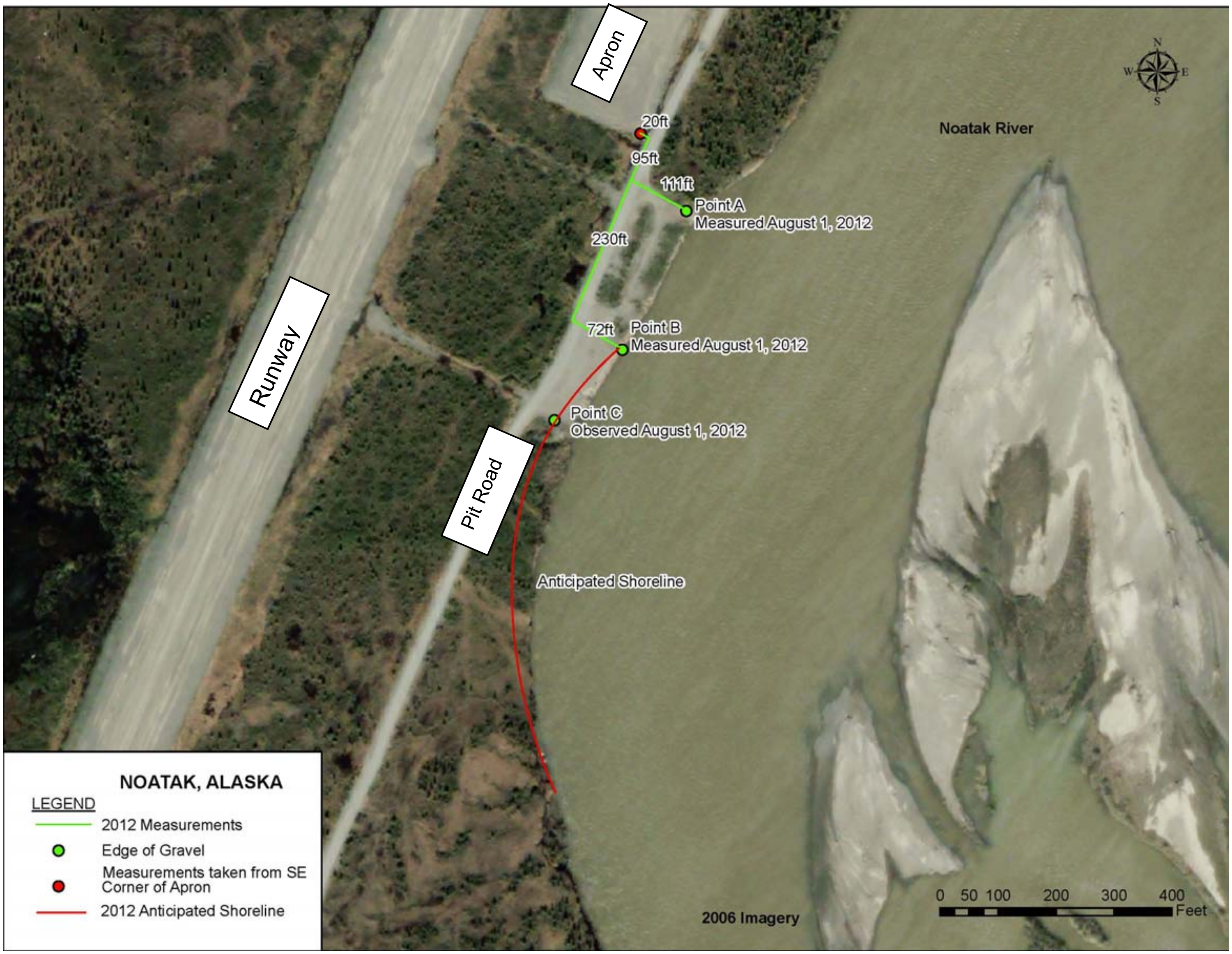


Figure 6: Measured Extents of Erosion August 2012

4 EROSION DRIVERS AND PROCESSES

Climate and river characteristics can influence the types and rates of riverbank erosion.

4.1 Types of Erosion

Thermal Erosion. Thermal erosion occurs when formerly frozen soil media thaws and slumps, particularly along rivers in permafrost settings (Scott, 1978; Lawson, 1989; Gatto, 1995). The Noatak watershed is underlain by continuous permafrost except in some localized areas; such as thaw bulbs associated with rivers, springs, or groundwater. Riverbank erosion processes in permafrost are primarily driven by this detachment of soil in the active (seasonally thawed) layer from the underlying permafrost layer. Deeper depths of thaw may be caused by exposure of the soil profile to ambient temperatures either after sloughing or due to site disturbance, which removes the insulating effects of vegetation (e.g., construction of the airport).

In non-cohesive (gravelly and sandy soils), thawing causes the loss of frozen water holding the soil matrix together at steep angles, and the exposed bank slumps to its angle of repose. In cohesive soils (silts and clays) deeper depths of thaw causes melt water to exert pore pressure as it drains. This seepage force and the saturation of bluff faces and cut banks causes slumping.

Sediment Transport. As the soil slumps, it may temporarily buttress the intact bank by providing slope toe protection and it may also provide thermal protection to the slope face as well. When this material is carried away by river flow, which may not necessarily require high flows, further slumping can occur. This starts the cycle over by exposing a new face to surface interaction, including warming and water seepage.

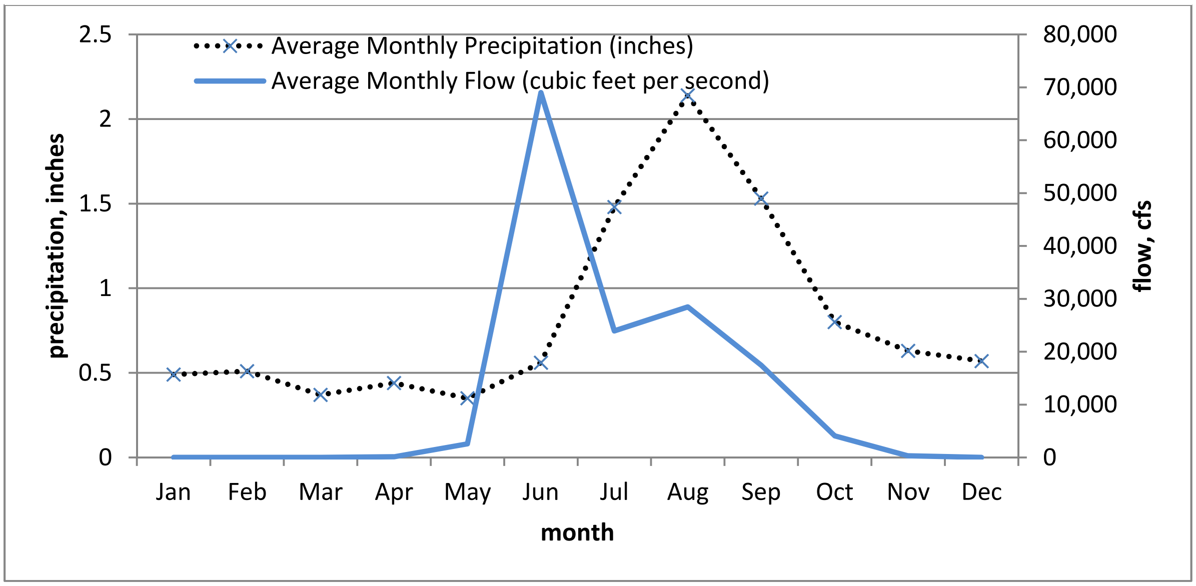
Particle Erosion. In addition to thermal erosion, due to changes in thaw depth and permafrost, aided by sediment transport, it has been observed (Kirk, 2013) that particle erosion due to shear stress and turbulence exerted by water flow occurs at higher flows. When higher flows occur at times when the bank material is not frozen, such as during late summer rains, the river flow will remove bank material as well as material at the toe.

4.2 Climate Influences

Historic Climate Setting. The precipitation pattern in the Noatak watershed follows a strong seasonal trend, with about 50 percent of the precipitation occurring in July, August, and September. Precipitation as snow accumulated from October through April melts during the May and June breakup period. Seasonal flows in the Noatak River respond to these climatic factors: spring high flows are linked to rapid snow melt while late summer and fall high flows are related to rainfall precipitation.

Figure 7 shows average monthly precipitation at Kotzebue and total flow in the Noatak River, as gauged by the U. S. Geologic Survey downstream from the split channel section. The Kotzebue Airport is the closest climate station to the Noatak Airport with a long record. Although these precipitation values were not measured at Noatak or in the Noatak watershed, they provide a representation of the seasonal precipitation variability. Flow was only measured for seven years (1965 to 1971) so does not reflect a robust or contemporary period of record, but does show seasonal flow variation.

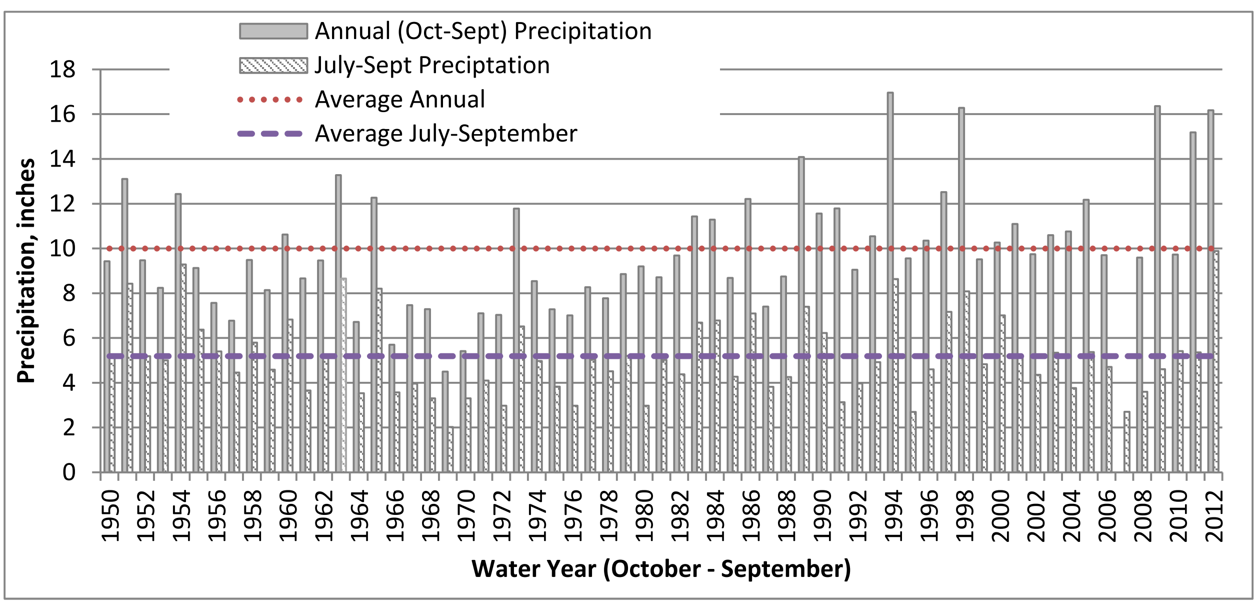
Figure 7: Average Monthly Precipitation and River Flow



Precipitation at Kotzebue Ralph Wein Memorial Airport Alaska, 1949 – 2012
Flow in Noatak River, U.S. Geological Survey (USGS) Gage 1574600, 1965 – 1971

Annual and late summer precipitation depths at Kotzebue Airport are shown in Figure 8. As mentioned above, although these values were not measured at Noatak, they provide a representation of the variability of precipitation from year to year and illustrate years of higher than normal precipitation. Note in particular the high precipitation in late summer 2012, corresponding with the erosion event that occurred in August 2012 as compared to the long-term July-September average.

Figure 8: Historic Precipitation at Kotzebue Ralph Wein Memorial Airport Alaska Period of Record: 1950-2012



Projected Climate Setting. In addition to year-to-year variability, the climate setting is experiencing decade-to-decade variability (Pacific Decadal Oscillation) and a trend towards long term warming.

Long term warming causing permafrost degradation due to deepening of the active (seasonally thawed) layer has been well documented (Romanovsky et al, 2010). The Scenarios Network for Alaska and Arctic Planning, University of Alaska, (SNAP, 2013) has developed projections of temperature and precipitation for communities in Alaska. Table 1 shows a summary of the projected increases in precipitation and temperature for Noatak through 2040.

Table 1: Historic and Projected Temperatures and Precipitation at Noatak

Temperature (^{o}F)		Precipitation (inches)	
Historic	Projected	Historic	Projected
(1961-1990)	(2031-2040)	(1961-1990)	(2031-2040)
26	27.3	12.4	14.9

Other climate factors, such as entering into a ‘cold’ period of the Pacific Decadal Oscillation (PDO) might have other effects. For example, during cold periods of the PDO, above average summer flows may occur (Brabets and Walvoord, 2009). Since there is less seasonal frost in warmer months, higher flows during those periods are more likely to transport materials deposited by slumping or to cause active particle erosion, as occurred in 2012.

These trends of higher precipitation and warmer temperatures, if continued, will accelerate normal thermal erosion processes. As noted above, higher flows related to fall precipitation occur at times when the banks are not frozen, so that both particle erosion and sediment transport of thermally eroded sediment can occur. Although the projected increase in precipitation has not been quantified by season, if it were to occur in late summer, it would likely cause corresponding high flows, leading to further bank erosion.

In general river processes, peak erosion events do not necessarily correlate with peak flows, indicating that erosion can occur at a steady rate. It is also common, in other settings, to have relatively long periods of little erosion punctuated by short periods of marked erosion. Along the west bank at the Noatak Airport, where both thermal and particle erosion processes are in play, both ordinary and high flow events contribute to sediment removal and bank erosion.

4.3 River Characteristics

Split Channel. As indicated in both the R&M study and the USACE letter report (UASCE, 2002) the split between the East and West channel is present, with the dominant flow in the East Channel at present. The USACE letter report indicates that the bifurcation appears to be fairly stable. Local observers (Kirk 2013) confirm that the East Channel continues to be the main channel. This is also apparent in a 2006 aerial photo (Figure 3).

Although the channels of split-channel rivers are generally more stable than braided channeled rivers, the history of channel-shifting upriver from Noatak indicates that this could happen again. Since the process leading to this shift is not well understood, a shift back to the West Channel cannot be discounted.

River Planform and Migration. Another pattern of the Noatak River in this area is its sinuosity, typical of braided and split-channel rivers, as shown by its arcuate channel forms. As mentioned previously, erosion along the bank at the airport and Village of Noatak are not isolated cases and are part of a more pervasive trend of channel migration in this arcuate pattern.

Underlying Materials. The Noatak River has capacity to move sediment, as evidenced by its mobile gravel bed and point bar islands. Its banks are comprised of erodible gravels, silts, and sands and there is a lack of any resistant material, such as bedrock control, to limit the erosion potential (Stevens et. al., 2003).

5 EROSION AND POTHOLING IN THE VICINITY OF THE AIRPORT

5.1 Erosion Processes in the Vicinity of the Airport

In the immediate area of the airport and village, localized effects of flow focusing, island position, channel plan form patterns, and bank protection affect the location of erosion.

Flow Focusing and Island Position. As discussed in the R&M study, the bifurcation of the West Channel into the A and B channels in the vicinity of the Village and the potential for changes in these channels creates more uncertainty about the trajectory of the water and timing of potential changes. Focusing the flow, and higher flow, towards the west bank, would accelerate erosion.

Channel Planform Patterns. The general pattern of planform of the Noatak River in this reach of the river is sinuous and arcuate (Figure 2) and the projected erosion extents in the R&M study reflects this. The leading edge of the erosion observed in 2004 and 2012 follows that pattern. Notable at the Noatak Airport, downriver from articulated mat, is a long stretch of linear rather than curved channel pattern. As discussed in the R&M study and apparent from observed erosion, a meander pattern is likely to develop. The upgradient bank armoring may have forestalled this channel migration and failure in that armoring may accelerate erosion.

Localized Bank Protection. Silt is the predominant foundation soil in the vicinity of the airport (DOT&PF, 1986) and there is a lack of any bedrock control. Although permafrost can act as erosion protection, its loss due to thermal erosion provides a thaw mechanism to accelerate erosion. However, the presence of the articulated concrete mat up river is likely to be affecting the flow such that it is focused parallel to the bank adjacent to the airport apron, and somewhat more towards Point C in Figure 6. Failure of the articulated mat could move the focus of the flow more towards the apron and accelerate erosion along a longer section of riverbank adjacent to the runway.

5.2 Pot-holing of Pit Road

Pot-holing and depressions in the access road parallel to the runway have occurred. The four most likely and interrelated reasons are non-homogeneous subgrade, thermokarsting, freeze-thaw action, and active piping of soil.

1. Non-homogeneous material can settle differentially, particularly when subjected to variable moisture conditions (dry early summer, wet late summer) and freeze-thaw conditions. A March 8, 1981, letter from the Alaska Village Electrical Cooperative to DOT&PF indicated that scrap metal had been buried in the road to the apron and that freeze-thaw action had brought it to the surface. While it is not known if this is in the same vicinity of the current areas of concern, it is an example of the possibility of non-homogenous material. Given comparatively light traffic usage on this road, it may take a longer time for the subsurface discontinuities to appear. But

given the 20+ years since the fill was placed and the road put into service, it is likely that these will continue to occur.

2. Thermokarsting. This phenomenon occurs when ice-rich lenses in the foundation material below the surface (in this case, below the road embankment) become thawed and melt water flows out. Melt water from these lenses can flow laterally through subsurface material and seep out of bluffs or cut faces, such as riverbanks, or it can wick up through the overlaying material, particularly if the material is fine-grained, where it pools on the surface and evaporates or flows off. As melt water leaves, the voids it occupied collapse, resulting in subsidence at the surface.

   Logs of boreholes installed by DOT&PF NR (to maximum depths of 8 feet) in the vicinity of the runway and apron in September 1986 (DOT&PF, 1986) noted ice-rich soils or lenses in three boreholes at depths from 1 to 6 feet below ground surface, and depth to frozen soil of no more than 5 feet. If the ice lenses were also present along the road alignment, which is likely, this would provide the setting for thermkarsting to occur.

   Note that by contrast, logs of boreholes installed (to maximum depths ranging from 10 to 13 feet) in September 2006 (DOT&PF 2008) in the apron area and along the runway indicate depth to frozen soil of 8 to 11 feet and no notations of ice lenses above the frozen soil. Although there is likely year-to-year variability in active layer thickness (in this case approximated by depth to frozen soil in September), the difference between a maximum of 5 feet in 1986 and a minimum of 8 feet in 2006 may also be reflective of a trend in permafrost degradation.

3. <u>Freeze-thaw action</u>. Localized depressions caused by settling, whether due to thermokarsting or non-homogenous subsurface material, will accumulate water. If water accumulates just before freeze-up, for instance due to late summer rains before it can evaporate or infiltrate, its expansion during winter freezing and subsequent contraction during breakup can cause potholing as well.

4. <u>Piping</u> is a mechanism of internal or subsurface erosion caused by seepage. When water accumulates, as in a temporary sinkhole caused by thermokarsting, and hydraulic pressures rise, seepage forces can erode fine soil particles, leading to loss of material and failure of the embankment or surface. Assuming the road is underlain by more permeable material (gravel) than the adjacent foundation soil, this offers a preferential pathway for the water to seep towards the riverbank, accelerating the loss of subsurface fines and leading to subsidence, and in some cases, more dramatic failure.

   Given the observed conditions of permafrost degradation and proximity to the eroding riverbank, it's likely that the sinkholes and depressions found in Pit Road are related to the mechanisms causing the riverbank failure.

6 CONCLUSIONS

6.1 Riverbank Erosion

The prognosis is that the west bank of the Noatak River in the vicinity of the Noatak Airport will continue to erode as suggested in the R&M study. The vertical face of the west bank of the Noatak River will continue to slump due to thermal erosion. As the slumped material is removed by river flow, the west bank will recede towards the west.

This prognosis is based on evidence of continued slumping since 2003 and environmental factors.

1. Evidence of Slumping. Major episodic sloughing of the banks next to the airport occurred in 2004 and 2012. Slumping and erosion of the west bank has also occurred in other places up and down the river.

2. Environmental Factors. The factors that contribute to the continuing potential for significant erosion are still at play, as follows:
   - Even in stable temperature regimes, slumping due to thermal erosion is a characteristic of rivers in areas with continuous permafrost. With projected warming trends, this thermal erosion is likely to accelerate, due to accelerated permafrost degradation.
   - Projected increase in precipitation is likely to increase the incidence of high flows leading to particle erosion.
   - Continued deterioration of the articulated mat upriver from the apron may lead to more failure in that vicinity. Failure in that area would likely change the trajectory of the flow and bring more shear stress and turbulent flow to bear on the riverbank adjacent to the airport apron. Changes in flow patterns in the West Channel immediately upriver from the Village (so called channels A and B) may also change the flow trajectory.
   - The upstream bifurcation of the East and West channels continues to shunt the water towards the east, which will reduce the risk somewhat, especially if depositional processes there maintain the East Channel as the dominant flow channel. While currently stable, if more water were to flow in the West Channel, it is more likely to cause accelerated erosion on the west bank in general and potentially in the vicinity of the Noatak Airport.

The timing of major erosion events is difficult to predict. The August 2012 erosion appeared to be due to extremely high precipitation and flow, while the 2004 event did not appear to be correlated with precipitation.

6.2 Access Road Deterioration

Based on information related by site observers, thermokarsting and piping appear to the contributing causes for sinkholes and depressions in Pit Road. The piping is accelerated as the distance to the cut bank is reduced, such that continued west bank erosion may cause more thermokarsting to occur by providing a path for melt water to dissipate.

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