COASTAL FLOOD IMPACT ASSESSMENTS FOR ALASKA COMMUNITIES—HOOPER BAY

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Flood waters surround the town of Hooper Bay and cut off access across the center. The airport road remains mostly above water. Photo: William Naneng, September 16, 2016.

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Report of Investigation 2021-1F Hooper Bay

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Division of Geological & Geophysical Surveys

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COASTAL FLOOD IMPACT ASSESSMENTS FOR ALASKA COMMUNITIES—HOOPER BAY

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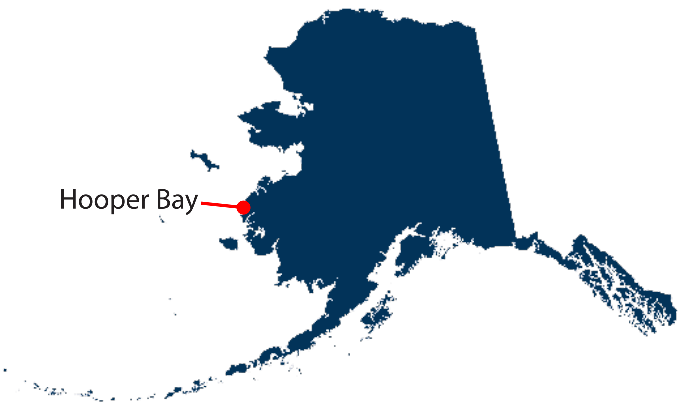
OVERVIEW

This report is an assessment of the historical flood record and flood impact levels for the community of Hooper Bay, Alaska. Methods used to evaluate historical floods and designate flood impact elevations (minor, moderate, or major; as defined by the National Weather Service) are described in detail in an overview report (Buzard and others, 2021). This community-specific report has three sections: data description, historical flood record, and flood impact categories. Flood and infrastructure heights are relative to the local mean higher high water (MHHW) datum. All estimate uncertainties are reported to the 95 percent confidence interval. Quoted text from the sources used to estimate storm heights can be found in Appendix A, and Appendix B has tables and figures used to determine flood category heights.



SUMMARY

Flood categories and related infrastructure heights are listed in table 1, and estimated storm heights are listed in table 2. There have been two federal disaster declarations for flooding that involved Hooper Bay (2005 and 2011). From the late 1960s to 2016, Hooper Bay may have experi-

Table 1. Summary of infrastructure heights and flood categories. Infrastructure that may be subject to wave runup is indicated. Purple = major, red = moderate, yellow = minor. Gray represents infrastructure not expected to be impacted by coastal flooding.

	Elevation Feature	Elevation (ft MHHW)	Vertical Uncertainty (ft)	Subject to Wave Runup
Other	School	28.0	4.0	
Major	Airstrip covered	12.5	0.3	
	Several buildings	10.0	1.0	
	Wastewater facility	10.0	0.3	
	Drinking water source	9.6	0.3	
	Lowest residences	9.0	1.0	
	Fuel Tanks	7.6	0.9	
	Major	**7.6**	**0.9**	
Moderate	Airstrip use or access	4.9	1.0	
	Access way to larger parts of town	4.8	0.3	
	Moderate	**4.8**	**0.3**	
Minor	Access road threatened	4.0	0.3	
	Lowest building	3.2	0.3	
	Beach property	3.1	0.8	
	Minor	**3.1**	**0.3**	

[1]Alaska Division of Geological & Geophysical Surveys, 3354 College Rd., Fairbanks, Alaska 99709-3707.

Table 2. Summary of estimated historical storm heights. Flood categories are included for reference: purple = major, red = moderate, yellow = minor. The categories are based on current infrastructure conditions, not the conditions when the storm occurred.

Estimated Storms

Storm	Elevation (ft MHHW)	Vertical Uncertainty (ft)
2005-SEP-22	7.7	1.4
2004-OCT-15	7.3	1.8
1979-NOV-15	7.3	1.8
1974-NOV-10	7.1	1.7
2011-NOV-08	5.5	1.2
2016-SEP-19	4.1	1.0
1978-DEC-01	3.9	1.2

Not Estimated Storms

Storm	Elevation (ft MHHW)	Vertical Uncertainty (ft)
2006-OCT-27	—	—
1991-NOV	—	—
1988	—	—
1960s	—	—

enced at least eleven significant coastal flood events from storm surge. Of these reported events, we estimated the peak still water elevations of seven storms. At the time they occurred, these storms caused two minor, two moderate, and three major floods. If these storms occurred with Hooper Bay's current infrastructure, they would have caused two minor, four moderate, and one major flood. The highest recorded storm occurred on September 22, 2005, reaching a still water height of 7.7 ± 1.4 ft MHHW. Water may have reached 2 to 4 ft higher in areas subject to wave runup.

DATA

Mapped data were used to interpret flood elevations from historical photographs and accounts. Data that were available and used for the community of Hooper Bay are described in this section.

Digital Elevation Model and Orthoimagery

Two digital elevation models were available for Hooper Bay (table 3). A digital surface model (DSM) and orthoimagery were collected in 2015 (Overbeck and others, 2016). In 2016, a lidar bare-earth digital elevation model (DEM) was collected (Woolpert, 2017). The airport runway was improved between these two collections, so both datasets are pertinent to this study.

Table 3. Specifications of elevation models available for Hooper Bay.

	Photogrammetric DSM	Lidar DEM
Collection date	9/1/2015	8/30/2016
Elevation type	Surface	Bare earth
Ground sample distance	0.19 m	1.00 m
Vertical accuracy	0.19 m	0.09 m
Vertical datum	NAVD88 (GEOID12B)	NAVD88 (GEOID12B)

Tidal Datum

Local tidal datums collected near Hooper Bay at Dall Point were used to convert elevations to MHHW for this report (station 9466931; National Oceanographic and Atmospheric Administration Center for Operational Oceanographic Products and Services [NOAA CO-OPS], 2018; table 4).

FLOOD IMPACT CATEGORIES

Flood impact categories are used by the National Weather Service to define and communicate flood risk to the public. The categories are designated as minor, moderate, and major. A flood advisory is issued when a storm is forecast to cause minor flooding, while a flood warning is issued for moderate or major flooding. Definitions of minor,

Coastal Flood Impact Map
Hooper Bay, Alaska

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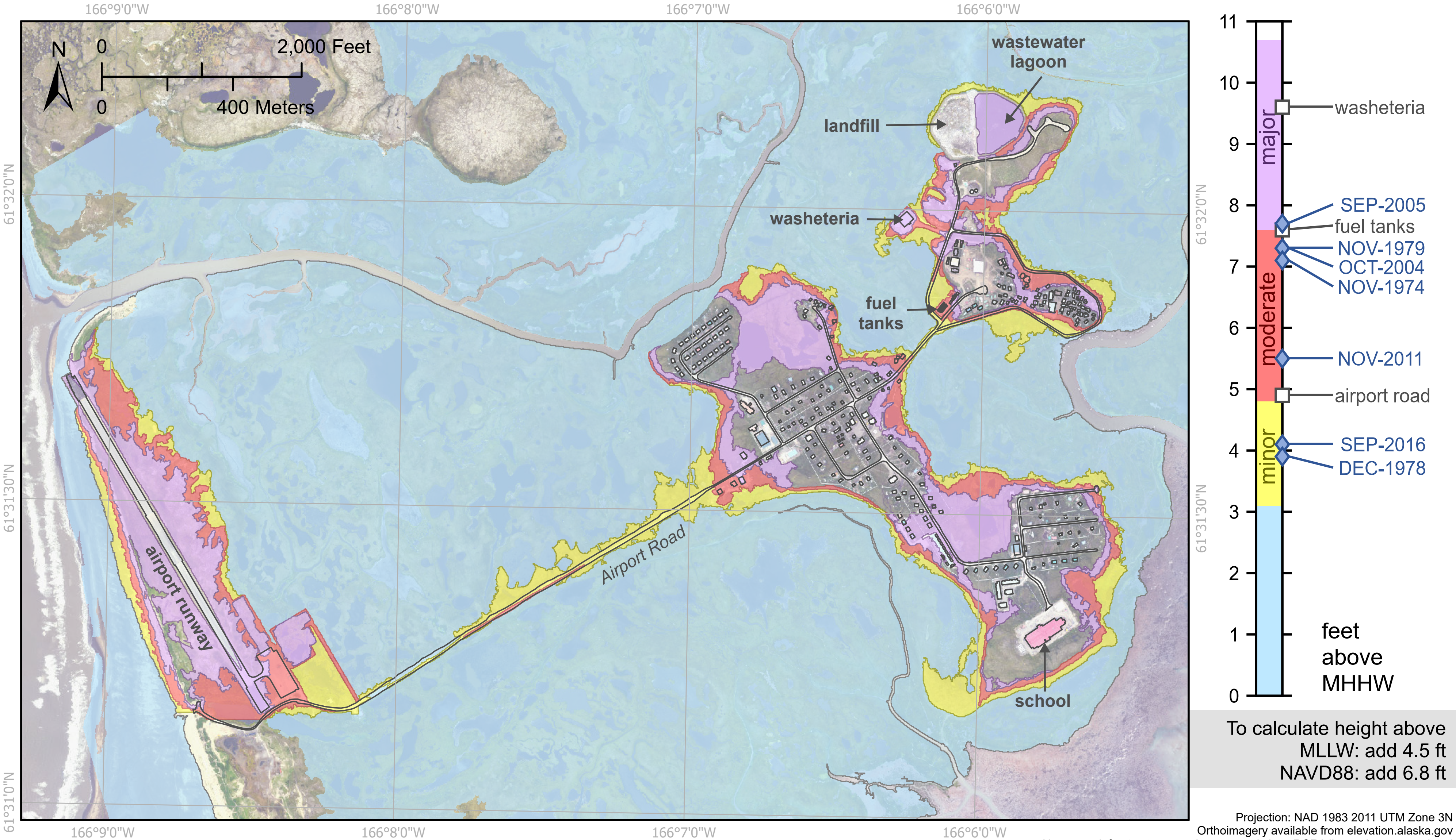

To calculate height above
MLLW: add 4.5 ft
NAVD88: add 6.8 ft

Projection: NAD 1983 2011 UTM Zone 3N
Orthoimagery available from elevation.alaska.gov
Houses or infrastructure may have moved since DCRA linework was completed

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Major Flooding is defined to have extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations are necessary.

Moderate Flooding is defined to have some inundation of structures and roads near the water. Some evacuations of people and/or transfer of property to higher elevations may be necessary.

Minor Flooding is defined to have minimal or no property damage, but possibly some public threat.

This work is part of the Digital Coast Fellowship project: Bringing Alaska to the Digital Coast. The analysis was paid for by the National Oceanic and Atmospheric Administration Office for Coastal Management, and the State of Alaska.

Table 4. Tidal datum for Hooper Bay from NOAA CO-OPS (2018), with reference to NAVD88 using shared solution of tidal benchmark (National Geodetic Survey, 2019).

Tidal Datum	Abbreviation	ft MHHW	m NAVD88
Mean Higher High Water	MHHW	0.00	2.06
Mean High Water	MHW	-0.71	1.85
Mean Tide Level	MTL	-2.40	1.33
Mean Sea Level	MSL	-2.61	1.26
Mean Low Water	MLW	-4.08	0.82
Mean Lower Low Water	MLLW	-4.46	0.70
North American Vertical Datum of 1988	NAVD88	-6.76	0.00

moderate, and major flooding are provided below followed by the information used to establish the elevation thresholds for each category at Hooper Bay. Elevation thresholds and locations mentioned in the narrative below have been mapped using the DEM (map sheet Hooper Bay, previous page).

Minor Flooding: Minimal or no property damage, but possibly some public threat.

Moderate Flooding: Some inundation of structures and roads near the water. Some evacuations of people and/or transfer of property to higher elevations may be necessary.

Major Flooding: Extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations are necessary.

Other Infrastructure

Evacuation center (school): 28 ± 4 ft MHHW

Flooding of the evacuation center (in this case the school) would represent a major flood. The school in Hooper Bay is higher than coastal flooding is expected to reach. The ground under the school ranged between 18 and 23 ft MHHW, with an average height of 21 ± 3 ft MHHW. From photographs, it appeared that the school was elevated above the ground by as much as 10 ± 3 feet where the ground is lowest. This would make the school height estimate 28 ± 4 ft MHHW. The lowest point of the access road to the school was about 10 ± 0.3 ft MHHW, so access would be cut off by up to 1 ft of water during a flood of 11 ft MHHW.

Major Flooding: 7.6 ± 0.9 ft MHHW

Fuel Tanks: 7.6 ± 0.9 ft MHHW

The current tank farm had a sandbag barrier that ranged between 6.6 and 8.8 ft MHHW and averaged 7.6 ± 0.9 ft MHHW (fig. B3).

Drinking water source: 9.6 ± 0.3 ft MHHW

City and Native Village of Hooper Bay (2015) explained that three drinking water wells were drilled in 1997, 3 miles northeast of town. The exact location could not be identified. The water treatment plant and washeteria were the same building, which was on ground up to 9.6 ± 0.3 ft MHHW. A flood reaching 9.6 ± 0.3 ft MHHW would cover the entire area of the water treatment plan, cutting off access to the facility.

Wastewater facility: 10.0 ± 0.3 ft MHHW

The sewage lagoon was the northernmost infrastructure in town. There was a dirt road system surrounding the sewage lagoon that acted as a barrier to flood water. The road averaged 13.2 ± 1.2 ft MHHW, but had a section dropping as low as 10.0 ± 0.3 ft MHHW (fig. B5). If a flood reached the lowest height, it would flood the sewage lagoon.

Several buildings (flooded 1 or more ft): 10 ± 1 ft MHHW

The ground height of 288 buildings was measured using the DEM. There were 31 buildings (11 percent) on ground below 10 ft MHHW (fig. B1). Using the conservative estimate that the first floor is 2 ± 1 ft above the ground, water reaching 10 ± 1 ft MHHW would flood 9 buildings with 1 or more feet of water.

Airstrip covered: 12.5 ± 0.3 ft MHHW

The majority of the current airstrip is between 12 and 12.5 ft MHHW, but it lowered to around 9 ft MHHW toward the southeast end by the apron (fig. B4). Water reaching 12.5 ± 0.3 ft MHHW would cover the airstrip, leaving debris and possibly eroding sections. The airstrip is subject to wave runup.

Moderate Flooding: 4.8 ± 0.3 ft MHHW

Lowest residences (flooded 0 to 1 ft): 9.0 ± 1.0 ft MHHW

City of Hooper Bay and others (2007) explained that homes along the banks of the slough areas are often flooded, although the context was related to spring river flooding. Residences were identified in the DCCED (2007) map, and 21 new structures were identified in the 2015 orthomosaic that were also assumed to be residences. The first floor elevations were not known for Hooper Bay buildings. From ground and aerial oblique images, most buildings appeared to be elevated above the ground, often by at least 2 ft. The maximum ground height under the lowest five residences identified was at most 7.0 ± 0.3 ft MHHW (fig. B1). Adding a conservative 2 ± 1 ft AGL estimate for the first floor, this meant these residences would flood at 9.0 ± 1.0 ft MHHW.

Airstrip use or access: 4.9 ± 1.0 ft MHHW

The USACE (2007) erosion report stated, “Loss of the access road or airstrip, even temporarily, could cause considerable social and economic stress to the community.” The road to the airstrip ranged from 4.0 to 6.5 ft MHHW and averaged 4.9 ± 1.0 ft MHHW. At the average height, half of the road would be under 0.9 ft of water or less, cutting off access.

Access way to larger parts of town: 4.8 ± 0.3 ft MHHW

The road between Old Town and New Town would be almost completely under water during a flood of 4.8 ± 0.3 ft MHHW, but the water would be less than 1 ft deep (fig. B3).

Minor Flooding: 3.1 ± 0.3 ft MHHW

Access road threatened: 4.0 ± 0.3 ft MHHW

There are three sections of the community that are connected by only one road. The northeast area is called “Old Town” and the southwest area “New Town,” and the third section is the airstrip (City and Native Village of Hooper Bay, 2015). All three are connected by Airport Road. The section of Airport Road connecting the airstrip to New Town ranged between 4.0 and 6.5 ft MHHW, averaging 4.9 ± 1.0 ft MHHW (fig. B2). Water would be near the road without cutting off access at 4.0 ± 0.3 ft MHHW.

Lowest building: 3.2 ± 0.3 ft MHHW

Ground heights under buildings were measured from the DEM using a vector shapefile of buildings created from Alaska Department of Commerce, Community and Economic Development (DCCED, 2007; fig. B1). The maximum ground height was used to estimate the height of each building. The lowest building was a structure near the airport at 3.2 ± 0.3 ft MHHW. The next lowest building was 5.1 ± 0.3 ft MHHW. The buildings may be elevated above the ground height, but this metric for minor flooding would be triggered if water goes under a building.

Beach property: 3.1 ± 0.8 ft MHHW

The property left on the beach was mainly boats at the river access area. The top of the boat ramp was 2.0 ft MHHW, and the road itself was 3.1 ± 0.8 ft MHHW. The road height was used as an indicator of when property near the beach may be at risk of minor flooding.

HISTORICAL FLOOD RECORD

The historical flood record for Hooper Bay, Alaska, is listed here from the earliest recorded storm to the most recent (up to September 2016). The sources used in evaluating each storm are listed, along with a brief summary of the relevant information found within. This historical information is used to estimate the flood height where possible. This storm record depends on information that is available to the public. As a consequence, it is possible that storm and flood events have occurred that are not reported here. For the direct quotations from each source that were used to evaluate these storms, see Appendix B.

Late 1960s | No water level estimate

Reference	Source information used to estimate storm height
USACE (1992)	2 feet above annual flooding, city dump site flooded

The only reference for this storm came from a written survey (U.S. Army Corps of Engineers [USACE], 1992). The exact date was not specified, but it may have been a 1967 storm in Norton Sound, or a 1969 storm that caused significant damage in Goodnews Bay. No homes were flooded, and the only impact stated was flooding of the city dump, which was not identified in historical aerial imagery, so the storm could not be estimated.

1974-NOV-10 | 7.1 ± 1.7 ft MHHW

Reference	Source information used to estimate storm height
USACE (2017)	High water mark on fuel tanks. http://maps.dggs.alaska.gov/photodb/#show=12&search=hooper%20bay%20november%201974
Terenzi and others (2014)	“erosion at airport and warehouse damage”
Chapman and others (2009)	None
Wise and others (1981)	None
Alaska Division of Emergency Affairs (1980)	Water reached steps of some homes. Wind and water knocked down a fuel tank. Water covered road between housing site and main town.

Flood water from this storm reached 36 inches above ground level at the fuel tank farm south of the Alaska Native Industries Cooperative Association (ANICA) store (USACE, 2017). The ANICA building and tank farm were in a different location than they are today, as evidenced in the 1980 and 1975 aerial images and photographs from circa 1968 and 1977. USACE (2017) provided two photos of residents identifying the high water mark on the tanks. The method used to measure the mark was not stated, and given that 36 inches is exactly 3 ft it was assumed that the water height was accurate to the nearest 1 ft.

The ground height at the old tank farm averaged 4.1 ± 0.8 ft MHHW (fig. 1). The ground cover had changed since removal of the tank farm. It was still a 1-ft-lower area than the nearby boardwalk, as it appeared in the 1968 photos, so it was estimated that the bare-earth height may have changed by 1 ft at most. The storm was estimated to have reached 7.1 ± 1.7 ft MHHW (table 5). Flooding at this height would have reached the steps of three homes near the dock, which no longer exist.

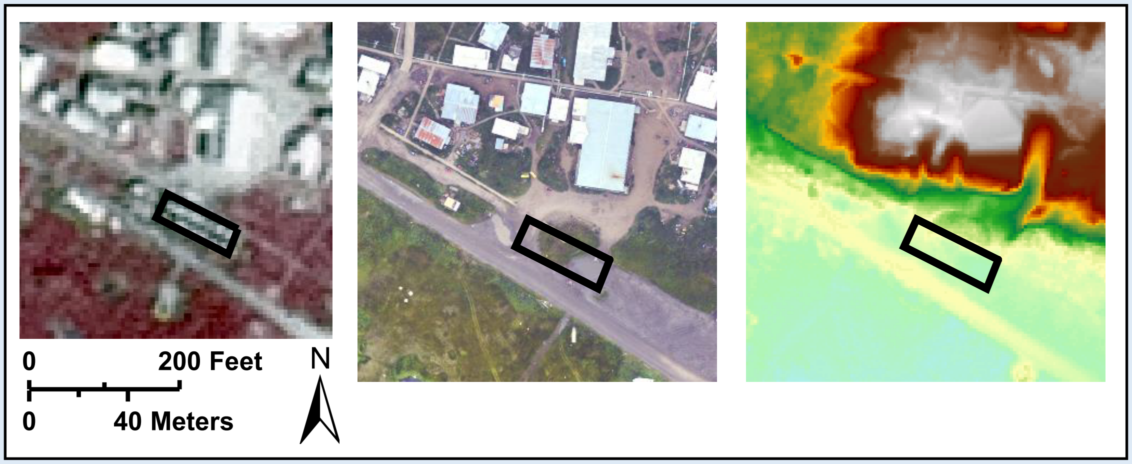

Figure 1. (Left) Image from 1980 of Hooper Bay tank farm outlined in black. (Middle) 2015 orthoimage with previous tank farm location outlined in black. (Right) Lidar bare-earth model of the same location.

Table 5. Flood parameters used to estimate the November 10, 1974, storm. Uncertainty was calculated using the root-sum-of-squares (RSS) error.

Feature	Water line on fuel tanks
Feature represents	Highest water
Water level type	Still water
Mean ground height (ft MHHW)	4.1
Water height estimate (ft above ground)	3.0
Ground height measurement uncertainty (ft)	0.9
Ground modification uncertainty (ft)	1.0
Uncertainty of elevation model (ft)	0.3
Water height uncertainty (ft)	1.0
Storm height and uncertainty (ft MHHW)	**7.1 ± 1.7**

1978-DEC-01 | 3.9 ± 1.2 ft MHHW

Reference	Source information used to estimate storm height
USACE (2017)	None
Wise and others (1981)	Boats and fish nets damaged
Alaska Division of Emergency Affairs (1980)	Boats, fish nets, fish racks, and other equipment damaged, erosion at airstrip. No public facilities or homes flooded.

Wise and others (1981) considered this event a minor flood, and the only damage listed was to beach property. The water reached high enough to damage beach property (3.1 ft MHHW), but possibly not high enough to cause more moderate damages (4.8 ft MHHW; table 1). The storm was estimated to reach 3.9 ± 1.2 ft MHHW (table 6).

Table 6. Flood parameters used to estimate the December 1, 1978, storm. Uncertainty was calculated using the upper-lower bounds method.

Feature	Minor flooding
Feature represents	Highest water
Water level type	Still water
Estimate of height (ft MHHW)	3.1 to 4.8
Elevation model error (ft)	0.3
Lower bound (ft MHHW)	2.8
Upper bound (ft MHHW)	5.1
Mean and uncertainty (ft MHHW)	**3.9 ± 1.2**

1979-NOV-09 | 7.3 ± 1.8 ft MHHW

Reference	Source information used to estimate storm height
USACE (2017)	None
USACE (2007)	Erosion at airstrip
City of Hooper Bay and others (2007)	Not as bad as 2005
Wise and others (1981)	"...damage exceeded November 1974 storm... Maximum Surge: 8 ft"
Alaska Division of Emergency Affairs (1980)	Water came within 20 to 30 feet of the back of the high school. The airport runway, city dock, and road between old and new village were flooded. Honeybucket dumpsite flooded.

The 1979 storm caused more damage than the 1974 storm (Wise and others, 1981), which was estimated to have reached 7.1 ± 1.7 ft MHHW (table 2). City of Hooper Bay and others (2007) stated that the 1979 flood "was not as bad" as the storm in 2005, which was estimated to have reached 7.7 ± 1.4 ft MHHW (table 2). The storm damaged the airstrip protection which can be reached by flooding of 3 to 4 ft MHHW. Both sources discussed "damage," which is related to, but not directly correlated with the height that the storm reached. Using the two related storms as upper and lower boundaries, the 1979 storm was estimated to reach 7.3 ± 1.8 ft MHHW (table 7). A storm reaching this height would have flooded the numerous honeybucket sites around the community, and may have come within 30 ft of the school at the time, consistent with observations (Alaska Division of Emergency Affairs, 1980).

Table 7. Flood parameters used to estimate the November 15, 1979, storm. Uncertainty was calculated using the upper-lower bounds method.

Feature	1974 storm estimate	2005 storm estimate
Feature represents	Highest water	Highest water
Water level type	Still water	Still water
Estimate of height (ft MHHW)	7.1	7.7
Uncertainty (ft)	1.7	1.4
Lower bound (ft MHHW)	5.5	6.3
Upper bound (ft MHHW)	8.8	9.1
Mean and uncertainty (ft MHHW)	**7.3 ± 1.8**	

1988 | No water level estimate

Reference	Source information used to estimate storm height
USACE (1999)	None

A large fall storm caused considerable erosion near the airport. There was no information describing flood impacts, so an estimate could not be made.

1991-NOV | No water level estimate

Reference	Source information used to estimate storm height
USACE (2017)	None
USACE (1992)	City dump flooded, water reached 1 to 2 feet above mean tide level

This storm was listed as an "extreme high water event…" along with the 1978 and 1979 floods (USACE, 2017). The written report estimated water heights 1 to 2 feet above mean tide level, but this would still be below MHHW. The flood reached the city dump. The dump location was not identified in any documents found, and was not identifiable with aerial imagery alone, so the storm could not be estimated.

2004-OCT-18 | 7.3 ± 1.8 ft MHHW

Reference	Source information used to estimate storm height
USACE (2007)	Erosion of airstrip and photo of debris on airstrip http://maps.dggs.alaska.gov/photodb/#show=12&-search=hooper%20bay%20october%202004
City of Hooper Bay and others (2006)	Dock washed away

A storm that occurred on October 18, 2004, impacted Yukon-Kuskokwim Delta and Norton Sound communities, and the Nome tide gauge measured a max height of 8.1 ft above local MHHW. It was considered the same storm that impacted Hooper Bay, although an exact storm day was not specified. USACE (2007) compared this storm to 1979 (7.3 ± 1.8 ft MHHW; table 2). Four post-storm photos were collected: three with general damage to erosion protection around the airport, and one showing debris left on the runway. The small debris indicated that water may not have reached much higher than the runway, so the surface was considered a reasonable estimate of peak flood height (± 1 ft). It was unclear how much of the runway was flooded, so the mean runway height was used for this estimate.

The runway was rebuilt between the acquisition of the 2015 DSM and the 2016 DEM. The runway, as identified in the 2015 orthoimagery, matched the runway shown in a 2004 land use map (City of Hooper Bay and others, 2007). From the DSM, the runway averaged 10.5 ± 1.4 ft MHHW, with a maximum height 11.7 ft MHHW toward the center (fig. 2). Since the airport is adjacent to the open ocean, the peak flood estimate was assumed to include wave runup at 10.5 ± 1.8 ft MHHW (table 8).

Only wave runup could be estimated using the available sources. Given that the 2004 storm reportedly reached a similar height as in 1979, the peak still water height was estimated to be the same, 7.3 ± 1.8 ft MHHW.

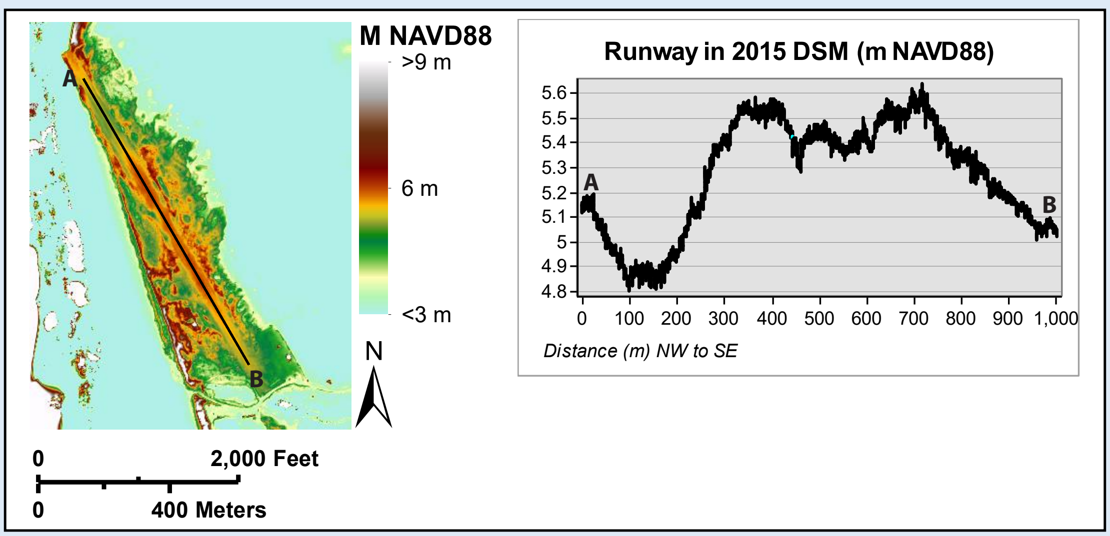

Figure 2. (Left) Digital surface model of Hooper Bay runway in 2015, before it was rebuilt. (Right) Elevation profile of the runway shows it varied in elevation by up to 0.8 m (2.6 ft).

Table 8. Flood parameters used to estimate the October 18, 2004, storm. Uncertainty was calculated using the RSS error.

Feature	Debris Runway
Feature represents	Highest water
Water level type	Wave runup
Estimate of height (ft MHHW)	10.5
Ground height measurement uncertainty (ft)	1.4
Elevation model error (ft)	0.6
Uncertainty that proxy is max water height (ft)	1.0
Storm height and uncertainty (ft MHHW)	**10.5 ± 1.8**

2005-SEP-22 | 7.7 ± 1.4 ft MHHW

Reference	Source information used to estimate storm height
City of Hooper Bay and others (2007)	Sandbags at fuel tanks were overtopped

The September 22, 2005 storm caused "the worst flood that anyone remembers," as of 2007 (City of Hooper Bay and others, 2007). It was considered worse than the 1979 flood, estimated to have reached 7.3 ± 1.8 ft MHHW (table 2). There were no specific impacts cited other than the tank farm.

The City of Hooper Bay (2007) stated that the "AVEC fuel tanks located in Old Town and identified as #18 on the land use map were topped by flooding in 2005." However, the report was inconsistent: The AVEC fuel tanks were identified as #39 on the provided map (the current tank farm with sand bags), and #18 was the "New Fuel Plant," also identified as the "Crowley Gas Station" in the DCCED (2007) map. If the gas station had flooded, water would have reached 15 ft MHHW and caused far greater impacts than were reported. Thus, it was assumed the report meant to refer to the AVEC fuel tanks identified as #39.

When looking at aerial imagery, the fuel tank farm appeared mostly unchanged from 2004 to 2015, so it was assumed that the height in the DEM was the same height in 2005. City of Hooper Bay and others (2007) said the fuel tanks were "topped," but their tops were 21 ft MHHW, so this more likely meant the sandbags were topped. A profile of the sandbags ranged between 6.6 and 8.8 ft MHHW and averaged 7.6 ± 0.8 ft MHHW (fig. 3). Since the degree of overtopping was not specified, a more conservative uncertainty method was applied, and the estimated height was 7.7 ± 1.4 ft MHHW (table 9).

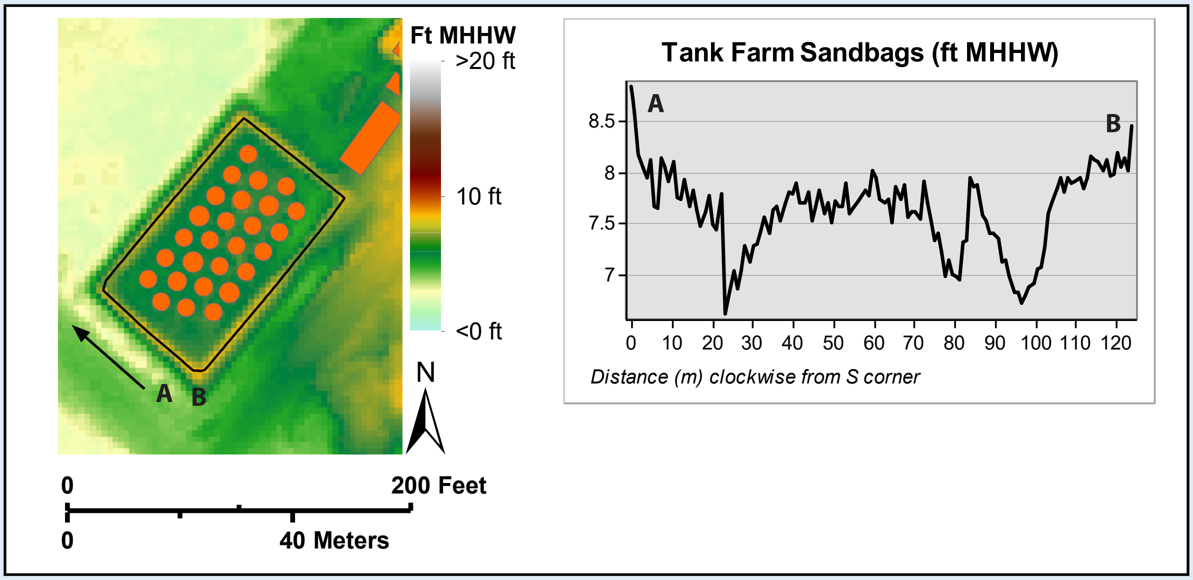

Figure 3. (Left) Digital elevation model of tank farm with fuel tanks delineated in orange and profile line drawn in black. (Right) Elevation profile of tank farm sandbag wall shows low sections on the west corner and southeast wall.

Table 9. Flood parameters used to estimate the September 22, 2005, storm. Uncertainty was calculated using the upper-lower bounds method.

Feature	Sandbags
Feature represents	Highest water
Water level type	Still water
Estimate of height (ft MHHW)	6.6 to 8.8
Elevation model error (ft)	0.3
Lower bound (ft MHHW)	6.3
Upper bound (ft MHHW)	9.1
Storm height and uncertainty (ft MHHW)	**7.7 ± 1.4**

2006-OCT-27 | No water level estimate

Reference	Source information used to estimate storm height
City of Hooper Bay and others (2007)	No damage occurred

This was likely a minor flooding event, but there was not enough information to make an estimate.

2011-NOV-08 | 5.5 ± 1.2 ft MHHW

Reference	Source information used to estimate storm height
City and Native Village of Hooper Bay (2015)	None
Photos taken by Steven Stone	Access at DGGS Photo Database: http://maps.dggs.alaska.gov/photodb/#show=12&search=hooper%20bay%20november%202011

Hooper Bay was listed as impacted by the 2011 storm (City and Native Village of Hooper Bay, 2015), but no reports were found citing specific impacts. Images hosted online were acquired in the morning after the storm. Three photos showed measureable impacts (table 10). The storm deposited debris near the telephone pole at the dock, leaving a water line in the snow that indicated it did not reach higher than the pole's location. The entire road to the airport appeared to be submerged in the photos. One photo showed a shipping container was flooded, while two others nearby were on higher ground and were not flooded. Using the average of the two estimates of highest water, the storm reached 5.5 ± 1.2 ft MHHW.

Table 10. Flood parameters used to estimate the November 8, 2011, storm. Uncertainty was calculated using the upper-lower bounds method. Only the estimates of highest water were used for the final storm height estimate.

Feature	Debris line at dock	Road to airport	Shipping container
Photo link	maps.dggs.alaska.gov/photodb/detail/15706	maps.dggs.alaska.gov/photodb/detail/15711	maps.dggs.alaska.gov/photodb/detail/15700
Feature represents	Highest water	Instantaneous	Highest water
Water level type	Still water	Still water	Still water
Estimate of height (ft MHHW)	5.9	4.9	5.2
Measurement uncertainty (ft)	0.8	1.0	1.5
Elevation model error (ft)	0.3	0.3	0.3
Total estimate uncertainty (ft)	0.9	1.0	1.5
Storm height and uncertainty (ft MHHW)		**5.5 ± 1.2**	

2016-SEP-16 | 4.1 ± 1.0 ft MHHW

Reference	Source information used to estimate storm height
Photo of flooding	http://maps.dggs.alaska.gov/photodb/detail/17835

A photo of this flood shows water surrounding the entire community (Division of Homeland Security & Emergency Management, 2013). The airport access road appeared partially submerged near the runway. The lowest part of this road was 4.0 ft MHHW, and flooding of 4.8 ft MHHW would submerge the majority (fig. B3). Water slightly overtopped the road going around the tank farm to the washeteria, allowing water to pool in the low area north of the tank farm. The flood must have reached at least 4.1 ± 0.3 ft MHHW to overtop this road (fig. 4). It was not known whether the photo was acquired during the highest part of the flood and no impacts were reported, so the total uncertainty was increased to make the final estimate 4.1 ± 1.0 ft.

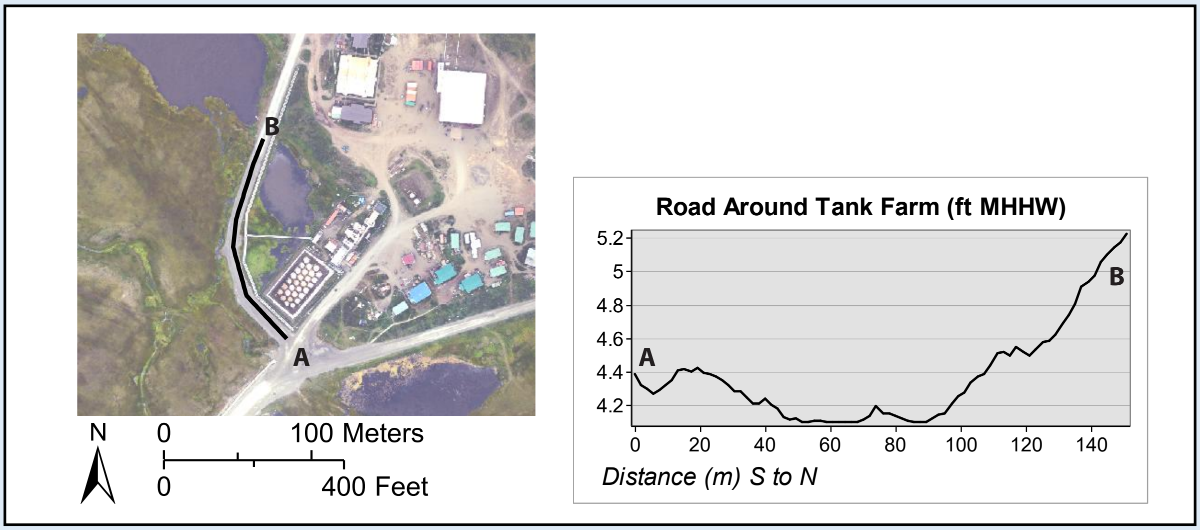

Figure 4. (Left) Image of tank farm area with an elevation profile line drawn in black on the road around tanks. (Right) Elevation profile of tank farm sandbag wall shows low sections on the west corner and southeast wall.

ACKNOWLEDGMENTS

This work was funded in part by the National Oceanic & Atmospheric Administration Office of Coastal Management through the Digital Coast Fellowship, and by the State of Alaska.

REFERENCES

References that were reviewed but did not contain flood information are listed in Appendix A.

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Buzard, R.M., Overbeck, J.R., Chriest, Jonathan, Endres, K.L., and Plumb, E.W., 2021, Coastal flood impact assessments for Alaska communities: Alaska Division of Geological & Geophysical Surveys Report of Investigation 2021-1. https://doi.org/10.14509/30573

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Division of Homeland Security & Emergency Management (DHS&EM), 2013, State of Alaska hazard mitigation plan 2013: Department of Military and Veterans Affairs, 569 p.

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U.S. Army Corps of Engineers (USACE), 1992, Community information form: U.S. Army Corps of Engineers, 6 p.

———1999, Hooper Bay, Alaska beach erosion control section 103 preliminary reconnaissance report: U.S. Army Engineer District, Alaska, 21 p.

———2007, Erosion information paper—City of Hooper Bay: Alaska baseline erosion assessment, 4 p.

———2017, Alaska Floodplain Management flood hazard data—Hooper Bay: USACE Civil Works Branch, 2 p.

Wise, J.L., Comiskey, A.L., and Becker, Richard, Jr., 1981, Storm surge climatology and forecasting in Alaska: Anchorage, Alaska, Arctic Environmental Information and Data Center, University of Alaska, 32 p.

Woolpert, 2017, Airborne LiDAR report—AK Yukon Kuskokwim QL2 Lidar: Woolpert, Inc., 22 p.

APPENDIX A: STORM-RELATED ACCOUNTS

There were many written reports that contained information pertaining to storm-driven flooding in Hooper Bay. Reports may be difficult to find in the future as their online linked location may change. This appendix provides the exact relevant text from each source used in this report to preserve the information. Any added commentary or summary information is encased in brackets.

U. S. Army Corps of Engineers, 2017, Alaska Floodplain Management flood hazard data—Hooper Bay: USACE Civil Works Branch, 2 p.

[Exact text from relevant sections:]

Flood of Record: N/A

Floodplain Notes: No buildings in the oldest portion of the community have ever been reported as flooded. The November 1974 flood reportedly left a high water mark 36” above the ground on the fuel storage tanks that are south of the ANICA Store, near the intersection of Church Street. Extreme high water also occurred in 1978, 1979, and 1991.

U. S. Army Corps of Engineers, 2007, Erosion information paper—City of Hooper Bay: Alaska baseline erosion assessment, 4 p.

[Exact text from relevant sections:]

Description of Erosion Problem: Major storms in 1979 and 2004 eroded away part of the airstrip by destroying sand-filled barrels used as shore protection and an interlocking concrete wall used to protect the airstrip.

Potential Damages: The airstrip, near the coast about 1.5 miles north from the community, is generally protected from erosion by sand dunes along the Bering Sea, however, storm waves pound into and overtop the small sand dunes and can cause considerable damage.

Based on the community survey, erosion occurring along the shoreline and banks on the south side of the community threatens the access road to the airstrip, the runway and related facilities, and several outbuildings and sheds… Loss of the access road or airstrip, even temporarily, could cause considerable social and economic stress to the community.

[Provided four photos of October 2004 storm aftermath]

City and Native Village of Hooper Bay, 2015, City of Hooper Bay, Alaska multi-jurisdictional hazard mitigation plan update: The City and Native Village of Hooper Bay Hazard Mitigation Planning Team, 185 p.

[All information about specific storms and flooding events in this report was copied from the 2007 hazard mitigation plan. The 2015 plan provided no new content related to storms or flooding, but did list the disaster declaration for the November 2011 storm that impacted Hooper Bay.]

City of Hooper Bay, ASCG Incorporated of Alaska, and Bechtol Planning and Development, 2007, The City of Hooper Bay, Alaska local hazards mitigation plan: 57 p.

[Exact text from relevant sections:]

Table 8. Hooper Bay Hazard Vulnerability Matrix

[table shows every numbered building (#1–#47) on DCCED map is vulnerable to flooding except #13 PHS Water Treatment & Washeteria, #21 Water/Sewer Line – School to Sewage Lagoon, #22 LYSD High School (destroyed in 2006 fire), #23 LYSD Elementary School (destroyed in 2006 fire), LYSD Teacher Housing, NVHB Administration Building, and #42 Traditional Council Building]

The Hooper Bay airport and access road into the village flood every spring and occasionally in the fall and winter. Boulders at the end of the airport while protecting the runway contribute to erosion. The road at the airport is in need of reconstruction.

AVEC fuel tanks located in Old Town and identified as #18 on the land use map were topped by flooding in 2005. The tank farm and generators need to be relocated out of the flood area.

During spring break up it is common for Old Village and New Village to be cut off from each other due to high water levels. Homes along the banks are often flooded and are in danger of eroding into the slough areas. Elevating or relocating homes in these areas are critical.

Previous Occurrence of Flooding and Erosion

Due to the isolation of Hooper Bay and the complete absence of a written record, documentation of previous occurrences of flooding and erosion in the village is only available through word of mouth passed down from the elders.

In addition to the lack of written documentation from the village the state and federal agencies also do not have written records.

During the public process the community provided the following verbal information, repeated here verbatim:

- "The sand dunes have eroded at least one-half mile in the last twenty years."
- "Four rows of sand dunes use to protect the City and without their protection the shoreline is eroding and causing more flood damage."
- "Old City and New City are often cut off from each other during spring break-up."
- "The City flooded on October 27, 2006, but the flood heights are unknown, and no damage occurred."
- "The worst flood that anyone remembers occurred in September 2005. Beginning on September 22, and continuing through September 26, a powerful fall sea storm produced high winds and wind-driven tidal surges resulting in severe and widespread coastal flooding and a threat to life and property. This storm was declared a federal disaster on December 9, 2005."
- "There was a flood in 1979, but was not as bad as the one in 2005."

City of Hooper Bay, Native Village of Hooper Bay, and Sea Lion Corporation, 2006, Hooper Bay community plan: 53 p.

[Exact text from relevant sections:]

In 2004, a number of sidewalks or walkways, winter trail markings, and Hooper Bay's dock were washed away or damaged by the Bering Sea Storm.

Known concerns regarding the airport include: … Seasonal flooding of the access road.

Wise, J.L., Comiskey, A.L., and Becker, R., Jr., 1981, Storm surge climatology and forecasting in Alaska: Anchorage, Alaska, Arctic Environmental Information and Data Center, University of Alaska, 32 p.

[Exact text from relevant sections:]

July 15, 1951: A storm moved from Unalaska to Hooper Bay and Kotzebue.

Sept. 30, 1974: [Hooper Bay listed, no further information]

Nov. 10-12, 1974: … Hooper Bay $35,000…

Dec. 1, 1978: $16,000 to boats and fish nets at Hooper Bay. Timing of storm was with high astronomical tides.

Nov. 15, 1979: Hooper Bay damage exceeded November 1974 storm.… Maximum Surge: 8 ft

Terenzi, J., Jorgenson, M.T., and Ely, C.R., 2014, Storm-surge flooding on the Yukon-Kuskokwim Delta, Alaska: Arctic, v. 67, no. 3, p. 360-374.

[Exact text from relevant sections:]

The 1974 storm … $35,000 (associated with erosion of the airport road and warehouse damage) in Hooper Bay

[Lists Chapman modeled storm values. They adjusted values from MLLW to MSL using 1.03 m, even though those tidal datums are only 0.56 m apart]

Alaska Division of Emergency Affairs, 1980, Flood hazard data: State of Alaska Department of Military Affairs, 2 p.

[Exact text from relevant sections:]

Hooper Bay: See attached survey form. Village president reported this to be worst flooding since the 1974 storm.

[First written survey of flood impacts]

Update 6/2/81

Worst Flood Known (cause and date): 1973, 1978

Depth of Flood (MAXIMUM): Est. 30 feet above sea-level

Highwater Marks (Describe & Locate): Bridge between housing site and Maintown (est.)

Number of Homes Flooded: 0

Number of Public Facilities and Type flooded: 0

We have our fishracks, boats and nets and subsistence fishing supplies and equipment damaged due to floods.

Other Pertinent Information (erosion & other problems): There is land deterioration due to flooding at our seawall near the river. Our airport is also eroding towards the southwest end and south of the runway.

[Second written survey of flood impacts]

Worst Flood Known (cause & date): 1974

Depth of Flood (MAXIMUM): 20'

Highwater Marks (Describe & Locate): Covered the road on the south side of the Maintown and got as high as the steps of some lower houses, but no flooding on inside.

Number of Homes Flooded: None

Number of Public Facilities and Type Flooded: None, but one storage fuel tank was toppled over by water and wind. Also, electrical wires for housing and airport lights were cut.

Other Years Flooded: 1978

Number of Homes: None

Public Facilities: Airport lights wiring cut.

Other Pertinent Information (erosion & other problems): North side of airport, on the 1978 flood, repaired.

[Third written survey of flood impacts]

Worst Flood Known (cause & date): Friday Nov 8, 1979 (3-6 am) coastal storm, high tides

Depth of Flood (MAXIMUM): [blank]

Highwater Marks (Describe & Locate): (See attached description of highwater.) See FIA Flood Hazard Boundary Map – Water reportedly covered the area north of village site and extended within 20-30' of the back of the High School.

Number of Homes Flooded: [blank]

Number of Public Facilities and Type Flooded: Airport runway; public road connecting old + new village; city boat dock.

Other Years Flooded: 1974, 1978 AOES records

Public Facilities [impacted by other floods]: 1974-City dock

Sewer System (cesspools, privies, PHS, etc.) HoneyBucket dump site was flooded [referring back to 1979]

Other Pertinent Information (erosion & other problems): Due to erosion of the road connecting old + new village, erosion may be a recurring problem. Extreme high water, presumably reported again on Dec. 3, peaking at 11:40 a.m.

[Fourth written survey of flood impacts]

Worst Flood Known (cause and date): December 1978

Highwater Marks (Describe & Locate): As described in community profile map of community and Regional Affairs

Number of Homes Flooded: None

Number of Public Facilities and Type Flooded: None (property damage for whole village totaled up to about 31 million in 1978)

Other Years Flooded: In the past years we had floods just about every year

Number of Homes: None

Public Facilities: None

Other Pertinent Information (erosion & other problems): The airport is eroding at the south end from the flood. The road gets washed out every time there is a flood and the village gets surrounded with water with no way to go [illegible]

[Memo dated 1 Aug 68]

Hooper Bay is located on Hooper Bay about 20 miles south of Cap Romanzof. It is located on the right bank of a small stream on a small high plateau in the middle of a large swampy flat area. Because of the large amount of relief afforded by the swamps surrounding the village, it is extremely unlikely that the town will ever be flooded. The plateau is now extremely crowded and any future expansion will probably take place in the lower areas and thus be subject to flooding.

Fall 74, 100% flooded, Maximum Depth 36”

U.S. Army Corps of Engineers, 1992, Community information form: U.S. Army Corps of Engineers, 6 p.

[Exact text from relevant sections:]

How Often Is Your Community Flooded? Once a year
What Is The Cause Of Most Floods (ice jams/stream overflow/storm surge/heavy rains, etc.)? Annual fall storm surge
How Many Homes Are Usually Flooded? None
What Public Facilities (school, generator, airport, sewage lagoon, etc.) Are Usually Flooded? City trash dump site

LAST FLOOD:
When Was The Last Flood (date)? Nov., 1991
What Caused the Last Flood? Annual fall storm surge

How Deep Did The Water Get (feet)? 1 to 2 feet more of mean tide
Where Is a Mark Left By The High Water? Debris (natural debris) around the city
How Many Homes Flooded? None
What Public Facilities Flooded? City dump

WORST FLOOD:
When Was the Worst Flood (date)? Sometime in late 60's
What Caused the Worst Flood? A strong southerly annual fall storm surge
How Deep Did The Water Get (feet)? More than 2 feet of annual flood
Where Is A Mark Left By The High Water? Natural debris/around the city
How Many Homes Flooded? None
What Public Facilities Flooded? City dumpsite

When we have annual fall storm surges the flood surrounds the city and the other town sites. Transportation between them is temporarily hindered. The subsistence fish racks along the rivers are effected [sic] but hardly they get much damages. However, the residents' small boats and commercial fishing boats are always in jeopardy during these annual floods especially when there is ice in the flood waters and those boats are not moved to higher grounds. Members of the community do not know when any of the houses or buildings were ever flooded.

Response from Hooper Bay in 1992

U.S. Army Corps of Engineers, 1999, Hooper Bay, Alaska beach erosion control section 103 preliminary reconnaissance report: U.S. Army Engineer District, Alaska, 21 p.

[Exact text from relevant sections:]

A large storm in the fall of 1988 caused noticeable dune depletion at unfortified areas, but no specific measurements were obtained.

ADDITIONAL REFERENCES REVIEWED

References reviewed that contained no storm information:

ASCG Incorporated, 2004, Hooper Bay comprehensive economic development strategy plan: ASCG Incorporated, 46 p.

Chapman, R.S., Kim, S.C., and Mark, D.J., 2009, Storm damage and flooding evaluation, storm-induced water level prediction study for the western coast of Alaska: Vicksburg, Mississippi, U.S. Army Research and Development Center, Coastal and Hydraulics Laboratory, 92 p.

The above report, Chapman and others (2009), simulated storm surge heights (surge + tide) for Hooper Bay. The model results were not verified. The model used a custom tidal datum that was not published and was not consistent with the published tidal datum. Thus, the storm surge simulation could not be compared to the current tidal datum.

APPENDIX B: FLOOD CATEGORY CALCULATION TABLES AND FIGURES

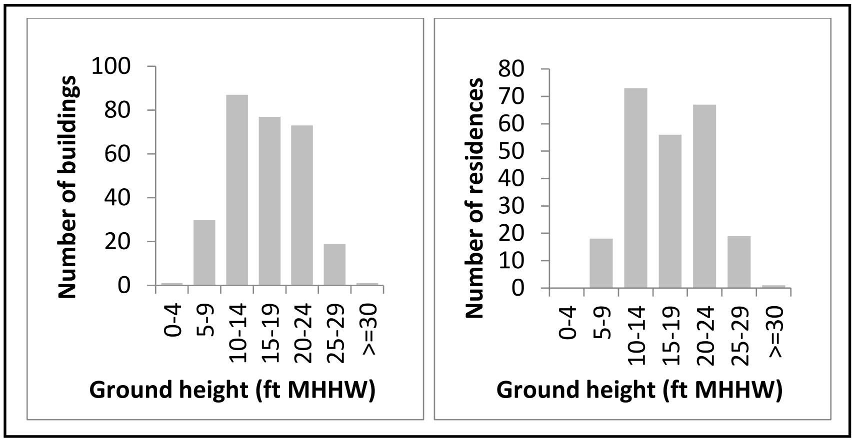

Figure B1. (Left) histogram of the highest ground height below all buildings in Hooper Bay. (Right) histogram of the highest ground height below all residences. Of 234 identified residences, only 18 were on ground below 10 ft MHHW. The highest ground height is not the first floor height.

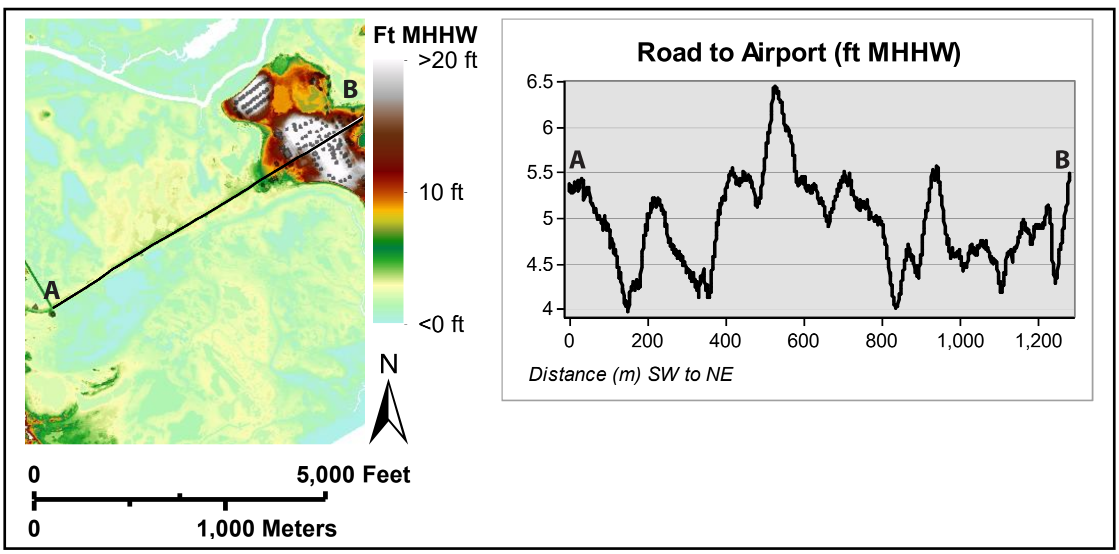

Figure B2. (Left) Elevation heat map with black profile line drawn along Airport Road. (Right) Elevation profile showing ground height around between 4.0 and 6.5 ft MHHW.

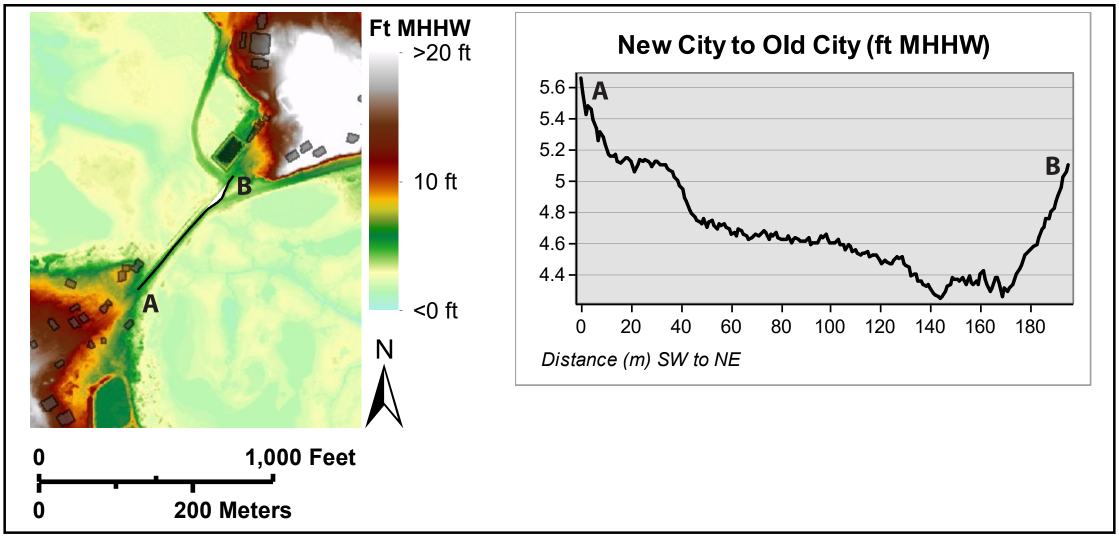

Figure B3.(Left) Elevation heat map with black profile line drawn along road connecting New City to Old City. (Right) Elevation profile showing road is mostly below 4.8 ft MHHW.

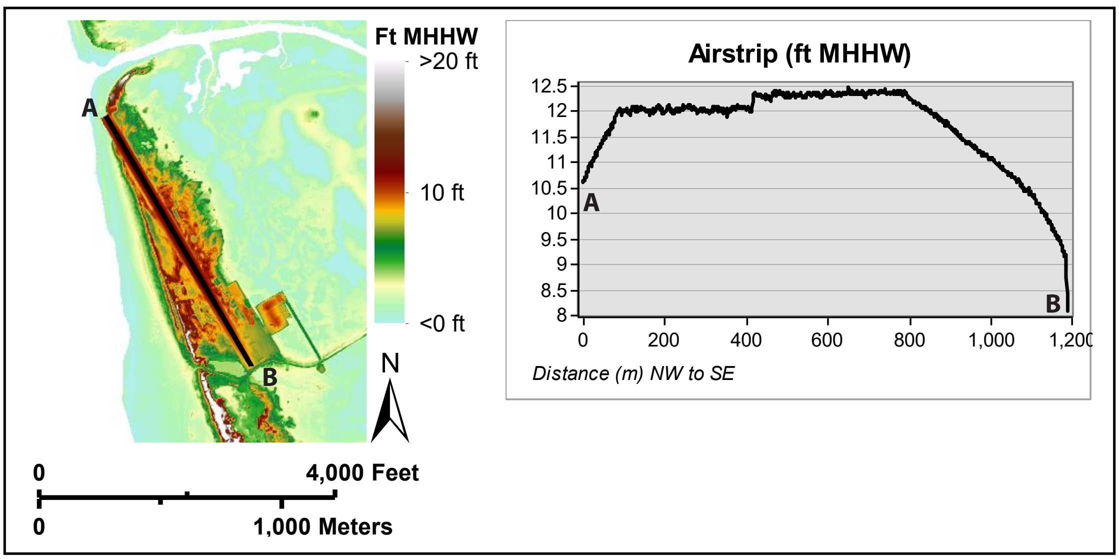

Figure B4.(Left) The 2016 lidar elevation model of the airport with a black line drawn where the elevation profile was extracted. A berm protects the majority of the airstrip from direct wave runup. (Right) Elevation profile of airstrip shows it is below 12.5 ft MHHW.

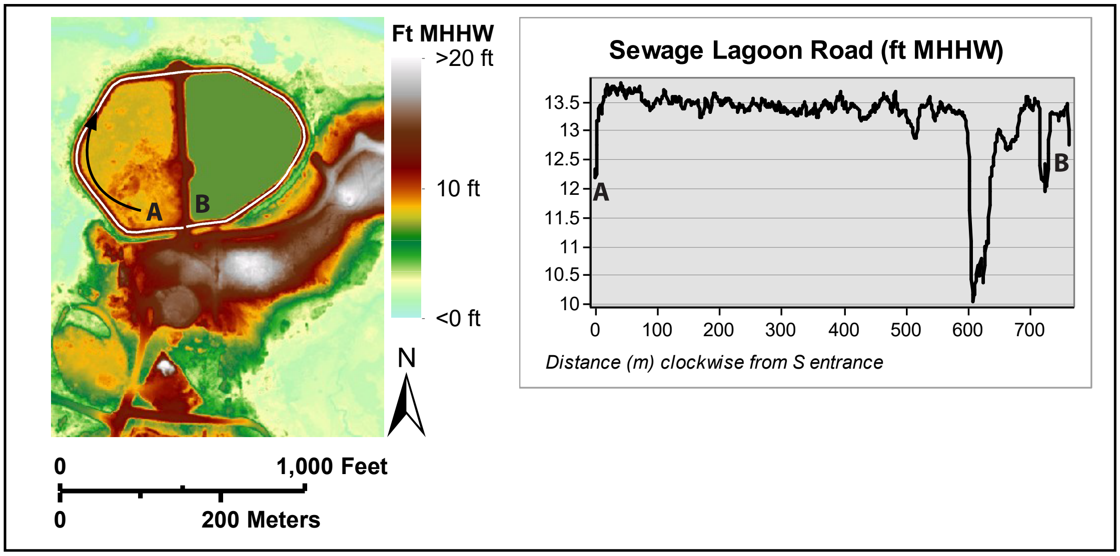

Figure B5.(Left) Digital elevation model of wastewater pond and dump area, with white line drawn on the barrier roadway where elevation profile was collected. (Right) Elevation profile of barrier roadway, which is mostly above 13 ft MHHW except for the SE section that drops to 10 ft MHHW.