Report of Investigation 2026-1

COASTAL FLOOD IMPACT ASSESSMENT FOR TUNTUTULIAK, ALASKA

Keith C. Horen and Nora M. Nieminski

View of Tuntutuliak, Alaska, taken with an Uncrewed Aerial Vehicle in 2023.

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State of Alaska
Department of Natural Resources
Division of Geological & Geophysical Surveys

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DEPARTMENT OF NATURAL RESOURCES
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COASTAL FLOOD IMPACT ASSESSMENT FOR TUNTUTULIAK, ALASKA

Keith C. Horen[1] and Nora M. Nieminski[1]

OVERVIEW

This Division of Geological & Geophysical Surveys (DGGS) report is an investigation of the historical flood record and provides an assessment of flood impacts for the community of Tuntutuliak, Alaska. This community-specific report has three sections: data description, flood impact categorization, and historical flood record. Methods used to evaluate historical floods and delineate flood impact categories (minor, moderate, major) are defined by the National Weather Service (NWS) and described in detail by Horen, Poisson, and others (2024), an update from the methods described by Buzard and others (2021). Flood and infrastructure heights are relative to the local mean higher high water (MHHW) datum in feet (ft).

SUMMARY

The community of Tuntutuliak is located within the Yukon-Kuskokwim Delta on the Qinaq River, sometimes called the Kinak River, about 5.0 miles (8.00 km) from its confluence with the Kuskokwim River. In 1945, the village of Qinaq was relocated to higher ground to avoid seasonal flooding and was renamed Tuntutuliak (Pavila and others, 2015). The community's Hazard Mitigation Plan (HMP) indicates the community "experiences storm surge, coastal ice run-up, and coastal wind scour along the [riverbank], and riverine high water flow scour along the [Qinaq] River, streams, and creek embankments from ice flows, wind, surface runoff, and boat traffic wakes" (Pavila and others, 2015).

According to The Alaska Division of Homeland Security & Emergency Management (DHS&EM) and the Federal Emergency Management Agency (FEMA) at least 12 disaster declarations (1979, 1989, 1990, 2004, 2005, 2006, 2011, 2013, 2015, 2022, 2023, 2025) have been reported for flooding in Tuntutuliak and/or the local region (DHS&EM, 2008; DHS&EM, 2018; FEMA, 2022; FEMA, 2023; FEMA, 2025). Based on research done for this report, Tuntutuliak experienced at least 21 flood events from storm surge between 1964 and 2025. We estimated the peak still water heights for six of these flood events, categorizing all as major. The highest recorded flood occurred on October 12, 2025, reaching a still water height of 4.6 ft (1.39 m) MHHW.

DATA

DGGS used geospatial data to assess infrastructure impacts and estimate flood heights from various sources of evidence (e.g., personal accounts, photographs, official reports, etc.). We used ArcGIS Pro version 3.5.3 to map and process these geospatial data. We used the National Oceanic and Atmospheric Administration (NOAA) Vertical Datum Transformation (VDatum) version 4.8 for ellipsoid to geoid conversions.

Digital Elevation Models and Orthoimagery

Accurate, high-resolution elevation models and orthoimagery are used to measure flood heights in the absence of high-water mark (HWM) data. Three digital elevation models (DEM; table 1), one aerial image (table 2), and two orthoimages (table 2) are available for Tuntutuliak. Aerial imagery was collected in 2004 for an Alaska Division of Community & Regional Affairs (DCRA) Community Profile Map (CMP). Additional aerial imagery was collected in 2015 and 2023 and used to create digital surface models (DSM),

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Table 1. Specifications of elevation models available for Tuntutuliak, Alaska.

	2015 DSM	2021 DTM	2023 DSM
Collection date	2015-AUG-21	2021-AUG-18	2023-JUN-08
Elevation type	Photogrammetric SfM	Lidar Bare Earth	Photogrammetric SfM
Vertical datum	NAVD88 (GEOID12A)	NAVD88 (GEOID12B)	NAVD88 (GEOID12B)
Ground sample distance	0.7 ft (0.20 m)	1.6 ft (0.50 m)	0.1 ft (0.04 m)
Accuracy	0.3 ft (0.08 m)	0.2 ft (0.07 m)	0.1 ft (0.04 m)

Table 2. Summary of aerial imagery and orthoimagery available for Tuntutuliak, Alaska.

	2004 Aerial Imagery	2015 Orthoimagery	2023 Orthoimagery
Collection date	2004-SEP-17	2015-AUG-21	2023-JUN-08
Ground sample distance	2.0 ft (0.61 m)	0.7 ft (0.20 m)	0.1 ft (0.03 m)

and orthoimagery derived from photogrammetric structure from motion (SfM) processing (Overbeck and others, 2018; Horen, Nieminski, and others, 2024). DGGS collected light detecting and ranging (lidar) data in August 2021, with a DSM and digital terrain model (DTM) created in 2023 (Zechmann and others, 2023).

Where first-floor height data were unavailable (e.g., unoccupied buildings, some facility-attached infrastructure, and private property), we extracted heights from the 2023 DSM if discernable from the 2023 SfM model, orthoimagery, or DSM (e.g., decking at entrances to buildings, visible platforms extending from building edges, etc.). All DEM and orthoimagery will be referenced in this report by the names assigned in tables 1 and 2.

First-Floor Survey

The Alaska Native Tribal Health Consortium (ANTHC) completed a field survey of the first-floor heights of occupied buildings in Tuntutuliak in March 2024. These data were collected and reported in the North American Vertical Datum 1988 with GEOID12B applied (NAVD88 [GEOID12B]) in U.S. survey feet (usft) (app. A). The reported vertical accuracy of these data is ± 0.1 ft (0.04 m). This survey will be referenced within this report as the 2024 first-floor survey. DGGS spatially joined these first-floor heights to building footprints digitized from the 2023 orthoimagery, identifying 166 as occupied buildings (i.e., residential, public, or commercial structures in which people live or work), 124 of which are residential.

GNSS Survey

DGGS performed a GNSS survey between June 8 to June 9, 2023, during a visit to Tuntutuliak. The purpose of this survey was to collect community reports and HWM data related to historical flooding, as well as the first-floor height of buildings constructed after the 2020 first-floor survey was completed. These data were collected in the NAVD88 (GEOID12B) vertical datum in meters and reported in feet. The vertical accuracy of these data is ± 0.2 ft (0.07 m). This survey will be referenced within this report as the 2023 survey.

Vertical Datums

Local tidal datums (table 3) for Tuntutuliak are described by National Oceanic and Atmospheric Administration Center for Operational Oceanographic Products (NOAA CO-OPS) tide station 946 6197 available from https://www.tidesandcurrents.noaa.gov/stationhome.

Table 3. Tidal datum for Tuntutuliak from NOAA CO-OPS station 946 6197 (2022).

Tidal Datum	Abbreviation	ft MHHW	m MHHW	ft NAVD88 (GEOID12B)	m NAVD88 (GEOID12B)
North American Vertical Datum 1988 (GEOID99)	NAVD88 (GEOID99)	2.8	0.85	11.9	3.62
Mean Higher High Water	MHHW	0.0	0.00	9.1	2.77
Mean High Water	MHW	-1.5	-0.46	7.6	2.31
Mean Tide Level	MSL	-4.0	-1.21	5.1	1.56
Mean Sea Level	MTL	-4.3	-1.32	4.8	1.45
Mean Low Water	MLW	-7.2	-2.18	1.9	0.59
Mean Lower Low Water	MLLW	-7.6	-2.33	1.5	0.45
North American Vertical Datum 1988 (GEOID12B)	NAVD88 (GEOID12B)	-9.1	-2.77	0.0	0.00

html?id=9466197. Additionally, the DCRA 2004 CMP for Tuntutuliak was reported in the NAVD88 (GEOID99) vertical datum.

FLOOD IMPACT CATEGORIES

Flood impact categories are used by the NWS to define and communicate flood risk to the public. These categories are designated as major, moderate, and minor (NWS, 2016). Definitions for these categories in the NWS guidance specific to Alaska are provided in the form of statements regarding flood impacts, some of which are more qualitative than quantitative (NWS, 2016). To ensure impact assessments are consistent and repeatable, DGGS developed a set of quantitative criteria for each category (Horen, Poisson, and others, 2024). A fourth category, extreme flooding, as defined by DGGS, is included in this report to delineate critical infrastructure situated at heights above the anticipated maximum based on the specifics of the local historical flood record, though flooding is still possible above this height (Horen, Poisson, and others, 2024).

Short definitions for each flood impact category are listed below and are explained in greater detail by Horen, Poisson, and others (2024). Table 4 provides a list of key infrastructure heights and the risk categories they fall within. Additional information about each piece of key infrastructure is detailed in the category blocks that follow table 4. The map series that accompanies this report depicts the potential inundation extents for each flood impact category.

Minor Flooding: "Minimal or no property damage, but possibly some public threat" (NWS, 2016).

Moderate Flooding: "Some inundation of structures and roads… Some evacuations of people and/or transfer of property to higher elevations may be necessary" (NWS, 2016).

Major Flooding: "Extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations are necessary" (NWS, 2016).

Extreme Flooding: Any flooding that reaches a height above the highest estimated flood height plus the confidence of that estimate. (Horen, Poisson, and others, 2024; NWS, 2018).

HISTORICAL FLOOD RECORD

The historical flood record for Tuntutuliak is listed in chronological order below, with estimated floods identified by impact category. This record

Table 4. Summary of infrastructure heights and flood categories for Tuntutuliak, Alaska. Gray = extreme, purple = major, red = moderate, and yellow = minor. The extreme category represents infrastructure situated above the highest estimated flood height with uncertainty included. Categories are based on current infrastructure conditions.

Feature	Height (ft MHHW)	Vertical Uncertainty (ft)	Height (m MHHW)	Vertical Uncertainty (m)
Airstrip DOT facilities	17.7	± 0.1	5.40	± 0.04
School	14.5	± 0.1	4.43	± 0.04
Clinic	12.7	± 0.1	3.88	± 0.04
Public safety office	11.0	± 0.1	3.36	± 0.04
Washeteria	10.7	± 0.1	3.26	± 0.04
Tribal office	10.5	± 0.1	3.19	± 0.04
Store (near armory)	10.4	± 0.1	3.17	± 0.04
Airstrip threatened	9.6	± 0.1	2.92	± 0.04
U.S. Post Office	9.0	± 0.1	2.74	± 0.04
Russian Orthodox church	8.8	± 0.1	2.69	± 0.04
City office	8.5	± 0.1	2.59	± 0.04
Tuntutuliak church	8.3	± 0.1	2.53	± 0.04
Top of fuel containment wall	7.8	± 0.1	2.39	± 0.04
Store (mid-town)	7.2	± 0.1	2.21	± 0.04
Power plant	6.8	± 0.1	2.07	± 0.04
Gas station	6.6	± 0.1	2.02	± 0.04
GCI building	6.5	± 0.1	1.99	± 0.04
Extreme	**5.0**		**1.52**	
Many buildings flooded	4.7	± 0.1	1.45	± 0.04
Several buildings flooded	4.5	± 0.1	1.37	± 0.04
Access to airstrip threatened	3.4	± 0.1	1.03	± 0.04
Low-lying boardwalks threatened	2.5	± 0.1	0.77	± 0.04
Lowest residence flooded	1.6	± 0.1	0.49	± 0.04
Wastewater lagoon / landfill	1.4	± 0.1	0.43	± 0.04
Major	**1.3**		**0.39**	
Subsistence materials threatened	0.3	± 0.1	0.09	± 0.04
Moderate	**0.2**		**0.05**	
Private property threatened	-0.7	± 0.1	-0.22	± 0.04
Minor	**-0.8**		**-0.26**	

Extreme Flooding: Greater than 5.0 ft (1.52 m) MHHW

Airstrip DOT facilities: 17.7 ± 0.1 ft (5.40 ± 0.04 m) MHHW

This is the first-floor height of the Department of Transportation (DOT) facilities at the airstrip.

School: 14.5 ± 0.1 ft (4.43 ± 0.04 m) MHHW

The first-floor height of the school is the highest within the community, and, as the largest facility in the community, it is the most suitable evacuation shelter.

Clinic: 12.7 ± 0.1 ft (3.88 ± 0.04 m) MHHW

The clinic is the only medical facility in the community.

Public safety office: 11.0 ± 0.1 ft (3.36 ± 0.04 m) MHHW

This building houses the Village Public Safety Office (VPSO).

Washeteria: 10.7 ± 0.1 ft (3.26 ± 0.04 m) MHHW

The washeteria provides resources such as laundry, showers, and toilets.

Tribal office: 10.5 ± 0.1 ft (3.19 ± 0.04 m) MHHW

This is the first-floor height of the Tribal office.

Store (near armory): 10.4 ± 0.1 ft (3.17 ± 0.04 m) MHHW

This is one of two stores in the community.

Airstrip threatened: 9.6 ± 0.1 ft (2.92 ± 0.04 m) MHHW

At this height, flood waters would reach but not overtop any portion of the airstrip.

U.S. Post Office: 9.0 ± 0.1 ft (2.74 ± 0.04 m) MHHW

This is the first-floor height of the U.S. Post Office.

Russian Orthodox church: 8.8 ± 0.1 ft (2.69 ± 0.04 m) MHHW

This is one of two churches in the community.

City office: 8.5 ± 0.1 ft (2.59 ± 0.04 m) MHHW

This is the first-floor height of the city office.

Tuntutuliak church: 8.3 ± 0.1 ft (2.53 ± 0.04 m) MHHW

This is one of two churches in the community.

Top of fuel containment wall: 7.8 ± 0.1 ft (2.39 ± 0.04 m) MHHW

The fuel tank farm is surrounded by a protective containment wall. This height is the lowest point atop this wall.

Store (mid-town): 7.2 ± 0.1 ft (2.21 ± 0.04 m) MHHW

This is one of two stores in the community.

Power plant: 6.8 ± 0.1 ft (2.07 ± 0.04 m) MHHW

The power plant provides electricity for the whole community and would begin flooding at this height.

Gas station: 6.6 ± 0.1 ft (2.02 ± 0.04 m) MHHW

The gas station is the primary source of fuel and would begin flooding at this height.

GCI building: 6.5 ± 0.1 ft (1.99 ± 0.04 m) MHHW

At this height, the lower of the two communications buildings at the cellular tower would begin flooding.

Major Flooding: 1.3 to 5.0 ft (0.39 to 1.52 m) MHHW

Many buildings flooded 1.0 ft (0.30 m) or more: 4.7 ± 0.1 ft (1.45 ± 0.04 m) MHHW

We consider “many” buildings to describe more than five occupied buildings. Occupied buildings are

residential, public, or commercial structures in which people live or work.

Several buildings flooded less than 1.0 ft (0.30 m): 4.5 ± 0.0 ft (1.37 ± 0.04 m) MHHW

We consider "several" buildings to describe more than one but fewer than six occupied buildings.

Access to airstrip threatened: 3.4 ± 0.1 ft (1.03 ± 0.04 m) MHHW

Measured from the 2023 DSM, at this height access to the airstrip boardwalk would become unsafe to cross. The NWS assumes a depth of 1.0 ft (0.30 m) to be the maximum for reasonably safe travel on flooded roads (NWS, 2023).

Low-lying boardwalks threatened: 2.5 ± 0.1 ft (0.77 ± 0.04 m) MHHW

Measured from the 2023 DSM, at this height the lowest portions of boardwalk in several locations would become difficult to traverse. The NWS assumes a depth of 1.0 ft (0.30 m) to be the maximum for reasonably safe travel on flooded roads (NWS, 2023). Additionally, the integrity of boardwalks may be impacted by erosion and water damage.

Lowest residence flooded: 1.6 ± 0.1 ft (0.49 ± 0.04 m) MHHW

At this height, the lowest residence would begin flooding.

Wastewater lagoon / landfill: 1.4 ± 0.1 ft (0.43 ± 0.04 m) MHHW

Measured from the 2021 DTM, this is the height at which flood waters would reach the sewage lagoon and landfill. This height forms the basis for the lower limit of the major flooding category.

Moderate Flooding: 0.2 to 1.3 ft (0.05 to 0.39 m) MHHW

Subsistence materials threatened: 0.3 ± 0.1 ft (0.09 ± 0.04 m) MHHW

Measured from the 2021 DTM, this is the height at which flooding would cause significant damage to private property, including storage sheds, boats, fishing equipment, vehicles, and other property at ground level outside of occupied structures. From the 2023 orthoimagery, we identified 402 features meeting this description. This height forms the basis for the lower limit of the moderate flooding category.

Minor Flooding: -0.8 to 0.2 ft (-0.26 to 0.05 m) MHHW

Private property threatened: -0.7 ± 0.1 ft (-0.22 ± 0.04 m) MHHW

Measured from the 2021 DTM, flood waters would reach the lowest private property at this height. Private property may include storage sheds, boats, fishing equipment, vehicles, and other property at ground level outside of occupied structures. This height forms the basis for the lower limit of the minor flooding category.

was compiled from local knowledge shared with DGGS staff during a June 2023 site visit and from information available to the public through open sources or upon request. It is possible that additional, undocumented flood events have impacted the community. Historical information was used in conjunction with the best available, temporally relevant geospatial data to estimate flood heights where possible.

All estimates and confidences were calculated following the methods developed by Horen, Poisson, and others (2024). As described by Horen, Poisson, and others (2024), each estimate is accompanied by two confidence metrics, an estimate confidence based on the combined known potential errors and a time-based confidence based on the temporal relevance of the data used to estimate a given event.

For each flood event, a list and summarization of sources is included, as well as an explanation of the data used and steps performed during estimation, where relevant. Each flood height estimate is

Table 5. Summary of historical floods. Flood categories are included for reference: purple = Major, red = Moderate, yellow = Minor.

Estimated Floods

	Flood Date	Type	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)
Major	2025-OCT-12	Storm Surge	4.6	± 0.4	± 0.0	1.39	± 0.13	± 0.00
	2024-AUG-18	Storm Surge	3.4	± 0.4	± 0.0	1.05	± 0.11	± 0.00
	2022-SEP-17	Storm Surge	3.3	± 0.3	± 0.1	1.02	± 0.09	± 0.02
	2012-OCT-05	Storm Surge	2.7	± 0.8	± 0.2	0.83	± 0.24	± 0.05
	2000-NOV-13	Storm Surge	2.6	± 0.9	± 0.8	0.78	± 0.28	± 0.23
	1990-AUG-17	Storm Surge	2.2	± 1.0	± 0.3	0.67	± 0.31	± 0.09

Floods Not Estimated

Date	Type
1964-OCT-26	Storm Surge
1970-AUG-05	Storm Surge
1974-NOV-12	Storm Surge
1979-NOV-09	Storm Surge
1987-OCT-14	Storm Surge
2000-AUG-29	Storm Surge
2003-DEC-09	Storm Surge
2004-SEP-09	Storm Surge
2004-NOV-19	Storm Surge
2005-SEP-22	Storm Surge
2005-OCT-17	Storm Surge
2006-SEP-07	Storm Surge
2011-NOV-09	Storm Surge
2013-NOV-07	Storm Surge
2017-OCT-04	Storm Surge

classified into a single flood impact category but estimate confidences may span more than one category. Table 5 provides a complete list of the flood events found during our research, with estimated floods categorized and listed in order from highest to lowest, and floods not estimated listed in chronological order. Figure 1 provides a timeline of the estimated flood events, and a visual representation of the flood height estimates and confidences.

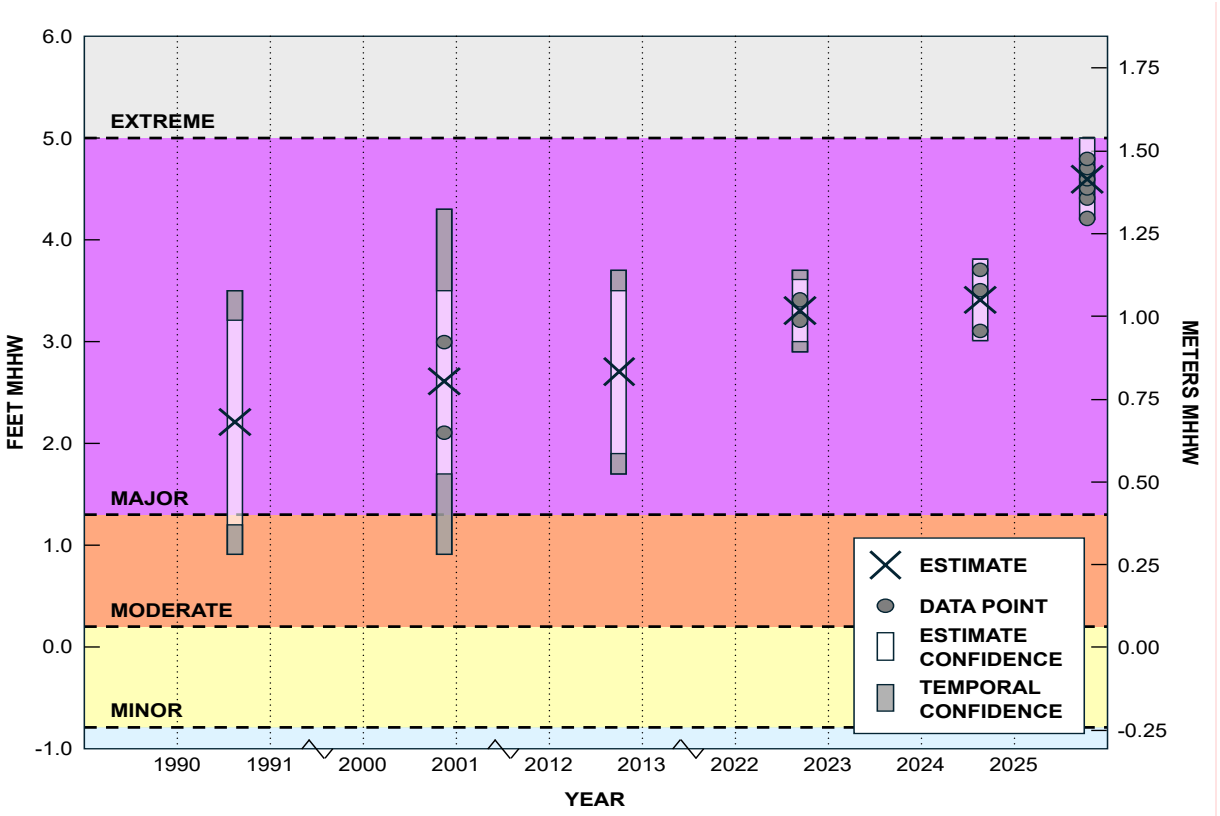

Figure 1. Timeline of estimated flood events and visual representation of flood height estimates and confidences for Tuntutuliak, Alaska. Flood height estimates were calculated following the methods developed by Horen, Poisson, and others (2024). Estimates are denoted by black X symbols. Data points used during estimation are represented by dark-gray dots. Estimate confidences are displayed as vertical, light-gray boxes. Temporal confidences are displayed as vertical, dark-gray boxes. Each flood height estimate may only be classified into a single flood impact category, but total estimate confidence may exceed the upper and lower bounds of the data used during estimation and may span more than one flood impact category.

FLOOD EVENT SUMMARIES

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
1964-OCT-26	---	---	---	---	---	---	No flood height estimate

A Weather Bureau (1964) Storm Data report notes a "storm… entered the Bristol Bay area by the morning of Oct. 26," with "strong winds extend[ing] up the western Alaska Mainland to Seward Peninsula area."

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
1970-AUG-05	---	---	---	---	---	---	No flood height estimate

According to Wise and others (1981), a storm associated with a significant low-pressure system impacted the Kuskokwim Bay region between August 5 and 6, 1970.

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
1974-NOV-12	---	---	---	---	---	---	No flood height estimate

In a NOAA technical memorandum, Fathauer (1978) noted "The Great Bering Sea Storm" resulted in "moderate to major flood damage… all the way from Bristol Bay to Kotzebue Sound."

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
1979-NOV-09	---	---	---	---	---	---	Major

In a letter from the Alaska Division of Emergency Services to USACE (1980), flooding was identified in Tuntutuliak, where "eight (8) homes were reported flooding [sic]."

The number and location of residences changed significantly between the date of this event and the collection of the 2024 first-floor survey; thus, a flood height could not be estimated. Based on the information provided, though, we categorize the flooding during this event as major.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
1987-OCT-14	---	---	---	---	---	---	No flood height estimate

NOAA (1987) reported "an intense Bering Sea storm brought winds… and minor flooding to the Yukon-Kuskokwim delta coast" on October 14, 1987.

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
1990-AUG-17	---	---	---	---	---	---	Major

NOAA (1990) reported "a strong low… and high tides caused coastal flooding along the lower Kuskokwim River, Kuskokwim Bay, and Bristol Bay" on August 17, 1990, with Tuntutuliak among the communities impacted, stating "the worst damage was to private property such as subsistence food, boats, motors, fishing nets, fishing camps, and homes."

The 2004 DCRA map, reported to be "accurate to within 1 foot," references a 1990 flood height identified in a level survey performed in 1996 and included in a USACE (2000a) trip report, which it lists as the "published flood of record which occured [sic] in 1990 with a flood elevation of -0.57 feet" in the NAVD88 (GEOID99) vertical datum.

To estimate the height of this flood, we converted the NAVD88 (GEOID99) height provided on the DCRA map to the local MHHW datum for a height of 2.2 ft (0.67 m) MHHW.

Although this flood estimate is categorized as moderate, the estimate confidence range could also potentially place this flood within the minor or major impact categories.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2000-AUG-29	---	---	---	---	---	---	No flood height estimate

The HMP (Pavila and others, 2015) and National Centers for Environmental Information (NCEI, 2000a) reported "one of the first Bering Sea storms of the year… presented the possibility of coastal flooding across low lying areas of the southwest coast," with beach erosion and high water levels reported "at several coastal villages, along with at least one report of damaged boardwalks."

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2000-NOV-13	---	---	---	---	---	---	No flood height estimate

NCEI (2000b) reported a storm surge event that impacted the Kuskokwim Delta on November 13, 2000, noting "a prolonged south and southwest fetch brought high water to many coastal communities" and "the onset of this coastal flooding coincided with very high tides," causing "significant damage… to several locations." Citing an article that appeared in "the Situation report from the

Alaska Division of Emergency Services," NCEI (2000b) quoted "Tuntutuliak has minor damage to boardwalk and bridges and some personal property damage." A USACE (2000b) trip report detailed flood impacts in Tuntutuliak in the days immediately after this event, including several pictures, two of which showed cut line HWM on the embankment of the fuel tank farm gravel pad (fig. 2).

Figure 2. Photographs of cut line high-water marks on fuel tank farm gravel pad associated with the November 2000 flooding in Tuntutuliak, Alaska (credit: Roger E. Burleigh [USACE, 2000b]).

To estimate this flood, we identified the fuel tank farm depicted in the photographs, located it within the 2004 aerial imagery, and overlayed this imagery with a simple bathtub model applied to the 2015 DSM to approximate the height of the cut line HWM. Based on the evidence, the height of water likely ranged between 2.1 and 3.0 ft (0.63 and 0.93 m) MHHW. We averaged these upper and lower values for a flood height estimate of 2.6 ft (0.78 m) MHHW. This result is consistent with a water height capable of impacting some boardwalks and bridges within the community.

Although this flood estimate is categorized as moderate, the estimate confidence range could also potentially place this flood within the minor or major impact categories.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2003-DEC-09	---	---	---	---	---	---	No flood height estimate

The HMP (Pavila and others, 2015) and NCEI (2003) reported a storm surge event that impacted the Kuskokwim Delta on December 9, 2003, noting "the strong long southwest fetch across the Bering Sea resulted in a coastal storm surge along the Yukon and Kuskokwim Delta and northern Bristol Bay."

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2004-SEP-09	---	---	---	---	---	---	No flood height estimate

The HMP (Pavila and others, 2015) and NCEI (2004a) reported a flood event that impacted the Kuskokwim Delta September 9–10, 2004, noting "a strong storm in the Bering Sea created a long fetch with high wind" that "produced a coastal storm surge resulting in minor coastal flooding along the Kuskokwim Delta."

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2004-NOV-19	---	---	---	---	---	---	No flood height estimate

The HMP (Pavila and others, 2015) and NCEI (2004b) reported a flood event that impacted the Kuskokwim Delta on November 19, 2004, noting "a west to southwest fetch across the Bering Sea, combined with high astronomical tide, resulted in coastal flooding across the west coast of the state."

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2005-SEP-22	---	---	---	---	---	---	No flood height estimate

The HMP (Pavila and others, 2015) and NCEI (2005a) reported a flood event that impacted the Kuskokwim Delta September 22–23, 2005, noting a "storm produced strong southwest wind across the southern Bering Sea into the Bering Sea coast of Alaska," where "the resulting surge combined with high tides resulting in coastal flooding."

Although a report of "all low lying areas flooded" in nearby Quinhagak (NCEI, 2005a; Pavila and others, 2015) indicates flooding was likely in Tuntutuliak, a flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2005-OCT-17	---	---	---	---	---	---	No flood height estimate

The HMP (Pavila and others, 2015) and NCEI (2005b) reported a flood event that impacted the Bristol Bay area and Kuskokwim Delta on October 17, 2005, noting "the combination of the strong wind and long fetch produced a surge that coincided with high tides," and "flooding occurred in the Bristol Bay area north to Kipnuk along the Kuskokwim Delta."

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2006-SEP-07	---	---	---	---	---	---	No flood height estimate

NCEI (2006) reported coastal flooding for the Kuskokwim Delta September 6–8, 2006, noting "the Remnants of super typhoon Ioke… produced strong west wind across the Bering Sea that produced seas in excess of 30 feet" and "this surge coincided with very high astronomical tides along the Bristol Bay coast and the coast of the Kuskokwim Delta" with "the combination of storm surge and very high tides" producing "minor coastal flooding."

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2011-NOV-09	---	---	---	---	---	---	No flood height estimate

The HMP (Pavila and others, 2015) and NCEI (2011) reported coastal flooding for the Kuskokwim Delta November 8–9, 2011, noting "strong wind and long fetch resulted in a coast storm surge that produced minor coastal flooding in the Kuskokwim Delta region."

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2012-OCT-05	---	---	---	---	---	---	Major

On October 5, 2012, the NWS Alaska Pacific River Forecast Center (APRFC; 2012) reported "minor flooding due to storm surge up Kuskokwim Delta; schools closed today in Napakiak, Napaskiak, and Tuntutuliak due to high water/flooding." A Coastal Impact Assistance Program (CIAP), Waste Erosion Assessment and Review (WEAR) report from the Alaska Department of Environmental Conservation (ADEC; 2012) noted "observations from a 2012 October storm event showed that both the sewage lagoon and landfill flooded."

To estimate this flood, we identified the sewage lagoon and landfill from the CMP (DCRA, 2004), located these features within the 2015 orthoimagery, and overlayed this imagery with a simple bathtub model applied to the 2015 DSM to determine at what water height each would experience flooding. From this model, the sewage lagoon begins to flood at roughly 2.1 ft (0.63 m) MHHW, with the flood waters reaching the lowest portions of the landfill at approximately 2.7 ft (0.83 m) MHHW. Since the ADEC (2012) report indicates that both the sewage lagoon and landfill flooded, but an upper limit of that flooding was not provided, we have chosen the height of the landfill as our minimum estimate for this event.

Although this flood estimate is categorized as moderate, the estimate confidence range could also potentially place this flood within the major impact category.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2013-NOV-07	---	---	---	---	---	---	No flood height estimate

The HMP (Pavila and others, 2015) and NCEI (2013) reported coastal flooding for the Kuskokwim Delta November 6–9, 2013, noting "an intense and large storm in the Bering Sea produced a long fetch of strong wind across the Bering Sea aligned with the Kuskokwim Delta coast" and "this produced a surge of up to 5 feet along the Kuskokwim Delta Coast."

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2017-OCT-04	---	---	---	---	---	---	No flood height estimate

NCEI (2017) reported coastal flooding for the Kuskokwim Delta October 4–5, 2017, noting "a long fetch of strong westerly winds brought coastal flooding to portions of Southwest Alaska."

A flood height could not be estimated for this event because no specific impacts to Tuntutuliak were provided.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2022-SEP-17	---	---	---	---	---	---	Major

NCEI (2022) reported coastal flooding September 16–19, 2022, stating "a myriad of impacts were noted across the West Alaska Coastline" as the remnants of Typhoon Merbok reached the Kuskokwim Delta coast, adding "impacts, including damaging wind gusts and storm surge, were observed from the Kuskokwim Delta to the Yukon Delta…"

Four GNSS measurements (table 6) based on photographic evidence (fig. 3) were collected by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) on October 5, 2022, and uploaded to the U.S. Geological Survey (USGS; 2022) Flood Event Viewer. It is unclear from the documentation provided in the USGS Flood Event Viewer if the reported heights include the measure up values, so we identified the locations depicted in the photographs, located them within the 2023 orthoimagery, and overlayed this imagery with a simple bathtub model applied to the 2023 DSM to simulate the water height depicted. We matched two of these photographs to modeled flood heights of 3.2 ft (0.98 m) MHHW and 3.4 ft (1.03 m) MHHW, which align relatively well to the height of one NRCS measurement with its measure-up added (highlighted).

Figure 3. Photographic evidence used by NRCS to collect HWM measurements on October 5, 2022, in Tuntutuliak, Alaska (point numbers from top to bottom: 2001, 2002, 2003, 2004).

Figure 3, cont. Photographic evidence used by NRCS to collect HWM measurements on October 5, 2022, in Tuntutuliak, Alaska (point numbers from top to bottom: 2001, 2002, 2003, 2004).

Table 6. HWM measurements collected by NRCS on October 5, 2022, in Tuntutuliak, Alaska.

Point	Height (ft MHHW)	Height (m MHHW)	Measure-up (ft)	Measure-up (m)	Combined (ft)	Combined (m)
2001	2.1	0.64	0.8	0.25	2.9	0.89
2002	2.4	0.73	1.0	0.30	3.4	1.03
2003	2.7	0.81	2.5	0.76	5.2	1.57
2004	2.5	0.76	1.7	0.51	4.1	1.26

Additionally, DGGS collected five GNSS measurements (table 7) during the 2023 survey based on photographic evidence (fig. 4) and interviews with community members. Two of these measurements are in relatively strong agreement with the validated NRCS measurement and the water heights modeled using the 2023 DSM.

Figure 4. Community reported evidence used by DGGS to collect HWM measurements on June 8-9, 2023, in Tuntutuliak, Alaska. Point number 3013 provided by Norman Jimmie (left) and 3087 provided by Paul Jimmie (right).

Table 7. HWM measurements collected by DGGS on June 8–9, 2023, in Tuntutuliak, Alaska.

Point	Height (ft MHHW)	Height (m MHHW)	Measure-up (ft)	Measure-up (m)	Combined (ft)	Combined (m)
3001	3.2	0.98	---	---	3.2	0.98
3013	2.5	0.77	1.0	0.30	3.5	1.07
3073	0.8	0.24	2.4	0.72	3.1	0.96
3084	3.8	1.16	---	---	3.8	1.16
3087	1.8	0.56	2.0	0.60	3.8	1.16

Due to the ambiguity of the USGS Flood Event Viewer report and the wide range of all measurements taken, we have chosen to eliminate the outliers and include the two modeled results. An average of these five heights was calculated to estimate a flood height of 3.3 ft (1.02 m) MHHW.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2024-AUG-18	---	---	---	---	---	---	Major

NCEI (2024a) reported flooding for the Kuskokwim Delta August 16–19, 2024, noting "two Bering Sea low pressure systems tracked into Western Alaska… bringing a period of nearly-persistent southerly winds [that] led to storm surge and coastal flooding along the Kuskokwim Delta coast and backed up flow along the lower Kuskokwim River" with "moderate to heavy rain in Southwest Alaska, which exacerbated flooding issues along the Kuskokwim River" where "roads were inundated and closed and at least two houses were flooded in the community of Tuntutuliak." NCEI (2024a) further elaborated "residents reported flooding and rapid bank erosion during high tides on August 16 and 17 at Akiak, Napakiak, Kasigluk, and Tuntutuliak."

Yukon-Kuskokwim Delta public media outlet, KYUK, published an article on August 21, 2024, that included photographs of flooding in Tuntutuliak (fig. 5) and noted "a few houses were reportedly inundated in Tuntutuliak" (Smiley, 2024).

Figure 5. Flooding in Tuntutuliak, Alaska on Aug. 18, 2024 (credit: Christopher Ondola [Smiley, 2024]).

On August 18, the NWS APRFC (2024) reported a "resident in Tuntutuliak says water levels are currently worse than during Merbok" and "at least 2 houses were reported to have water in them." On August 19, the NWS APRFC (2024) noted:

> "Tuntutuliak Public Safety Office reports multiple houses filled up with water. The depth of the water inside structures was not measured. [The] majority of houses that were impacted are located along, or in proximity to, the river. Observer reported conditions were worse than Merbok, citing stronger winds, rain, and wave action along the water's surface…"

To estimate this flood, we identified the residences with the lowest first-floor heights measured during the 2024 first-floor survey. Since the exact number of homes flooded was not specified in Smiley (2024) and the second report from NWS APRFC (2024), it is necessary to interpret "a few"

and "multiple," although it is safe to assume at least more than two homes were flooded based on these reports. Bearing in mind this event was characterized as "worse than Merbok" (NWS APRFC, 2024), we found simulated flooding of four to six homes meets the descriptions provided, but it is possible more were impacted. An average of the fourth, fifth, and sixth lowest residential first-floor heights, 3.1, 3.5, and 3.7 ft (0.94, 1.07, and 1.14 m) MHHW, respectively, was calculated to estimate a flood height of 3.4 ft (1.05 m) MHHW.

Flood Date	Height (ft MHHW)	Estimate Confidence (ft)	Temporal Confidence (ft)	Height (m MHHW)	Estimate Confidence (m)	Temporal Confidence (m)	Category
2025-OCT-12	---	---	---	---	---	---	Major

NWS (2025) reported the remnants of Typhoon Halong "reached the Yukon–Kuskokwim Delta coast early on Sunday morning, October 12," bringing "a record-breaking storm surge," with "the Kuskokwim River also backed up due to the surge and sustained onshore flow, resulting in major flooding in Bethel, Napakiak, Napaskiak, and Tuntutuliak."

In response to the "catastrophic flooding and destruction" (NWS, 2025), DGGS contracted JOA Surveys, LLC, to collect survey data in multiple communities following this event, including 15 HWM in Tuntutuliak (app. B).

To estimate this flood, we first assessed the quality of the HWM data, discarding three as outliers: points 4, 9, and 15 (app. B). An average of the remaining 12 HWM was calculated to estimate a flood height of 4.6 ft (1.39 m) MHHW.

ACKNOWLEDGMENTS

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APPENDIX A: TUNTUTULIAK, ALASKA, FIRST-FLOOR HEIGHT SURVEY

ALASKA NATIVE TRIBAL HEALTH CONSORTIUM
Environmental Health & Engineering

March 15, 2024

Tuntutuliak, Alaska Finish Floor Elevation Study
ANTHC Project No. 10-0189-01-01

The data provided is from a field survey completed by ANTHC on March 13, 2024. Project elevations are NAVD88 Orthometric heights (U.S. Feet), computed using GEOID12B, and were measured utilizing Trimble R10 and R12i GPS Receivers using RTK GPS.

BASIS OF HORIZONTAL CONTROL:
The Basis of Horizontal Control is ANTHC Point 401, a 6" steel spike, set south of the Tuntutuliak Traditional Council's COVID housing. The position for this point was derived through a static GPS session using a Trimble R12i GPS Receiver post processed using the National Geodetic Survey (NGS) Online Positioning User Service (OPUS). Said point has the following coordinates:

NAD83(2011)(EPOCH2010.00) Geodetic Coordinates:
Latitude = 60° 20' 32.98186" N
Longitude = 162° 40' 00.33920" W

NAD83(2011)(EPOCH2010.00) Alaska State Plane Zone 7, U.S. Feet:
Northing = 2,317,683.88'
Easting = 1,519,629.77'

BASIS OF VERTICAL CONTROL:
The Basis of Vertical Control is ANTHC Point 552, NOAA tidal benchmark 6197 E 2021, NOAA station designation 9466197, a chiseled notch on the I-beam holding power pole #36b. Said point has a NAVD88 Orthometric height of 3.536m/11.60'.

Sincerely,

Paul Russell, PLS
Survey Manager

Enclosures:
- Tuntutuliak-FF_AKSPZ7.csv
- Tuntutuliak-FF_NAD83(2011).csv
- OPUS Report_Pt-401_20240313.pdf
- Published Bench Mark Sheet for 9466197 TUNTUTULIAK AK.pdf

Alaska Native Tribal Health Consortium//Division of Environmental Health & Engineering
4500 Diplomacy Drive, Suite 454, Anchorage, Alaska 99508//Main: (907) 729-3600 //Fax: (907) 729-4090//anthc.org

FILE: 01770731.24o OP1710528567602

NGS OPUS SOLUTION REPORT
========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information:
https://urldefense.com/v3/__https://www.ngs.noaa.gov/OPUS/about.jsp*accuracy__;Iw!!PD8KOL_GOQI!ww2CShdG4d7jzWT04pJoj-g83PqsGBKaQy8t10JOVsrb0_4_bhYxh21ZLtfi2rTPFhQqxoRL7MF9ayqG$

USER: ajbrennan@anthc.org DATE: March 15, 2024
RINEX FILE: 0177073r.24o TIME: 19:40:02 UTC

SOFTWARE: page5 2008.25 master274.pl 160321 START: 2024/03/13 17:21:00
EPHEMERIS: igr23053.eph [rapid] STOP: 2024/03/14 00:26:00
NAV FILE: brdc0730.24n OBS USED: 19517 / 20165 : 97%
ANT NAME: TRMR12I NONE # FIXED AMB: 80 / 82 : 98%
ARP HEIGHT: 1.5677 OVERALL RMS: 0.013(m)

REF FRAME:	NAD_83(2011)(EPOCH:2010.0000)		ITRF2014 (EPOCH:2024.1991)	
X:	-3020324.494(m)	0.013(m)	-3020325.745(m)	0.013(m)
Y:	-942648.838(m)	0.017(m)	-942647.841(m)	0.017(m)
Z:	5519470.232(m)	0.004(m)	5519470.480(m)	0.004(m)
LAT:	60 20 32.98186	0.006(m)	60 20 32.96062	0.006(m)
E LON:	197 19 59.66080	0.020(m)	197 19 59.57447	0.020(m)
W LON:	162 40 0.33920	0.020(m)	162 40 0.42553	0.020(m)
EL HGT:	14.285(m)	0.005(m)	14.944(m)	0.005(m)
ORTHO HGT:	3.536(m)	0.354(m)	[NAVD88 (Computed using GEOID12B)]	

	UTM COORDINATES (Zone 03)	STATE PLANE COORDINATES (SPC (5007 AK 7)
Northing (Y) [meters]	6691834.117	706431.458
Easting (X) [meters]	628776.980	463184.080
Convergence [degrees]	2.02785833	-0.57941944
Point Scale	0.99980322	0.99991660
Combined Factor	0.99980098	0.99991436

US NATIONAL GRID DESIGNATOR: 3VXG2877791834(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DK4091	BET1 BETHEL WAAS CORS ARP	N604716.508	W1615030.124	67161.3
DI2154	AB15 NYAC_GOLD_AK2006 CORS GRP	N610223.117	W1595242.014	170989.2
DL6431	AB17 UNALAKLEETAK2008 CORS GRP	N635310.903	W1604140.939	408035.2

NEAREST NGS PUBLISHED CONTROL POINT

UV8199	TULIAK 1975	N602051.026	W1624609.900	5695.9

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

FF = Finish Floor

GS = Ground Shot

401	2317683.88	1519629.77	11.60	SPIKE
551	2317477.19	1516458.34	19.87	6197 D 2021
552	2317424.20	1516117.06	18.67	6197 E 2021
4001	2317805.22	1519562.92	14.16	FF HOME
4002	2317805.20	1519562.90	14.21	FF HOME
4003	2317733.69	1519461.13	14.55	FF HOME
4004	2317725.00	1519500.75	12.84	FF HOME
4005	2317736.02	1519178.55	17.76	FF HOME
4006	2317766.20	1519176.25	16.19	FF HOME
4007	2317784.02	1519103.64	16.31	FF HOME
4009	2317756.46	1519106.42	15.23	FF HOME
4010	2317685.89	1519058.64	17.40	FF CHURCH
4011	2317797.90	1518981.91	16.77	FF HOME
4012	2317733.41	1518890.00	17.45	FF HOME
4013	2317809.58	1518914.32	17.75	FF HOME
4014	2317795.50	1518834.49	17.11	FF HOME
4015	2317835.11	1518727.99	16.33	FF HOME
4016	2317869.83	1518716.60	17.65	FF HOME
4017	2317990.47	1518781.32	17.96	FF HOME
4018	2317913.69	1518562.41	15.29	FF HOME
4019	2318118.56	1518685.88	14.18	GS CEMETARY
4020	2318291.60	1518574.53	18.07	FF POST OFFICE
4021	2318327.58	1518602.14	19.55	FF TRIBAL OFFICE
4022	2318200.01	1518703.49	18.81	FF HOME
4023	2318204.13	1518754.96	20.14	FF HOME
4024	2318192.35	1518888.90	20.05	FF HOME
4025	2318173.30	1518945.09	17.15	FF OFFICE
4026	2318392.81	1519168.75	19.11	FF HOME
4027	2318424.13	1519193.06	13.59	FF HOME
4028	2318358.11	1519255.44	14.96	FF HOME
4029	2318368.90	1519419.03	14.16	FF HOME
4030	2318520.04	1519343.44	13.95	FF HOME
4031	2318430.63	1519470.74	14.73	FF HOME
4032	2318409.37	1519537.01	13.40	FF HOME
4033	2318271.82	1519515.30	14.25	FF HOME
4034	2318625.91	1519625.77	15.55	FF HOME
4035	2318422.93	1519978.46	10.71	FF HOME
4036	2318058.99	1519663.43	15.00	FF HOME
4037	2317986.27	1519674.63	14.14	FF HOME
4038	2318169.23	1518777.82	20.13	FF VPSO
4039	2318414.53	1518396.64	15.66	FF HOME
4040	2318505.10	1518328.62	16.09	FF HOME

4041	2318712.82	1518120.40	17.78	FF NATIONAL GUARD ARMORY
4042	2318758.82	1518101.18	19.51	FF STORE
4043	2318678.90	1517812.57	21.81	FF CLINIC
4044	2318775.00	1517703.61	17.31	FF HOME
4045	2318806.80	1517630.50	17.37	FF HOME
4046	2318683.69	1517652.02	17.12	FF HOME
4047	2318593.09	1517594.47	17.76	FF HOME
4048	2318730.54	1517579.24	16.88	FF HOME
4049	2318651.99	1517485.56	17.31	FF HOME
4050	2318771.03	1517413.44	17.11	FF HOME
4051	2318700.77	1517373.93	17.39	FF HOME
4052	2318750.44	1517259.72	17.11	FF HOME
4053	2318821.23	1517298.63	17.15	FF HOME
4054	2318857.32	1517215.13	18.11	FF HOME
4055	2318791.93	1517163.76	17.15	FF HOME
4056	2318982.94	1517028.12	20.54	FF HOME
4057	2318880.00	1517009.30	18.95	FF HOME
4058	2318774.80	1516990.08	18.36	FF HOME
4059	2318634.86	1516821.72	14.93	FF HOME
4060	2318629.86	1517011.09	17.33	FF HOME
4061	2318594.73	1517086.34	16.37	FF HOME
4062	2318587.32	1517179.49	18.38	FF HOME
4063	2318481.28	1517348.44	18.77	FF HOME
4064	2318424.27	1517332.95	14.69	FF HOME
4065	2318466.37	1517411.12	15.32	FF HOME
4066	2318412.41	1517516.26	15.49	FF HOME
4067	2318440.45	1517647.52	17.21	FF HOME
4068	2318306.60	1517530.78	18.32	FF HOME
4069	2318319.09	1517601.31	20.39	FF HOME
4070	2318331.55	1517672.20	20.82	FF HOME
4071	2318344.72	1517742.28	19.95	FF HOME
4072	2318355.36	1517813.64	19.28	FF HOME
4074	2320588.33	1521060.47	26.81	FF DOT
4075	2320739.39	1521184.45	26.89	FF DOT
4076	2320779.89	1521211.88	27.42	FF DOT
4077	2320604.37	1521261.39	27.51	GS APRON
4078	2320398.60	1521578.54	28.33	GS RUNWAY
4079	2320884.15	1521910.36	26.92	GS RUNWAY
4081	2320019.45	1521326.59	28.21	GS RUNWAY
4082	2317716.33	1518066.96	14.51	FF HOME
4083	2317770.76	1518077.15	16.32	FF HOME
4084	2317757.71	1517983.94	16.88	FF HOME
4085	2317718.20	1517966.89	17.60	FF HOME
4086	2317718.06	1517895.58	16.04	FF HOME

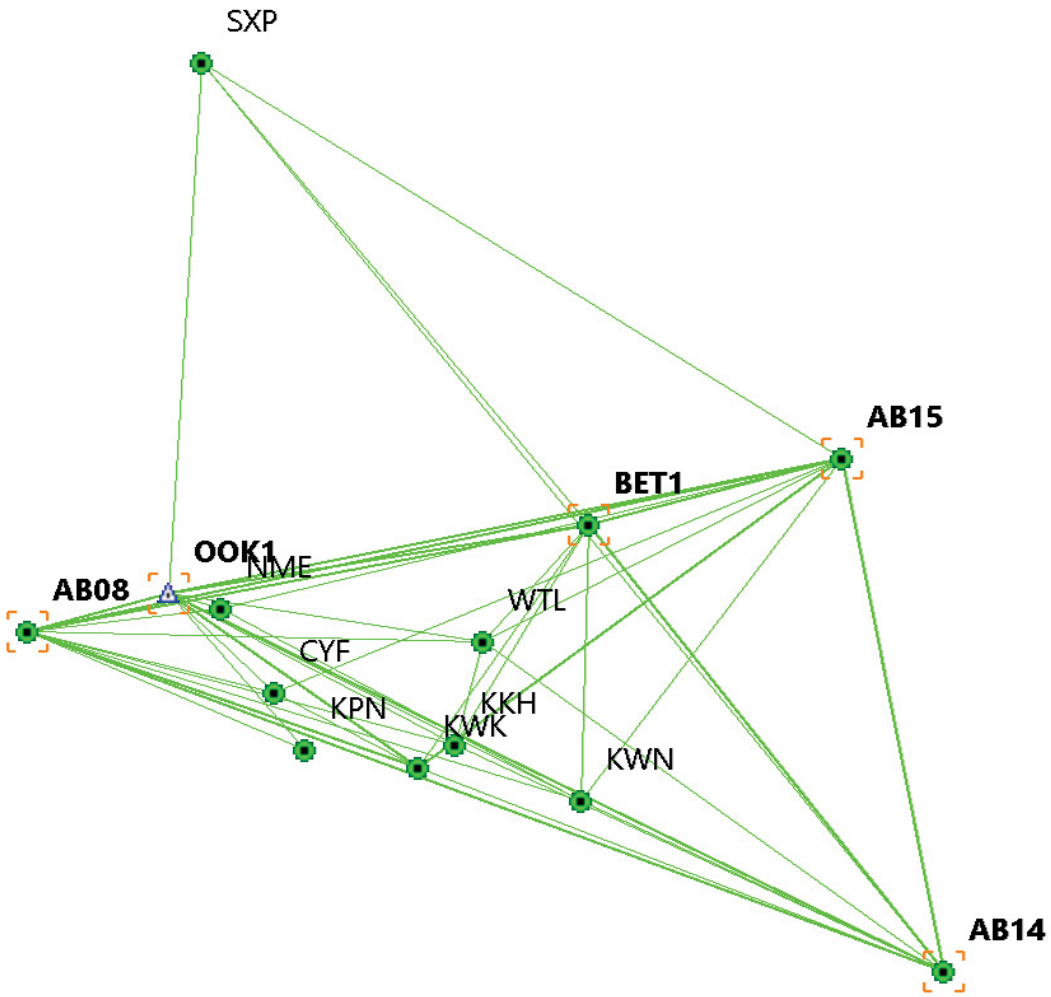
4087	2317689.30	1517875.36	16.04	FF GARAGE
4088	2317824.00	1517797.79	23.64	FF SCHOOL
4089	2317748.75	1517728.35	16.60	FF HOME
4090	2318009.94	1517953.25	20.46	FF HOME
4092	2318241.77	1519428.45	12.94	FF HOME
4093	2317581.37	1519047.22	19.35	FF HOME
4094	2317380.49	1518085.03	14.52	FF HOME
5000	2315439.93	1520636.80	14.94	FF WIND TURBINE
5001	2315619.48	1520497.15	14.92	FF WIND TURBINE
5002	2315802.50	1520381.58	13.93	FF WIND TURBINE
5003	2315981.58	1520242.37	13.20	FF WIND TURBINE
5004	2316161.19	1520102.85	15.22	FF WIND TURBINE
5005	2316149.28	1520208.50	13.66	FF GARAGE
5006	2316008.92	1520293.73	12.52	FF SHED
5007	2315982.92	1520340.64	17.98	FF COMMUNITY SERVICE CENTER
5008	2315759.56	1520720.19	3.78	GS BARGE LANDING
5009	2315711.05	1520684.63	11.33	GS BARGE LANDING
5010	2315384.88	1520146.05	14.50	FF GARAGE
5011	2316374.51	1520022.97	15.72	FF GAS STATION
5012	2316312.27	1519974.35	16.94	FF TOP FUEL CONTAINMENT
5013	2316401.24	1519877.95	15.90	FF POWER PLANT
5014	2316401.64	1519999.67	13.74	FF FUEL PUMP
5015	2316727.22	1519701.89	17.04	FF GCI BUILDING
5016	2316742.24	1519688.73	15.61	FF COMM BUILDING
5017	2316774.04	1519599.76	14.72	FF BUILDING
5018	2316899.08	1519629.97	17.08	FF HOME
5019	2316938.48	1519584.92	16.17	FF HOME
5020	2316991.25	1519588.57	18.09	FF HOME
5021	2316959.78	1519494.44	17.58	FF HOME
5022	2316968.54	1519406.95	15.63	FF HOME
5023	2317024.72	1519375.16	17.18	FF HOME
5024	2316823.74	1519298.36	19.79	FF WASHETERIA
5025	2316977.86	1519307.29	17.16	FF CITY STORAGE
5026	2316994.83	1519277.01	17.60	FF CITY OFFICE
5027	2317014.60	1519235.47	15.62	FF CITY SHOP
5028	2317074.13	1519233.33	17.98	FF HOME
5029	2317091.97	1518895.44	18.16	FF HOME
5030	2317063.54	1518859.32	15.22	FF HOME
5031	2317011.93	1519043.30	18.31	FF BURNED RUINS
5032	2317204.61	1519130.55	15.36	FF HOME
5033	2317289.71	1518925.55	14.45	FF HOME
5034	2317288.99	1519033.25	14.22	FF HOME
5035	2317317.19	1519044.26	13.53	FF HOME
5036	2317288.15	1519133.83	13.80	FF HOME

5037	2317311.19	1519234.35	12.89	FF HOME
5038	2317417.88	1518832.11	13.99	FF HOME
5039	2317253.97	1518615.46	14.31	FF HOME
5040	2317306.60	1518452.98	15.16	FF HOME
5041	2317374.61	1519254.26	14.58	FF HOME
5042	2317400.56	1519243.08	12.19	FF HOME
5043	2317484.77	1519231.94	11.71	FF HOME
5044	2317341.95	1519282.73	12.05	FF HOME
5045	2317339.33	1519312.62	11.77	FF HOME
5046	2317350.90	1519642.75	13.69	FF HOME
5047	2317396.12	1519655.76	14.58	FF HOME
5048	2317393.55	1519391.94	13.80	FF HOME
5049	2317452.44	1519468.34	14.19	FF HOME
5050	2317516.18	1519432.94	15.00	FF HOME
5051	2317492.81	1519430.91	14.25	FF SHED
5052	2317474.22	1519514.30	12.60	FF HOME
5053	2317477.07	1519575.86	14.58	FF HOME
5054	2317549.64	1519569.12	13.54	FF HOME
5055	2317605.77	1519610.02	13.79	FF HOME
5056	2317704.01	1519647.98	15.41	FF HOME
5057	2317613.81	1515254.44	15.47	FF HOME
5058	2317779.24	1515732.43	19.37	FF HOME
5059	2317713.28	1515781.71	17.83	FF HOME
5060	2317651.29	1515796.42	19.55	FF HOME
5061	2317851.96	1515805.85	18.24	FF HOME
5062	2317786.66	1515854.59	19.10	FF HOME
5063	2317723.50	1515895.84	19.41	FF HOME
5064	2317663.27	1515938.38	17.69	FF HOME
5065	2317480.75	1515995.93	14.89	FF HOME
5066	2317483.33	1516181.57	19.47	FF HOME
5067	2317414.21	1516259.66	18.08	FF HOME
5068	2317519.08	1516393.76	16.35	FF HOME
5069	2317550.08	1516491.82	12.86	GS CEMETERY
5070	2317667.77	1516462.70	18.11	FF HOME
5071	2317876.28	1516507.90	16.05	FF HOME
5072	2318314.75	1516876.60	13.72	FF HOME
5073	2318151.39	1516851.71	18.55	FF HOME
5074	2318064.25	1516799.40	18.29	FF HOME
5075	2318024.38	1516859.56	18.11	FF HOME
5076	2318115.48	1516912.97	18.16	FF HOME
5077	2318083.08	1516963.44	18.27	FF HOME
5078	2317708.82	1517010.60	17.91	FF CHURCH
5079	2317715.38	1517114.08	17.61	FF HOME
5080	2317595.38	1517228.49	15.06	FF HOME

5081	2317962.72	1517164.89	19.18	FF HOME
5082	2317929.34	1517224.10	19.04	FF HOME
5083	2317896.53	1517290.46	18.96	FF HOME
5084	2317858.43	1517340.98	19.31	FF HOME
5085	2317825.21	1517432.36	16.84	FF HOME
5086	2317790.41	1517477.47	18.51	FF HOME
5087	2317797.08	1517526.22	18.48	FF HOME
5088	2317815.40	1517590.30	19.64	FF HOME
5089	2317825.87	1517692.40	17.65	FF HOME
5090	2317992.95	1517910.60	18.96	FF HOME
5091	2318114.60	1518177.31	14.17	GS BOARDWALK BY FUEL TANKS

APPENDIX B: ACCURACY REPORT WITH OPUS SOLUTIONS

2025 Typhoon Halong High-Water Mark Accuracy Assessment



Survey Results– The field response was conducted during the Federal Government shutdown and the NGS OPUS positioning service was unavailable. To obtain final coordinates a least squares adjustment of a regiomal network including the RTK base in each surveyed village and six nearby CORS sites, holding the ACORN site OOK1 at Toksook Bay fixed was performed. The results of the adjustment (Table 3) show standard errors of +/- 0.01 m horizontal and +/- 0.02-0.03 m vertical. As a check on the least squares adjustment OPUS solutions were obtained. Tables 1 and 2 summarize the OPUS results. The RMSE of the solution differences is +/- 0.022 m horizontal and +/- 0.025 m vertical.

Given short baseline lengths and fixed RTK solutions, rover positioning accuracy is expected to be comparable to the network RMSE values. Accordingly, RTK survey accuracy is conservatively quoted as ±0.03 m horizontal and ±0.05 m vertical.

Table 1

2025 Halong High Water Mark Survey Village Base Statio Coordinate Checks

	Field Solution Topcon Magnet							OPUS Check									
Village	Latitude			Longitude			Ellip. Ht.(m)	Latitude			Longitude			Ellip. Ht.(m)	dN(m)	dE(m)	dHt.(m)
BET2	60	47	28.63987	-161	45	20.35263	15.968	60	47	28.64126	-161	45	20.35248	15.966	-0.043	0.002	0.002
CYF	60	9	27.53819	-164	17	4.61717	20.890	60	9	27.53809	-164	17	4.61699	20.882	0.003	0.003	0.008
KKH	59	57	37.49944	-162	53	1.63527	20.564	59	57	37.49825	-162	53	1.63093	20.603	0.037	0.067	-0.039
KPN	59	56	34.91689	-164	2	31.04466	13.178	59	56	34.91657	-164	2	31.04394	13.124	0.010	0.011	0.054
KWK	59	52	32.33283	-163	9	58.13696	14.602	59	52	32.33262	-163	9	58.13618	14.566	0.007	0.012	0.036
KWN	59	45	6.67084	-161	53	54.77391	18.350	59	45	6.67170	-161	53	54.77363	18.351	-0.027	0.004	-0.001
NME	60	28	24.74153	-164	42	2.68863	17.580	60	28	24.74177	-164	42	2.68895	17.574	-0.007	-0.005	0.006
SXP	62	31	29.38853	-164	50	43.67362	11.319	62	31	29.38861	-164	50	43.67544	11.255	-0.003	-0.028	0.064
WTL	60	21	1.76695	-162	39	33.76335	20.069	60	21	1.76717	-162	39	33.76379	20.054	-0.007	-0.007	0.015
														RMSE	**0.022**	**0.025**	**0.034**
AB08	60	23	5.40615	-166	12	3.00222	25.797	CORS									
AB14	59	6	29.40381	-159	5	29.43297	657.062	CORS									
AB15	61	2	23.11692	-159	52	42.01403	559.737	CORS									
BET1	60	47	16.50771	-161	50	30.12395	51.078	CORS									
NGMT	60	28	31.56528	-164	43	24.94228	19.596	CORS									
OOK1	**60**	**31**	**43.14590**	**-165**	**6**	**27.81555**	**16.416**	**Fixed Position in the Adjustment (CORS)**									

Table 2

OPUS Solution Quality Metrics

Site	Duration	RMS	%Obs.	%Amb.	P2P Lat/Lon/Hgt.
BET	02h 21m	0.01	95%	**58%**	0.015 / 0.026 / 0.011
CYF	03h 42m	0.02	97%	86%	0.011 / 0.023 / 0.017
KKH	02h 56m	0.02	96%	91%	0.007 / 0.022 / 0.030
KPN	04h 18m	0.02	98%	91%	0.014 / 0.027 / 0.008
KWK	03h 46m	0.01	97%	94%	0.011 / 0.010 / 0.014
KWN	03h 15m	0.01	98%	89%	0.019 / 0.006 / 0.013
NME	03h 21m	0.02	99%	93%	0.011 / 0.015 / 0.023
WTL	06h 06m	0.01	98%	96%	0.010 / 0.024 / 0.023

Table 3

Topcon Magnet Processing - Least Squares Adjustment Results

Name	Latitude (°)	Longitude (°)	Ell.Height (m)	Elevation (m)	Hz Stdev,(m)	Hgt, Stdev. (m)	Geoid 12B
BET2	60°47'28.63987"N	161°45'20.35263"W	15.968	5.334	0.006	0.009	10.634
CYF	60°09'27.53819"N	164°17'04.61717"W	20.89	10.767	0.009	0.016	10.123
KKH	59°57'37.49944"N	162°53'01.63527"W	20.564	9.204	0.011	0.018	11.36
KPN	59°56'34.91689"N	164°02'31.04466"W	13.178	2.791	0.013	0.023	10.388
KWK	59°52'32.33283"N	163°09'58.13696"W	14.602	3.291	0.009	0.015	11.311
KWN	59°45'06.67084"N	161°53'54.77391"W	18.35	6.384	0.012	0.020	11.965
NME	60°28'24.74153"N	164°42'02.68863"W	17.58	7.565	0.003	0.004	10.015
SXP	62°31'29.38853"N	164°50'43.67362"W	11.319	11.319	0.019	0.025	0
WTL	60°21'01.76695"N	162°39'33.76335"W	20.069	9.333	0.010	0.017	10.735
AB08	60°23'05.40615"N	166°12'03.00222"W	25.797	16.018	0.004	0.007	9.78
AB14	59°06'29.40381"N	159°05'29.43297"W	657.062	643.575	0.008	0.011	13.487
AB15	61°02'23.11692"N	159°52'42.01403"W	559.737	559.737	0.006	0.009	0
BET1	60°47'16.50771"N	161°50'30.12394"W	51.078	40.468	0.005	0.009	10.61
NGMT	60°28'31.56528"N	164°43'24.94228"W	19.596	9.569	0.002	0.004	10.027
OOK1*	**60°31'44.54055"N**	**165°06'26.05568"W**	**25.001**	**14.977**			**10.024**

*** Fixed point in Adjustment**

Jim Mitchell <jim@joasurveys.com>

OPUS solution : bet22920.25o OP1768175359882

1 message

opus <opus@ngs.noaa.gov> Sun, Jan 11, 2026 at 2:50 PM
Reply-To: ngs.opus@noaa.gov
To: jim@joasurveys.com

FILE: bet22920.25o OP1768175359882

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: https://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: jim@joasurveys.com DATE: January 11, 2026
RINEX FILE: bet2292v.25o TIME: 23:50:09 UTC

SOFTWARE: page5 2008.25 master255.pl 160321 START: 2025/10/19 21:24:00
EPHEMERIS: igs23890.eph [precise] STOP: 2025/10/19 23:45:00
NAV FILE: brdc2920.25n OBS USED: 6909 / 7262 : 95%
ANT NAME: TPSHIPER_HR NONE # FIXED AMB: 28 / 48 : 58%
ARP HEIGHT: 2.000 OVERALL RMS: 0.013(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) ITRF2020 (EPOCH:2025.7998)

X:	-2963592.253(m)	0.014(m)	-2963593.570(m)	0.014(m)
Y:	-976921.959(m)	0.025(m)	-976920.983(m)	0.025(m)
Z:	5544044.745(m)	0.012(m)	5544044.951(m)	0.012(m)

LAT:	60 47 28.64126	0.015(m)	60 47 28.61783	0.015(m)
E LON:	198 14 39.64754	0.026(m)	198 14 39.55902	0.026(m)
W LON:	161 45 20.35246	0.026(m)	161 45 20.44098	0.026(m)
EL HGT:	15.966(m)	0.011(m)	16.607(m)	0.011(m)
ORTHO HGT:	5.332(m)	0.356(m)	[NAVD88 (Computed using GEOID12B)]	

	UTM COORDINATES (UTM (Zone 04))	STATE PLANE COORDINATES (SPC (5007 AK 7))
Northing (Y) [meters]	6742689.702	756270.561
Easting (X) [meters]	350011.578	513306.279
Convergence [degrees]	-2.40571111	0.21327778
Point Scale	0.99987565	0.99990217
Combined Factor	0.99987315	0.99989967

US NATIONAL GRID DESIGNATOR: 4VCN5001142689(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DL7658	AC24 KINGSALMONAK2006 CORS GRP	N584053.668	W1563909.837	370736.3
DL6422	AB08 MEKORYUK_AK2008 CORS GRP	N602305.408	W1661203.007	247733.9
DR5470	AT01 STMICHAEL_AK2018 CORS GRP	N632902.581	W1620022.945	300359.4

NEAREST NGS PUBLISHED CONTROL POINT

DR6569	946 6477 B	N604728.640	W1614520.351	0.0

knowledge by the National Geodetic Survey regarding the equipment or
field operating procedures used.
8002 Was this collected on a published mark? Please help update
8002 NGS records by sharing https://geodesy.noaa.gov/marks/sharing/ or
8002 updating descriptions https://geodesy.noaa.gov/marks/recovery/

JOA Surveys

Jim Mitchell <jim@joasurveys.com>

OPUS solution : cyf_2960.25o OP1768171333024

1 message

opus <opus@ngs.noaa.gov> Sun, Jan 11, 2026 at 1:44 PM
Reply-To: ngs.opus@noaa.gov
To: jim@joasurveys.com

FILE: cyf_2960.25o OP1768171333024

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: https://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: jim@joasurveys.com DATE: January 11, 2026
RINEX FILE: cyf_296t.25o TIME: 22:43:44 UTC

SOFTWARE: page5 2008.25 master293.pl 160321 START: 2025/10/23 19:56:00
EPHEMERIS: igs23894.eph [precise] STOP: 2025/10/23 23:38:00
NAV FILE: brdc2960.25n OBS USED: 12058 / 12474 : 97%
ANT NAME: TPSHIPER_HR NONE # FIXED AMB: 57 / 66 : 86%
ARP HEIGHT: 0.0001 OVERALL RMS: 0.015(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) ITRF2020 (EPOCH:2025.8107)

X:	-3062949.662(m)	0.020(m)	-3062950.945(m)	0.020(m)
Y:	-861843.783(m)	0.019(m)	-861842.778(m)	0.019(m)
Z:	5509256.459(m)	0.013(m)	5509256.700(m)	0.013(m)

LAT:	60 9 27.53809	0.011(m)	60 9 27.51498	0.011(m)
E LON:	195 42 55.38301	0.023(m)	195 42 55.29776	0.023(m)
W LON:	164 17 4.61699	0.023(m)	164 17 4.70224	0.023(m)
EL HGT:	20.882(m)	0.017(m)	21.571(m)	0.017(m)
ORTHO HGT:	10.759(m)	0.355(m)	[NAVD88 (Computed using GEOID12B)]	

	UTM COORDINATES (UTM (Zone 03))	STATE PLANE COORDINATES (SPC (5008 AK 8))
Northing (Y) [meters]	6669183.511	686889.383
Easting (X) [meters]	539711.952	595245.966
Convergence [degrees]	0.62053056	1.48803056
Point Scale	0.99961933	1.00001114
Combined Factor	0.99961606	1.00000787

US NATIONAL GRID DESIGNATOR: 3VWG3971169183(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DK4091	BET1 BETHEL WAAS CORS ARP	N604716.507	W1615030.123	151593.9
DI2154	AB15 NYAC_GOLD_AK2006 CORS GRP	N610223.117	W1595242.014	260584.5
DR5470	AT01 STMICHAEL_AK2018 CORS GRP	N632902.581	W1620022.945	389543.9

NEAREST NGS PUBLISHED CONTROL POINT

DQ2641	CFK B	N600900.910	W1641709.616	827.7

This position and the above vector components were computed without any

JOA Surveys

Jim Mitchell <jim@joasurveys.com>

OPUS solution : kkh12940.25o OP1768175422396

1 message

opus <opus@ngs.noaa.gov> Sun, Jan 11, 2026 at 2:52 PM
Reply-To: ngs.opus@noaa.gov
To: jim@joasurveys.com

FILE: kkh12940.25o OP1768175422396

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: https://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: jim@joasurveys.com DATE: January 11, 2026
RINEX FILE: kkh1294u.25o TIME: 23:51:53 UTC

SOFTWARE: page5 2008.25 master243.pl 160321 START: 2025/10/21 20:55:00
EPHEMERIS: igs23892.eph [precise] STOP: 2025/10/21 23:51:30
NAV FILE: brdc2940.25n OBS USED: 8864 / 9276 : 96%
ANT NAME: TPSHIPER_HR NONE # FIXED AMB: 48 / 53 : 91%
ARP HEIGHT: 2.000 OVERALL RMS: 0.017(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) ITRF2020 (EPOCH:2025.8053)

X:	-3059163.325(m)	0.025(m)	-3059164.606(m)	0.025(m)
Y:	-942069.223(m)	0.019(m)	-942068.215(m)	0.019(m)
Z:	5498288.595(m)	0.022(m)	5498288.824(m)	0.022(m)

LAT:	59 57 37.49825	0.007(m)	59 57 37.47604	0.007(m)
E LON:	197 6 58.36907	0.022(m)	197 6 58.28267	0.022(m)
W LON:	162 53 1.63093	0.022(m)	162 53 1.71733	0.022(m)
EL HGT:	20.603(m)	0.030(m)	21.265(m)	0.030(m)
ORTHO HGT:	9.243(m)	0.357(m)	[NAVD88 (Computed using GEOID12B)]	

	UTM COORDINATES (UTM (Zone 03))	STATE PLANE COORDINATES (SPC (5007 AK 7))
Northing (Y) [meters]	6648892.259	664009.925
Easting (X) [meters]	618165.074	450631.732
Convergence [degrees]	1.83217222	-0.76509167
Point Scale	0.99977112	0.99992986
Combined Factor	0.99976790	0.99992664

US NATIONAL GRID DESIGNATOR: 3VXG1816548892(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DL7658	AC24 KINGSALMONAK2006 CORS GRP	N584053.668	W1563909.837	382086.5
DI2154	AB15 NYAC_GOLD_AK2006 CORS GRP	N610223.117	W1595242.014	204279.3
DL6422	AB08 MEKORYUK_AK2008 CORS GRP	N602305.408	W1661203.007	190072.0

NEAREST NGS PUBLISHED CONTROL POINT

UV7883	ILKEVIK	N595702.991	W1625005.665	2932.5

This position and the above vector components were computed without any

JOA Surveys

Jim Mitchell <jim@joasurveys.com>

OPUS solution : kpn12950.25o OP1768175469303

1 message

opus <opus@ngs.noaa.gov> Sun, Jan 11, 2026 at 2:53 PM
Reply-To: ngs.opus@noaa.gov
To: jim@joasurveys.com

FILE: kpn12950.25o OP1768175469303

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: https://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: jim@joasurveys.com DATE: January 11, 2026
RINEX FILE: kpn1295t.25o TIME: 23:52:50 UTC

SOFTWARE: page5 2008.25 master241.pl 160321 START: 2025/10/22 19:46:00
EPHEMERIS: igs23893.eph [precise] STOP: 2025/10/23 00:04:00
NAV FILE: brdc2950.25n OBS USED: 13994 / 14339 : 98%
ANT NAME: TPSHIPER_HR NONE # FIXED AMB: 98 / 108 : 91%
ARP HEIGHT: 2.00 OVERALL RMS: 0.017(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) ITRF2020 (EPOCH:2025.8080)

X:	-3079188.200(m)	0.011(m)	-3079189.482(m)	0.011(m)
Y:	-880503.288(m)	0.028(m)	-880502.278(m)	0.028(m)
Z:	5497312.328(m)	0.001(m)	5497312.566(m)	0.001(m)

LAT:	59 56 34.91657	0.014(m)	59 56 34.89371	0.014(m)
E LON:	195 57 28.95606	0.027(m)	195 57 28.87081	0.027(m)
W LON:	164 2 31.04394	0.027(m)	164 2 31.12919	0.027(m)
EL HGT:	13.124(m)	0.008(m)	13.808(m)	0.008(m)
ORTHO HGT:	2.736(m)	0.355(m)	[NAVD88 (Computed using GEOID12B)]	

	UTM COORDINATES (UTM (Zone 03))	STATE PLANE COORDINATES (SPC (5008 AK 8))
Northing (Y) [meters]	6645454.220	663362.313
Easting (X) [meters]	553528.040	609425.056
Convergence [degrees]	0.82923333	1.69490833
Point Scale	0.99963511	1.00004670
Combined Factor	0.99963306	1.00004465

US NATIONAL GRID DESIGNATOR: 3VWG5352845454(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DL6422	AB08 MEKORYUK_AK2008 CORS GRP	N602305.408	W1661203.007	129572.5
DK4091	BET1 BETHEL WAAS CORS ARP	N604716.507	W1615030.123	153619.0
DR5470	AT01 STMICHAEL_AK2018 CORS GRP	N632902.581	W1620022.945	408915.0

NEAREST NGS PUBLISHED CONTROL POINT

UV7899	KIPNUK ASTRO USAF 1949	N595618.405	W1640232.529	511.5

This position and the above vector components were computed without any

JOA Surveys

Jim Mitchell <jim@joasurveys.com>

OPUS solution : kwk12960.25o OP1768183582051

1 message

opus <opus@ngs.noaa.gov> Sun, Jan 11, 2026 at 5:08 PM
Reply-To: ngs.opus@noaa.gov
To: jim@joasurveys.com

FILE: kwk12960.25o OP1768183582051

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: https://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: jim@joasurveys.com DATE: January 12, 2026
RINEX FILE: kwk1296v.25o TIME: 02:07:56 UTC

SOFTWARE: page5 2008.25 master290.pl 160321 START: 2025/10/23 21:15:00
EPHEMERIS: igs23894.eph [precise] STOP: 2025/10/24 01:01:00
NAV FILE: brdc2960.25n OBS USED: 11823 / 12151 : 97%
ANT NAME: TPSHIPER_HR NONE # FIXED AMB: 50 / 53 : 94%
ARP HEIGHT: 2.000 OVERALL RMS: 0.013(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) ITRF2020 (EPOCH:2025.8109)

X:	-3071587.833(m)	0.006(m)	-3071589.114(m)	0.006(m)
Y:	-929347.549(m)	0.012(m)	-929346.538(m)	0.012(m)
Z:	5493549.610(m)	0.015(m)	5493549.841(m)	0.015(m)
LAT:	59 52 32.33262	0.011(m)	59 52 32.31026	0.011(m)
E LON:	196 50 1.86382	0.010(m)	196 50 1.77778	0.010(m)
W LON:	163 9 58.13618	0.010(m)	163 9 58.22222	0.010(m)
EL HGT:	14.566(m)	0.014(m)	15.234(m)	0.014(m)
ORTHO HGT:	3.255(m)	0.355(m) [NAVD88 (Computed using GEOID12B)]		

	UTM COORDINATES (UTM (Zone 03))	STATE PLANE COORDINATES (SPC (5007 AK 7))
Northing (Y) [meters]	6638983.752	654812.010
Easting (X) [meters]	602662.892	434693.609
Convergence [degrees]	1.58630556	-1.00868333
Point Scale	0.99972917	0.99995225
Combined Factor	0.99972689	0.99994997

US NATIONAL GRID DESIGNATOR: 3VXG0266238983(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DK4091	BET1 BETHEL WAAS CORS ARP	N604716.507	W1615030.123	125229.8
DI2154	AB15 NYAC_GOLD_AK2006 CORS GRP	N610223.117	W1595242.014	222568.2
DL6422	AB08 MEKORYUK_AK2008 CORS GRP	N602305.408	W1661203.007	177929.8

NEAREST NGS PUBLISHED CONTROL POINT

UV7885	GILL	N595135.116	W1630709.893	3160.7

This position and the above vector components were computed without any

JOA Surveys

Jim Mitchell <jim@joasurveys.com>

OPUS solution : kwn12970.25o OP1768183423428

1 message

opus <opus@ngs.noaa.gov> Sun, Jan 11, 2026 at 5:05 PM
Reply-To: ngs.opus@noaa.gov
To: jim@joasurveys.com

FILE: kwn12970.25o OP1768183423428

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: https://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: jim@joasurveys.com DATE: January 12, 2026
RINEX FILE: kwn1297s.25o TIME: 02:05:26 UTC

SOFTWARE: page5 2008.25 master295.pl 160321 START: 2025/10/24 18:03:00
EPHEMERIS: igs23895.eph [precise] STOP: 2025/10/24 21:18:00
NAV FILE: brdc2970.25n OBS USED: 9495 / 9661 : 98%
ANT NAME: TPSHIPER_HR NONE # FIXED AMB: 49 / 55 : 89%
ARP HEIGHT: 2.000 OVERALL RMS: 0.012(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) ITRF2020 (EPOCH:2025.8132)

X:	-3061610.551(m)	0.013(m)	-3061611.855(m)	0.013(m)
Y:	-1000774.441(m)	0.010(m)	-1000773.452(m)	0.010(m)
Z:	5486618.147(m)	0.014(m)	5486618.349(m)	0.014(m)

LAT:	59 45 6.67170	0.019(m)	59 45 6.64898	0.019(m)
E LON:	198 6 5.22637	0.006(m)	198 6 5.14022	0.006(m)
W LON:	161 53 54.77363	0.006(m)	161 53 54.85978	0.006(m)
EL HGT:	18.351(m)	0.013(m)	18.995(m)	0.013(m)
ORTHO HGT:	6.386(m)	0.355(m)	[NAVD88 (Computed using GEOID12B)]	

	UTM COORDINATES (UTM (Zone 04))	STATE PLANE COORDINATES (SPC (5007 AK 7))
Northing (Y) [meters]	6627335.708	640451.029
Easting (X) [meters]	337150.693	505702.778
Convergence [degrees]	-2.50446111	0.08763889
Point Scale	0.99992502	0.99990040
Combined Factor	0.99992215	0.99989753

US NATIONAL GRID DESIGNATOR: 4VCM3715027335(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DL6422	AB08 MEKORYUK_AK2008 CORS GRP	N602305.408	W1661203.007	249669.1
DI2154	AB15 NYAC_GOLD_AK2006 CORS GRP	N610223.117	W1595242.014	181634.7
DL7658	AC24 KINGSALMONAK2006 CORS GRP	N584053.668	W1563909.837	322316.9

NEAREST NGS PUBLISHED CONTROL POINT

UV7874	EC 10717	N594517.415	W1615305.781	834.2

This position and the above vector components were computed without any

JOA Surveys

Jim Mitchell <jim@joasurveys.com>

OPUS solution : nme12970.25o OP1768183459395

1 message

opus <opus@ngs.noaa.gov> Sun, Jan 11, 2026 at 5:06 PM
Reply-To: ngs.opus@noaa.gov
To: jim@joasurveys.com

FILE: nme12970.25o OP1768183459395

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: https://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: jim@joasurveys.com DATE: January 12, 2026
RINEX FILE: nme1297t.25o TIME: 02:05:42 UTC

SOFTWARE: page5 2008.25 master271.pl 160321 START: 2025/10/24 19:09:00
EPHEMERIS: igs23895.eph [precise] STOP: 2025/10/24 22:30:00
NAV FILE: brdc2970.25n OBS USED: 10754 / 10831 : 99%
ANT NAME: TPSHIPER_HR NONE # FIXED AMB: 51 / 55 : 93%
ARP HEIGHT: 0.0001 OVERALL RMS: 0.016(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) ITRF2020 (EPOCH:2025.8133)

X:	-3039633.413(m)	0.021(m)	-3039634.697(m)	0.021(m)
Y:	-831507.013(m)	0.012(m)	-831506.015(m)	0.012(m)
Z:	5526683.310(m)	0.016(m)	5526683.556(m)	0.016(m)

LAT:	60 28 24.74177	0.011(m)	60 28 24.71826	0.011(m)
E LON:	195 17 57.31105	0.015(m)	195 17 57.22588	0.015(m)
W LON:	164 42 2.68895	0.015(m)	164 42 2.77412	0.015(m)
EL HGT:	17.574(m)	0.023(m)	18.268(m)	0.023(m)
ORTHO HGT:	7.558(m)	0.356(m)	[NAVD88 (Computed using GEOID12B)]	

	UTM COORDINATES (UTM (Zone 03))	STATE PLANE COORDINATES (SPC (5008 AK 8))
Northing (Y) [meters]	6704187.477	721549.643
Easting (X) [meters]	516452.489	571449.458
Convergence [degrees]	0.26038889	1.13056389
Point Scale	0.99960332	0.99996254
Combined Factor	0.99960057	0.99995979

US NATIONAL GRID DESIGNATOR: 3VWH1645204187(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DR5470	AT01 STMICHAEL_AK2018 CORS GRP	N632902.581	W1620022.945	363913.5
DL6671	AB04 SAVOONGA__AK2007 CORS GRP	N633924.727	W1703402.710	468524.8
DK4091	BET1 BETHEL WAAS CORS ARP	N604716.507	W1615030.123	160343.5

NEAREST NGS PUBLISHED CONTROL POINT

UV8243	TOOKSOOK	N602928.869	W1644349.167	2566.0

This position and the above vector components were computed without any

JOA Surveys

Jim Mitchell <jim@joasurveys.com>

OPUS solution : wtl12940.25o OP1764038209313

1 message

opus <opus@ngs.noaa.gov> Mon, Nov 24, 2025 at 5:37 PM
Reply-To: ngs.opus@noaa.gov
To: jim@joasurveys.com

FILE: wtl12940.25o OP1764038209313

1008 NOTE: You provided a zero or negative antenna height.
1008 If ARP HGT = 0.0, OPUS solves for the position of your selected antenna's reference point (ARP).
1008 If ARP HGT < 0.0, OPUS solves for a location inside or above the antenna
1008

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: https://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: jim@joasurveys.com DATE: November 25, 2025
RINEX FILE: wtl1294s.25o TIME: 02:37:29 UTC

SOFTWARE: page5 2008.25 master262.pl 160321 START: 2025/10/21 18:11:00
EPHEMERIS: igs23892.eph [precise] STOP: 2025/10/22 00:17:30
NAV FILE: brdc2940.25n OBS USED: 19635 / 20087 : 98%
ANT NAME: TPSHIPER_HR NONE # FIXED AMB: 76 / 79 : 96%
ARP HEIGHT: 0.000 OVERALL RMS: 0.012(m)

REF FRAME: NAD_83(2011)(EPOCH:2010.0000) ITRF2020 (EPOCH:2025.8052)

X:	-3019466.714(m)	0.010(m)	-3019467.997(m)	0.010(m)
Y:	-942808.067(m)	0.022(m)	-942807.073(m)	0.022(m)
Z:	5519916.019(m)	0.025(m)	5519916.247(m)	0.025(m)

LAT:	60 21 1.76717	0.010(m)	60 21 1.74474	0.010(m)
E LON:	197 20 26.23621	0.024(m)	197 20 26.14942	0.024(m)
W LON:	162 39 33.76379	0.024(m)	162 39 33.85058	0.024(m)
EL HGT:	20.054(m)	0.023(m)	20.712(m)	0.023(m)
ORTHO HGT:	9.319(m)	0.355(m)	[NAVD88 (Computed using GEOID12B)]	

	UTM COORDINATES (UTM (Zone 03))	STATE PLANE COORDINATES (SPC (5007 AK 7))
Northing (Y) [meters]	6692738.717	707318.130
Easting (X) [meters]	629152.678	463600.588
Convergence [degrees]	2.03443611	-0.57305000
Point Scale	0.99980440	0.99991623
Combined Factor	0.99980126	0.99991309

US NATIONAL GRID DESIGNATOR: 3VXG2915292738(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DK4091	BET1 BETHEL WAAS CORS ARP	N604716.507	W1615030.123	66227.2
DR5470	AT01 STMICHAEL_AK2018 CORS GRP	N632902.581	W1620022.945	350850.0
DI2154	AB15 NYAC_GOLD_AK2006 CORS GRP	N610223.117	W1595242.014	170209.8

NEAREST NGS PUBLISHED CONTROL POINT

UV8191	KINAK	N602150.144 W1623344.911	5554.4

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

Datum NAD83(2011)(2010.00) NAVD88 (Geoid12b) UTM Zone 3N

community	point	north (m)	east (m)	elev (m)	Measure Up	HWM Elev.
WTL	1	6692729.30	629149.72	4.13	0.00	4.13
WTL	2	6691989.63	628557.91	4.04	0.00	4.04
WTL	3	6691979.42	628457.45	4.13	0.00	4.13
WTL	4	6691954.14	628388.12	3.92	0.00	3.92
WTL	5	6691932.88	628235.95	4.19	0.00	4.19
WTL	6	6691888.19	628258.08	4.20	0.00	4.20
WTL	7	6691843.77	628192.50	4.12	0.00	4.12
WTL	8	6691721.37	627679.25	3.34	0.85	4.19
WTL	9	6691984.91	627910.74	3.16	0.00	3.16
WTL	10	6692075.24	627995.45	2.73	1.48	4.21
WTL	11	6692095.46	628251.80	4.18	0.00	4.18
WTL	12	6692004.70	628704.76	3.05	1.10	4.15
WTL	13	6692060.07	628870.86	3.04	1.18	4.22
WTL	14	6691551.50	628803.99	3.02	1.15	4.17
WTL	15	6691416.35	628908.57	3.82	0.00	3.82