Akutan Harbor Navigational Improvements

Appendix D: Hydraulics and Hydrology

Akutan, Alaska

US Army Corps of Engineers
Alaska District

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1.0 INTRODUCTION

1.1 Appendix Purpose

This hydraulic design appendix describes the technical aspects of the Akutan Harbor Navigational Improvements. It provides the background for determining the Federal interest in construction of a navigation improvement project to decrease transportation inefficiencies between the community of Akutan on Akutan island and the airport on Akun island by constructing a harbor with entrance channel and turning basin protected by a breakwater. To determine the feasibility of a project, existing data was gathered and analyzed to determine wave climate for design of the proposed navigation improvements

1.2 Study Location

The study location is on the islands of Akutan and Akun in the eastern Aleutian Island archipelago, 35 miles east of the city of Dutch Harbor, Unalaska and approximately 763 air miles southwest of Anchorage (Figure 1-Figure 2).

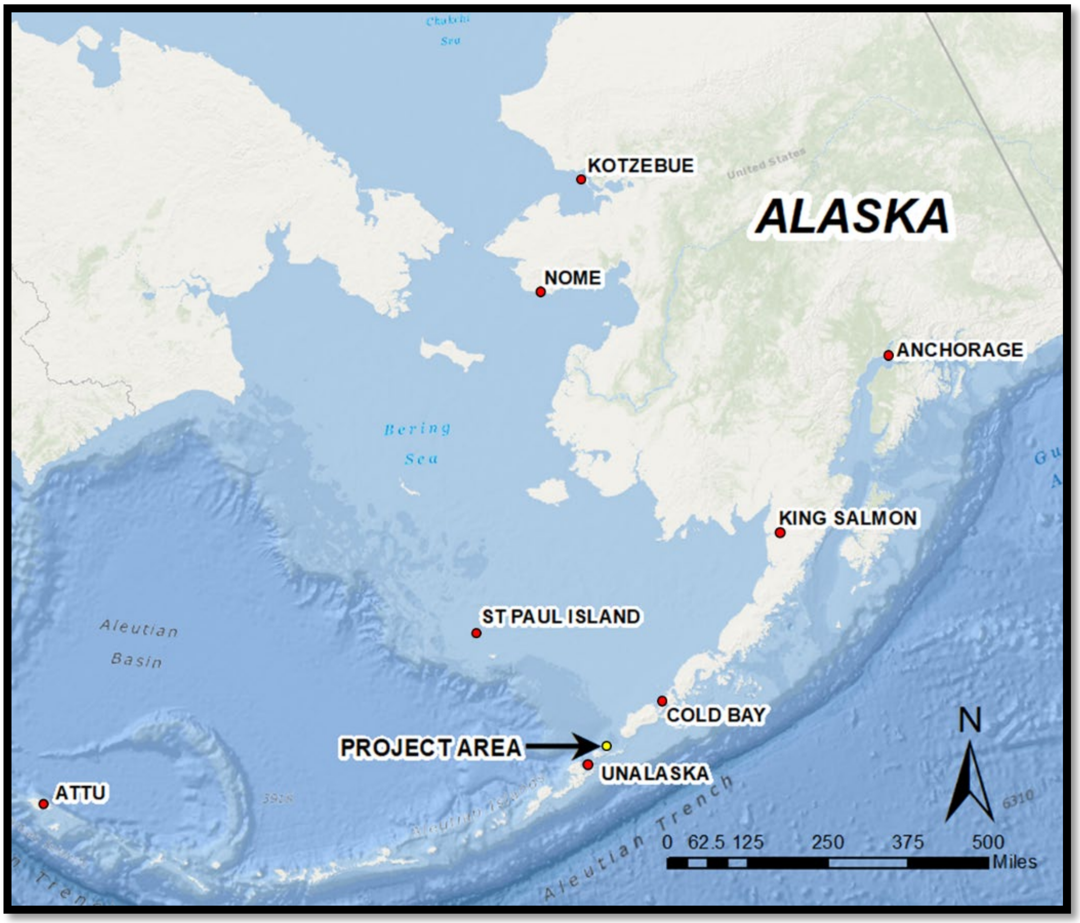


Figure 1: Vicinity Map of Project Area

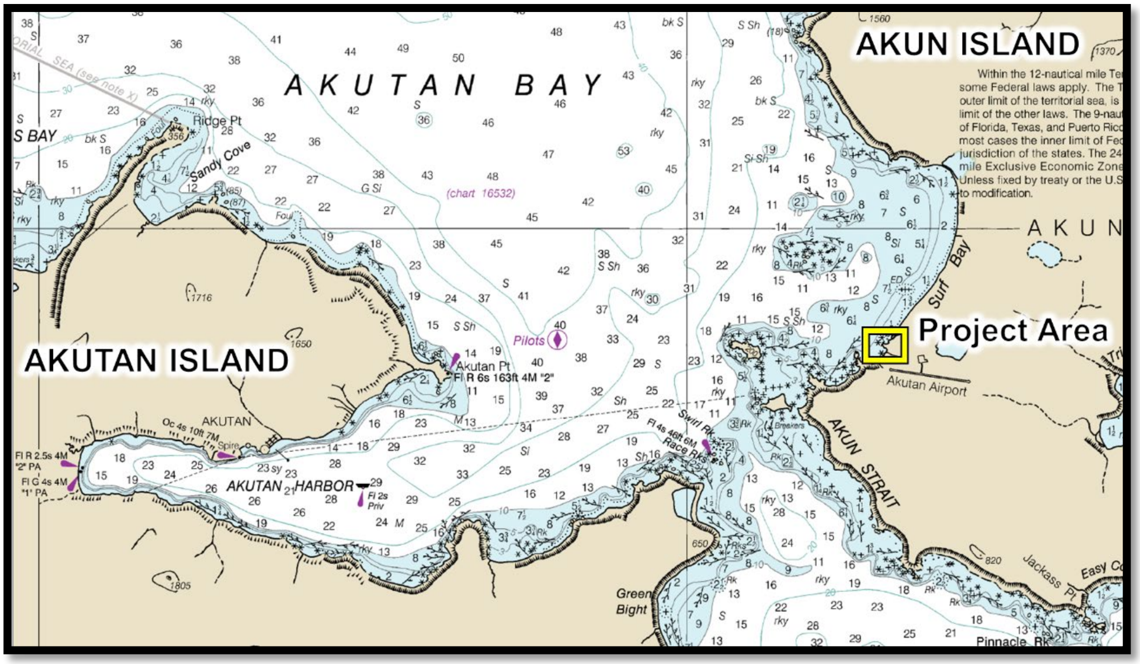


Figure 2: NOAA Coastal Chart 16531, Published 12/01/2015

The community of Akutan is located on the eastern side of Akutan Island, on a flat piece of land on the north shore of Akutan Harbor with the steep slope of a mountain rising behind the village, confining the community to a small area. Akutan Harbor is a large deep body of water protected by the island's active volcano that blocks much of the prevailing easterly winds of the Aleutian Islands. The harbor accommodates large vessels, including floating processors, and large container and cargo ships that service both the community of Akutan as well as the large adjacent shore-based seafood processing facility, Trident Seafoods. There is a USACE Federally Constructed boat harbor at the western end of Akutan Harbor that often shares the same name as Akutan Harbor (Figure 3).

Figure 3: Akutan Harbor Location

Akutan Harbor is a USACE Federally Constructed boat harbor that was completed in 2012. Akutan Harbor consists of a 12 acre basin with depths of -14, -16, and -18 feet MLLW (Figure 4). A helicopter maintenance hangar is located at the north end of the boat harbor. The harbor is located under 2 miles from Akutan and construction of the road to Akutan Harbor is currently underway.

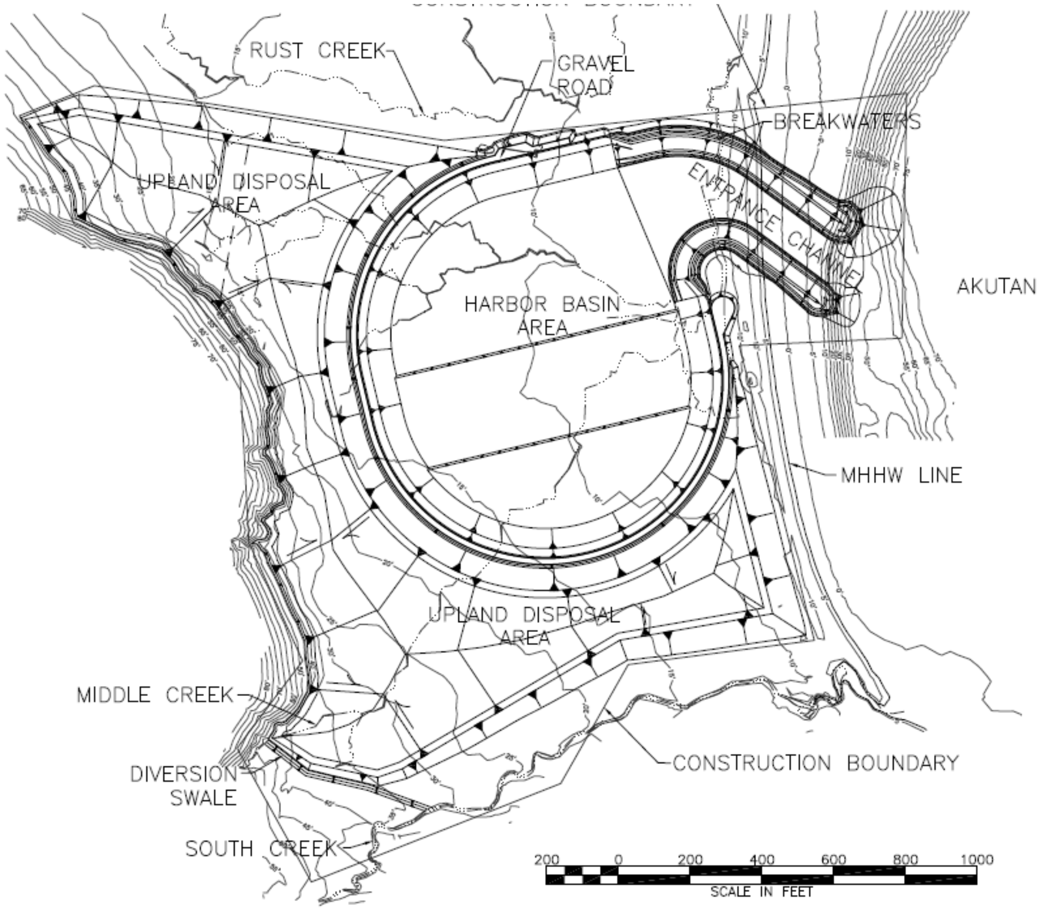


Figure 4: Akutan Harbor Drawing – Plan View

Akun Island lies immediately northeast of Akutan Island and has a land area of 64 square miles. The proposed project area on Akun island is located approximately 7 miles east of the community of Akutan immediately west of Akutan Airport. Promontory features inside the project area include Un-Named Point and Rocky Outcrop. Facilities at Akun include the Akutan airport and a road connecting the airport to the Surf Bay Inn and the airport to the Former Hover Craft pad (Figure 5). The airport was opened in 2012 and includes a 4500 foot runway, parking apron, and maintenance building. Surf Bay Inn has 31 double occupancy rooms and houses passengers that are stranded by weather and unable to transfer from Akun to Akutan.

Figure 5: Akun Project Area Location

2.0 CLIMATOLOGY, METEOROLOGY, HYDROLOGY

Akun island is characterized as a maritime climate moderated by the Japanese Current (Miller, Phillips, & Wilson, 2005). The area is characterized by persistently overcast skies, high winds, and frequent cyclonic storms.

Short term climate data for Akutan is available from January 1986 through February 1990 from a National Weather Service and National Oceanic and Atmospheric Administration (NWS/NOAA) recording station for temperature, precipitation, and snowfall. Long term climate data for the project area is not available, with the next closest site located at Dutch Harbor, Unalaska, 35 miles to the southwest. Due to the limited period of record (4 years) in Akutan as compared to Dutch Harbor (54 years) and closeness in proximity, Dutch Harbor data may be more representative of actual conditions.

2.1 Temperature

Temperature data for Akutan (1986 to 1990) and Dutch Harbor (1951 to 2005) is provided in Table 1 below (DUTCH HARBOR, ALASKA (502587), 2017). The highest recorded temperature at Dutch Harbor is 79°F, and the lowest recorded temperature is -8°F, but typically temperatures range from 27°F in the winter to 59°F in the summer.

Table 1: Temperature Data for Dutch Harbor (DUT) and Akutan (AKN)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave Min Temp	DUT	28.0	27.2	28.6	31.3	36.7	41.7	46.0	47.6	43.2	37.0	31.8	30.1	35.8
(°F)	AKN	29.7	29.8	29.9	31.9	36.5	42.8	47.3	47.1	43.6	41.5	34.4	29.9	37.0
Extreme Min Temp	DUT	-8	0	2	-5	15	30	34	30	19	11	8	5	-8
(°F)	AKN	17	15	8	19	25	38	43	35	32	33	16	12	8
Ave Max Temp	DUT	37.0	37.1	39.1	40.9	46.3	51.7	57.0	59.1	54.1	47.4	42.8	39.2	46.0
(°F)	AKN	36.8	37.1	38.5	40.8	45.7	49.9	54.6	56.9	53.0	47.5	41.0	39.1	45.1
Extreme Max Temp	DUT	58	54	61	58	60	73	75	79	74	65	57	59	79
(°F)	AKN	46	46	57	49	56	60	66	72	64	57	52	45	72

2.2 Precipitation

Akutan frequently experiences cloud cover accompanied by light precipitation. Rains occur any time of the year, with an average annual precipitation of 79 inches. The wettest month is October, with a record of 13.4 inches and an average of 11.3 inches of precipitation. A summary of precipitation data for Dutch Harbor and Akutan is given in Table 2 below.

Table 2: Precipitation Data for Dutch Harbor (DUT) and Akutan (AKN)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave Min Precip	DUT	1.0	1.6	1.6	0.6	0.1	0.1	0.2	0.1	0.8	1.4	1.1	2.4	21.3
(inches)	AKN	4.3	3.2	3.1	4.1	2.8	4.2	3.8	4.4	6.4	10.1	5.3	4.2	72.4
Ave Max Precip	DUT	17.0	14.0	14.8	6.9	10.3	4.9	7.3	6.2	10.0	18.1	19.6	19.1	86.7
(inches)	AKN	9.4	9.3	8.8	5.8	5.5	6.4	6.2	6.9	8.3	13.4	11.0	13.2	89.3
Ave Precip	DUT	7.5	6.6	5.8	3.6	3.9	2.5	2.2	2.8	5.4	7.4	6.9	8.2	62.7
(inches)	AKN	7.4	6.0	5.1	4.9	4.1	5.3	4.8	5.5	7.4	11.3	7.3	8.9	79.0
1 Day Max	DUT	4.0	3.4	2.3	1.9	3.6	2.0	4.8	2.4	2.0	3.3	3.0	3.0	4.8
(inches)	AKN	1.8	1.2	1.3	0.9	1.0	1.5	1.1	1.7	2.0	2.0	2.3	2.0	2.3

2.3 Snowfall

Akutan typically receives snowfall between November and April. Snowfall data in particular may be underrepresented; interviews with Akutan residents report that the winter of 1999/2000 had an estimated snowfall of over 100 inches (Peterson, 2003).

Table 3: Snowfall Data for Dutch Harbor (DUT) and Akutan (AKN)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave Total Snowfall	DUT	23.0	21.7	14.9	6.0	0.2	0	0	0	0	0.6	5.7	16.4	88.5
(inches)	AKN	13.9	1.3	0.6	2.6	0	0	0	0	0	0	0.8	1.5	19.6
Extreme Total	DUT	93.0	68.0	57.0	18.4	2.5	0	0	0	0	8.0	29.5	60.3	165.7
Snowfall (inches)	AKN	21.4	1.9	1.1	4.5	0	0	0	0	0	0	0.8	2.9	27.7

2.4 Fog

Local pilots report fog is more common in Akun during summer when the seas are calmer. The percentage of time each month that are cloudy or experience heavy fog from 1961 to 1990 are given for Cold Bay, 140 miles to the east, in Table 4 below (Center, Cold Bay, Alaska, 2023). Heavy fog constitutes visibility of a ¼ mile or less observed sometime during the day.

Table 4: Percent of Time Cloudy or Heavy Fog – Cold Bay

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cloudy	75%	78%	75%	85%	89%	90%	92%	93%	88%	81%	78%	78%	84%
Heavy Fog	6%	5%	6%	4%	5%	7%	13%	11%	3%	1%	2%	5%	6%

2.5 Ice

The sea ice around Akutan and Akun does not freeze during the winter, but pan ice may sometimes develop at the head of Akutan Bay (Miller, Phillips, & Wilson, 2005). Past interviews of harbor employees at Unalaska, King Cove, and Sand Point conducted for the Akutan Harbor feasibility study revealed that these harbors experience occasional icing during the coldest winter days. The ice consists of a thin slush layer that does not interfere with boat maneuverability.

A recent study analyzed the sea ice extents in the Bering Sea from 1979 to 2012; the project area was at least 80 miles from the maximum ice extent on March 31, 2008 and at least 300 miles from the maximum ice extent on April 10, 2005 (Wendler, 2014).

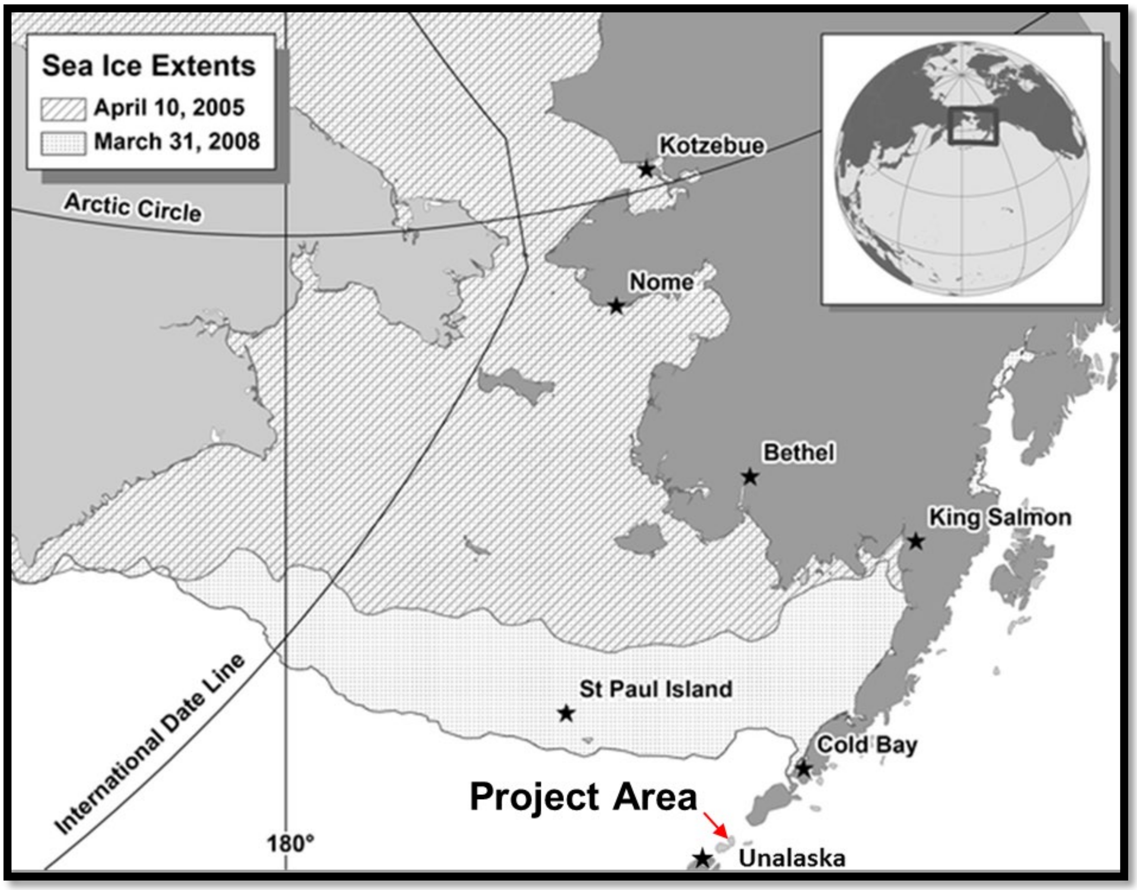


Figure 6: Bering Sea Ice Extents

2.6 Currents

Tidal currents are a significant consideration for small craft when traveling through the Akun Strait (also called Akutan Strait). NOAA Buoys measuring current were deployed near the project area during the summer of 2010, measuring a maximum current velocity of 0.8 knots at the Akutan Bay buoy and 7.5 knots at the Akutan Strait Buoy. Approximate flood (increasing) tide directions were 340° and 350° respectively, aligning as expected with the Akun Strait. Current practice is for skiffs to cross over to Akun during the slack tide, or else head north of the strait before heading south to Akun to avoid standing waves and strong tidal currents off the west coast of Akun.

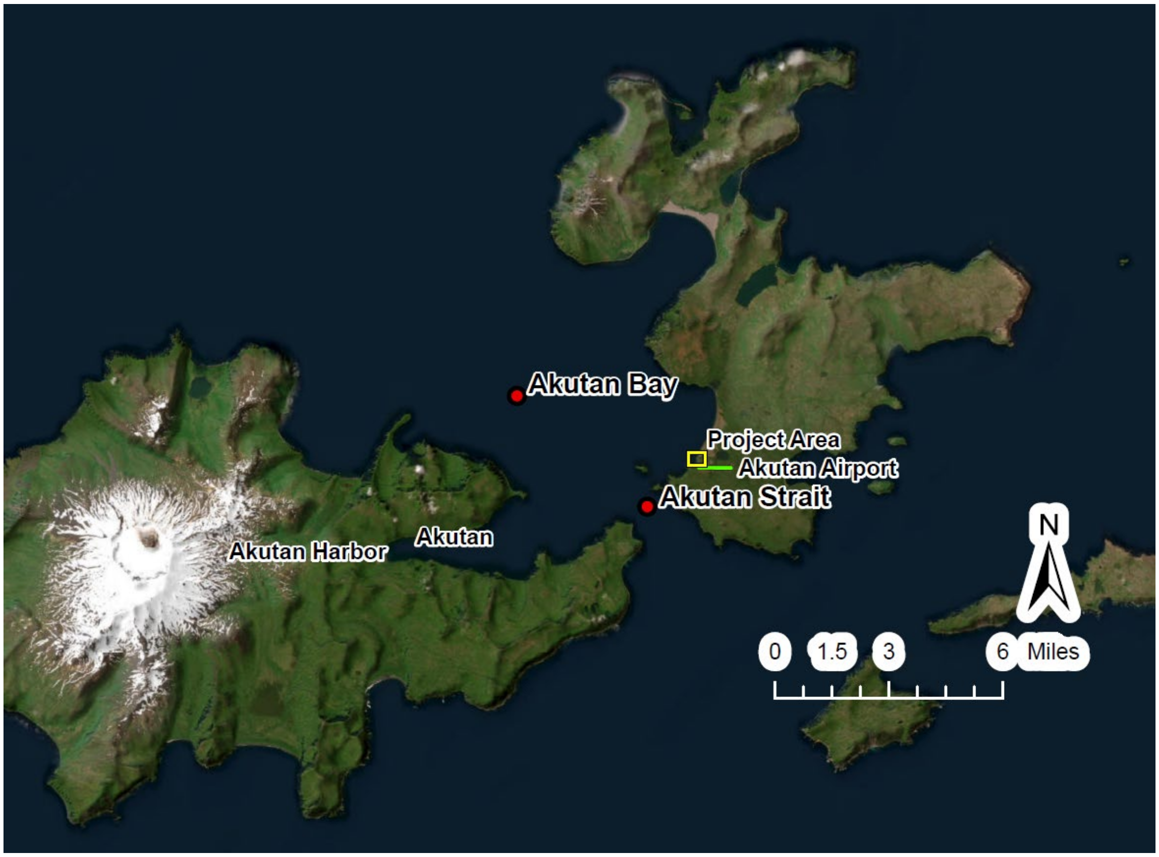


Figure 7: Location of NOAA Buoys Measuring Currents (Red)

Table 5: NOAA Currents Data

	Akun Strait	Akutan Bay
Depth of Data (ft)	10.8	31.8
Deployment Date (UTC)	6/11/2010	6/11/2010
Recovery Date (UTC)	7/23/2010	7/25/2010
Max Current (knots)	7.5	0.8
Approximate Flood Direction	350°	340°

A passenger ferry between Akutan and Akun would likely need to make trips through Akun Strait during unfavorable tidal currents. This could add time to the passage if the ferry must navigate north in a wide arc to avoid rough water. The project site lies in a large open body of water and is expected to have current values similar to the Akutan Bay Buoy. Currents are not expected to pose a navigational concern entering the harbor at the project area.

2.7 Tides

Akun is in an area of semi-diurnal tides with two high waters and two low waters each lunar day. NOAA tide stations for Akutan (9462694) and Surf Bay (9462711) were deployed for spring of 2009 and three years from 2008 to 2011 respectively. Surf Bay is the closest tidal station to the project area. The closest tidal station with long term data is 35 miles to the southwest at Unalaska (9462620), with over 68 years of data including lowest and highest observed water levels. The location (Figure 8) and data (Table 6) of the tide stations are shown below.

Figure 8: Location of NOAA Tide Stations (Yellow)

Table 6: NOAA Tide Station Data

	Akutan	Surf Bay	Unalaska
Station	9462694	9462711	9462620
Established	3/7/2009	7/15/2008	5/7/1955
Removed	5/1/2009	9/18/2011	N/A
		(Feet MLLW)	
Highest Observed Water Level	-	-	6.70
Mean Higher High Water (MHHW)	3.73	3.76	3.60
Mean High Water (MHW)	3.31	3.47	3.31
Mean Sea Level (MSL)	2.16	2.23	2.08
Mean Low Water (MLW)	0.93	1.00	0.93
Mean Lower Low Water (MLLW)	0.0	0.0	0.0
Lowest Observed Water Level	-	-	-2.78

A tide curve (Figure 9) was developed for Unalaska (9462620) with data recorded between 1982 and 2023. During this period, the tide was above 0'MLLW 92.1% of the time. Harbor alternatives at Akutan are designed to allow access at tides above 0.0 feet MLLW. An additional harbor depth of -0.5 foot would allow access 96.5% of the time, -1 foot access 98.8% of the time, and -1.5 feet for nearly 100% access.

Table 7: Water Level Duration - Unalaska (9462620)

Water Level (ft MLLW)	-1.5	-1	-0.5	0	+ 0.5	+ 1	+ 1.5
Percent of Time Equal or Above Water Level	99.7%	98.8%	96.5%	92.1%	86.0%	78.7%	69.9%

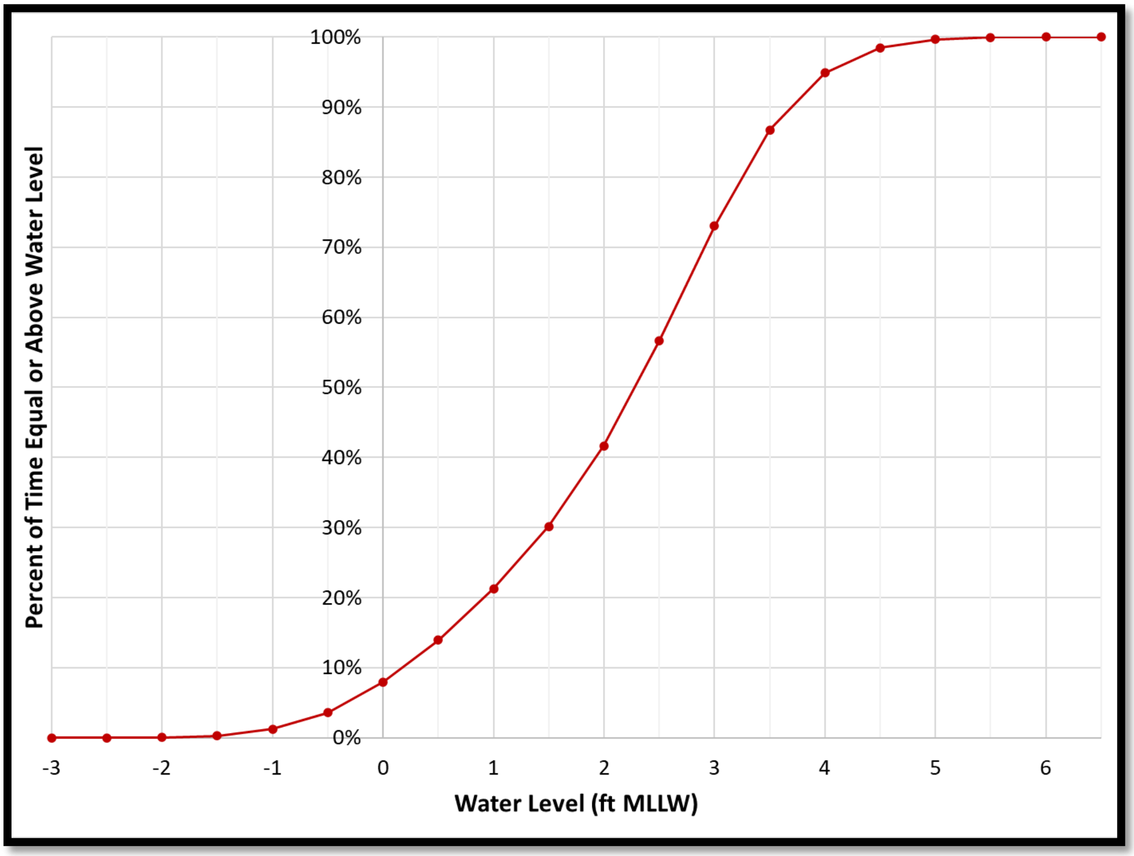


Figure 9: Water Level Duration Curve - Unalaska (9462620)

2.8 Wind

2.8.1 Wave Information Studies

Wind analysis was performed for this study by the Coastal and Hydraulics Laboratory, Flood and Storm Protection Division, Coastal Processes Branch (CEERD-HFC). The basis of the analysis are Wave Information Studies (WIS), a US Army Corps of Engineers (USACE) sponsored project that generates consistent, hourly, and long-term wave climatologies (Hesser, 2018). WIS point 82327 was chosen to be representative of offshore wind and wave conditions that would affect the project area at Akun. Station 82328 to the east is sheltered by Akun while station 82326 to the west is located farther from the Akun Strait. The WIS point is located approximately 30 miles from the project area.

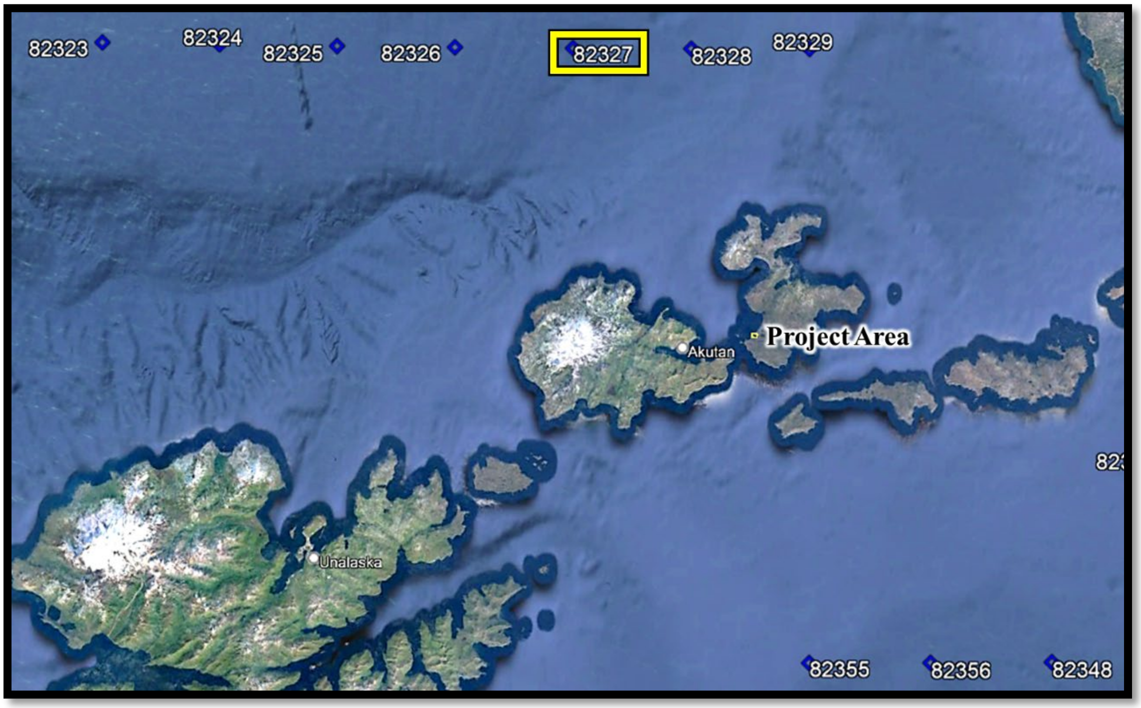


Figure 10: Location of WIS Point 82327

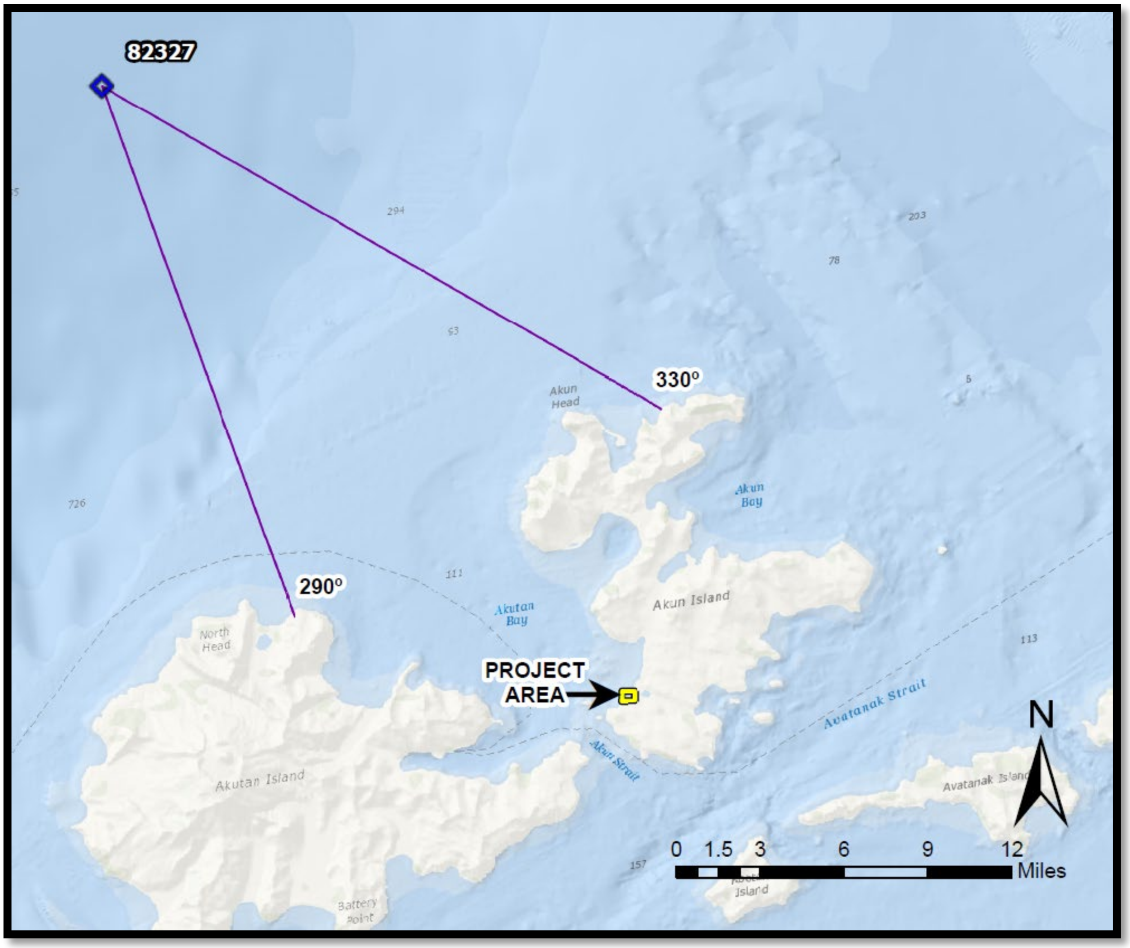


Figure 11: Area of Incluence of Point 82327

Meteorological and oceanographic measurements are available at 3 sites near the project area. Figure 11 displays the location of these sites as compared to WIS points in the area. Site 46126 (magenta) offshore Unalaska Island contains wave-wind estimates from 2013 to 2014. Site 9462620 (blue) on Unalaska Island contains meteorological information from 2010 to 2019, and buoy 46032 (blue) offshore Akun Island also contains meteorological information from 1984 to 1985.

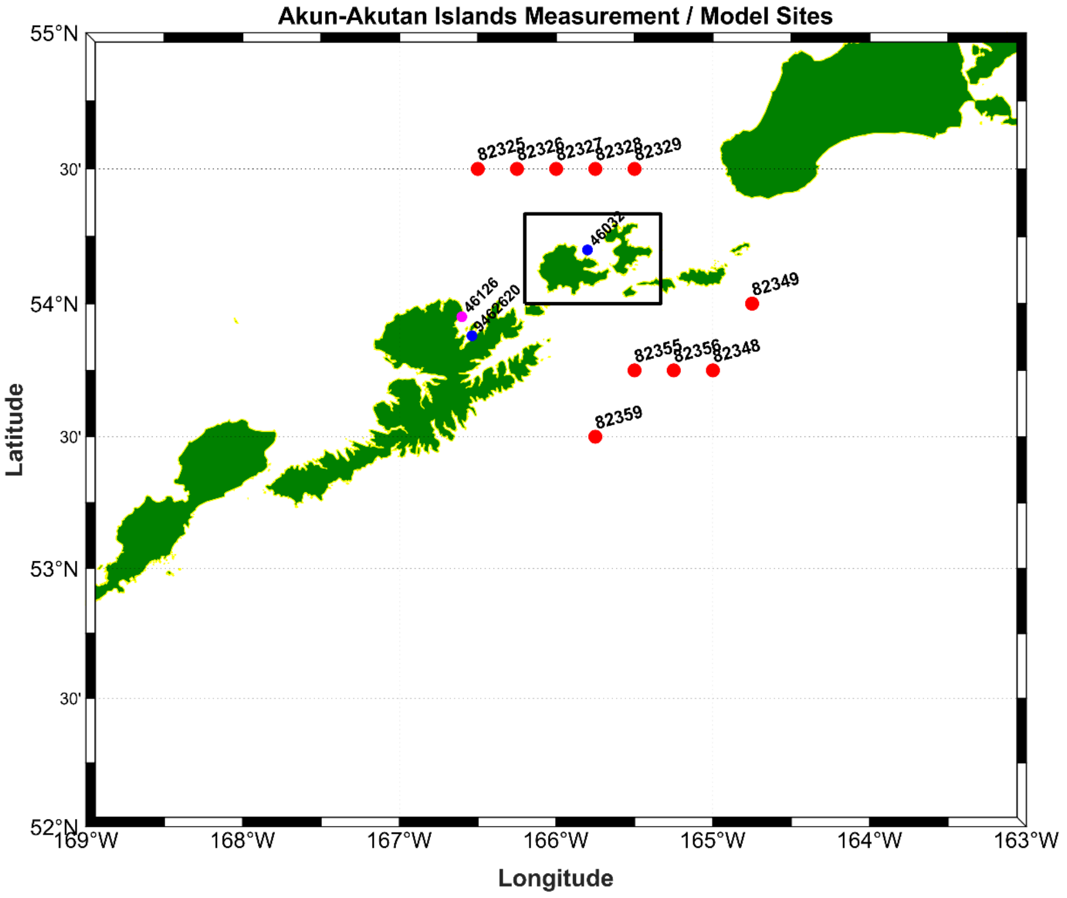


Figure 12: Location of WIS Stations (Red), Wave (Magetna), and Meterological Station/Buoy (blue)

Site 46032 is of limited duration but is the only wind measurement site located in the study area. Therefore site 46032 was the sole basis of the evaluation of WIS station 82327 relative to local conditions. Wind analysis performed by CEERD-HFC compared the one year of data overlap between modeled WIS wind and measured wind at site 46032 using a Quantile-Quantile (QQ) comparison. The result was the following QQ correlation equation, which when inverted, can be used to adjust the modeled wind speeds.

$$WS_{modeled\ WIS} = 0.13 + 1.03WS_{measured\ 46032}$$

The slope of the QQ equation being so close to one indicates that the differences between modeled WIS and measured site 46032 wind were nominal. Therefore, WIS station 82327 winds would be considered representative of the wind conditions in the project area and are used for design.

Figure 13: Location of Buoy Site 46032 relative to Akutan and Akun

Looking at the wind rose for 82327, the largest population of wind speeds is 5 to 10 m/s (10 to 19 knots).

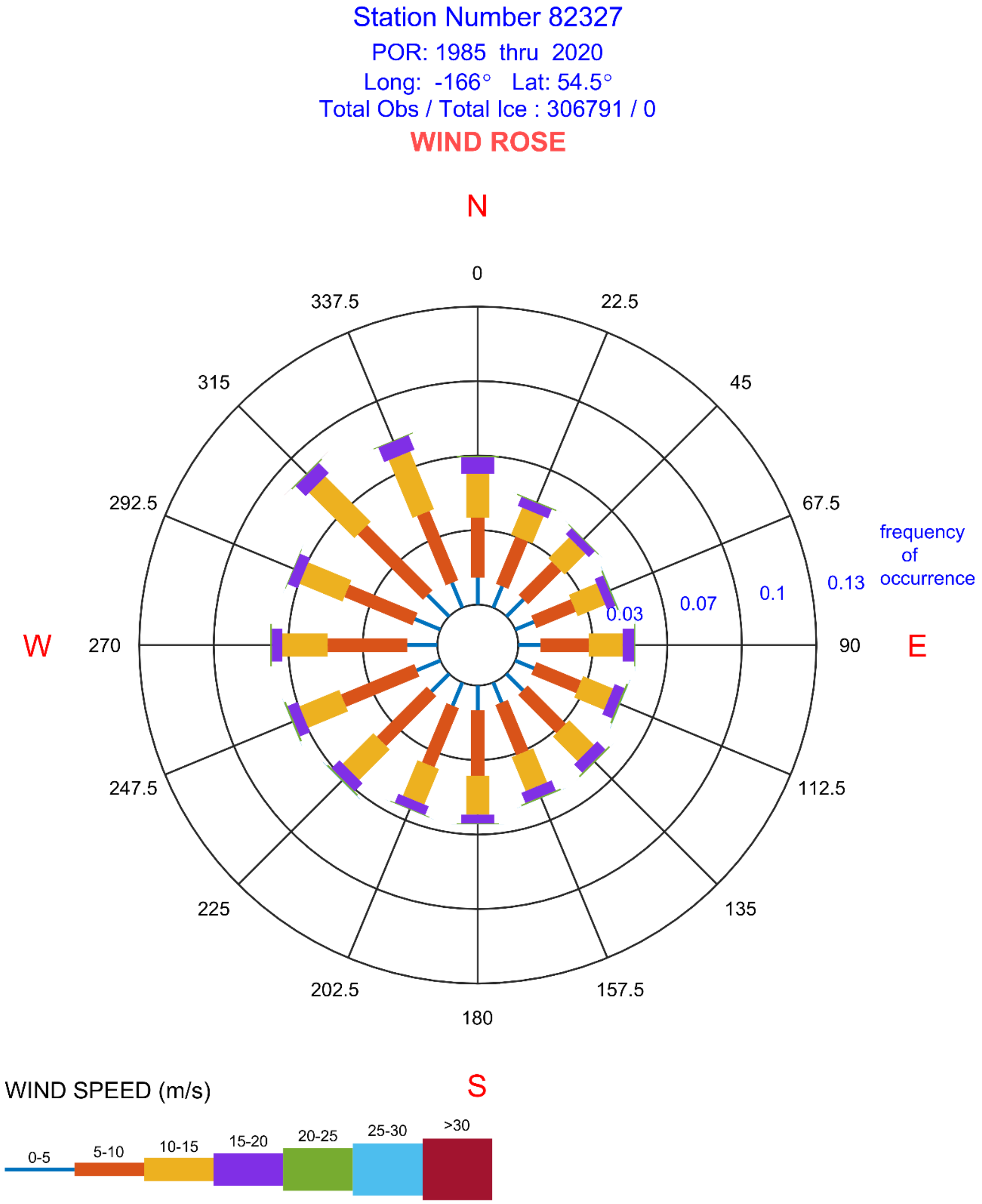
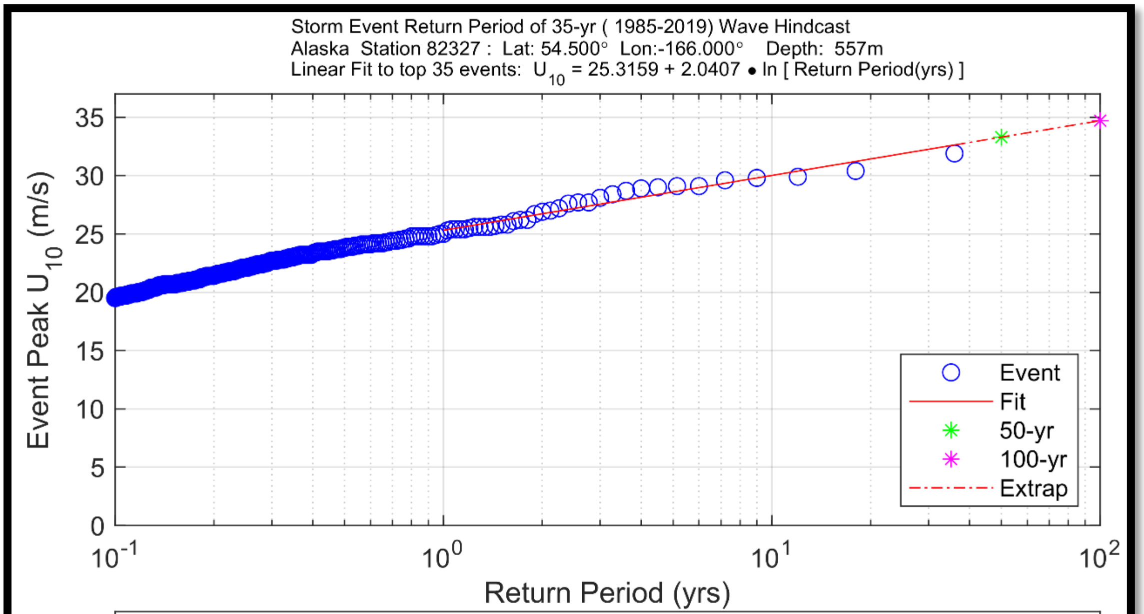


Figure 14: Wind Rose WIS Station 82327

2.8.2 Wind Extreme Analyses

The extremal analysis for the offshore wind and wave climate was performed by CEERD-HFC using a Peaks-Over-Threshold method (Jensen, 2022).

Table 8 below lists the top 35 storms for the 35-year period of record from 1985 to 2019. They are ranked by wind speed with corresponding significant wave height (**H_{m0}**) and period (**T_p**) provided as well. The author noted that the top ten storm values are surprisingly high. Wind speeds and direction reflect open water conditions and cannot capture local orographic steering of wind from the land masses of Akutan and Akun. Gap-wind studies for the Aleutian Islands confirm this (Pan, 1999).



Storm Event Return Period of 35-yr (1985-2019) Wave Hindcast
Alaska Station 82327 : Lat: 54.500° Lon:-166.000° Depth: 557m
Linear Fit to top 35 events: U_{10} = 25.3159 + 2.0407 • ln [Return Period(yrs)]

Top 10 events based on Peak U_{10}

Event	Date/Time(UTC)	U_{10}	θ_{wind}	Event	Date/Time(UTC)	U_{10}	θ_{wind}
1	1992/11/23 23:00	31.90	319.00	6	2000/11/03 23:00	29.10	115.00
2	1988/12/27 11:00	30.40	231.00	7	1994/10/01 05:00	29.10	59.00
3	2001/12/23 23:00	29.90	119.00	8	1988/03/09 17:00	29.00	16.00
4	1985/11/26 23:00	29.80	266.00	9	1988/12/10 23:00	28.90	355.00
5	2006/02/13 23:00	29.60	160.00	10	2015/12/14 00:00	28.70	218.00

An event is defined as any period when U_{10}> 17.38m/s θ_{wind} is direction that waves are arriving from

Figure 15: Wind Speed Extremes for WIS Station 82327

Table 8: WIS Station 82327 Wind Speed Extremes (Imperial)

Wind Speed Extremes (All Hourly Estimates)						
Rank	**Peak Date**	**WndSpd (knots)**	**WndDir (°)**	**H_{m0} (ft)**	**T_p (s)**	**WavDir (°)**
1	19921123230000	62.0	319	50.5	14.86	325
2	19881227110000	59.1	231	32.2	13.51	235
3	20011223230000	58.1	119	17.7	7.63	116
4	19851126230000	57.9	266	48.9	17.99	264
5	20060213230000	57.5	160	24.0	10.15	164
6	20001103230000	56.6	115	22.6	9.23	115
7	19941001050000	56.6	59	25.6	10.15	57
8	19880309170000	56.4	16	27.9	11.17	29
9	19881210230000	56.2	355	41.7	11.17	354
10	20151214000000	55.8	218	40.7	19.78	240
11	19970107170000	55.2	59	26.9	10.15	52
12	19880221170000	54.6	66	25.3	10.15	65
13	20111215000000	53.8	83	23.6	9.23	89
14	20111215000000	53.8	139	22.0	9.23	126
15	19911226110000	53.6	226	20.0	9.23	225
16	20170122210000	52.9	101	21.7	9.23	98
17	20110403120000	52.5	302	31.5	9.23	305
18	19910314110000	52.3	249	35.8	14.86	263
19	20070125050000	51.9	57	26.6	10.15	57
20	20041204110000	50.9	113	15.1	6.93	110
21	20020129110000	50.9	317	34.8	13.51	326
22	20001113170000	50.7	238	45.3	19.80	257
23	20140208060000	50.2	3	36.7	13.51	7
24	19971204230000	50.2	232	28.5	14.86	241
25	20111213090000	50.0	109	21.0	9.23	106
26	20151111180000	49.8	304	26.2	11.17	293
27	19990123050000	49.8	223	26.6	13.51	228
28	19940306050000	49.8	34	24.9	10.15	37
29	19920329170000	49.8	102	21.3	9.23	95
30	19950323230000	49.6	69	27.2	11.17	61
31	20161224000000	49.4	111	21.7	9.23	108
32	20090225140000	49.4	241	23.6	13.51	250
33	20041121110000	49.4	156	16.1	7.63	155
34	19931111110000	49.4	225	17.7	7.63	200
35	20161030120000	49.2	147	19.0	7.63	187

To try and account for the orographic effects of Akutan and Akun, winds originating from 290° to 330° are highlighted in green. This still includes the worst storm recorded in the area, 62 knots from 319°. Knowledge of local commercial vessels confirms that the most severe storm events are coming in from the Bering Sea to the north. This also represents the worst case for a ferry vessel transiting between Akutan and Akun.

2.8.3 Wind and Airport Operations

In general, winds that prevent small fixed-wing aircraft landing at the Akutan airport are crosswinds. The Akutan runway is aligned east to west. Based on the Pilot's Operating Handbook for a Piper Navaho 310, the type of fixed-wing aircraft landing at Akutan Airport, flights would likely be able to operate in up to 20 knot crosswinds ("LICENCIAS", 2013).

The crosswind component is calculated by taking the Sine(ϴ) of the wind angle multiplied by the total windspeed. Table 9 below shows a general rule of thumb used for calculating at what angle the total windspeed would exceed the 20 knot maximum crosswind. These values assume a dry or damp runway, whereas a runway covered with snow, slush, or standing water can reduce the maximum crosswind allowance by up to half. Winds exceeding these conditions would cause fixed-wing flights to cease operation as shown in Table 10.

Table 9: Crosswind Calculations

Wind Angle	**Crosswind Calculation**	**Max Total Wind Speed** (kts)
30°	1/2 x Total Wind	40
45°	3/4 x Total Wind	26.7
60°	1 x Total Wind	20

Table 10: Anticipated Fixed-Wing Flight Accessibility Due to Wind

Likely Operation	**Cease Operation**
Winds under 40 knots, crosswinds under 20 knots	Winds 40 knots or greater, crosswinds 20 knots or greater
80%	20%

Grant Aviation fixed-wing aircraft flights from 2020 to 2022 to Akutan airport were reported to be canceled on average 34% of the time due to weather. This is higher than predicted by Table 10, which does not include factors such as weather at the point of departure, fog, or wetness of the runway. Maritime helicopters had an average of 30% of their flights canceled due to weather over the same time period. Helicopters are better able to travel through cross winds but may cancel due to fog. Fixed-wing aircraft would control airport access for the harbor alternative. Note that these statistics reflect weather cancellations of scheduled trips, and the fixed-wing and helicopter operators frequently run "catch up" trips during good weather.

2.8.4 Local Wind-Wave Generation

Local wind generated fetch limited waves must also be considered for two different scenarios. One is a skiff transporting crew between the community of Akutan and Akutan Harbor, and the other is the ferry traveling between the community of Akutan and the proposed Akun harbor. Locally generated waves would have short periods of approximately 2 to 4 seconds. Formulas used to calculate fetch limited used were obtained from the Shore Protection Manual (1984), using the fetch length (F) in nautical miles, the wind speed U_A in knots, and the significant wave height (H_{m0}) in feet.

Fetch Limited:

$$H_{m0} = 3.714 * 10^{-2} U_A F^{1/2}$$
$$T_m = 6.14 * 10^{-1} [U_A \cdot F]^{1/3}$$

2.8.4.1 Skiff

The longest fetch length for wind generated waves that would affect a skiff traveling between the community of Akutan and Akutan Harbor is approximately 6.7 nautical miles. The directional band from WIS station 82327 that would affect this route is from 80° to 120° and 250° to 290°. A wind speed of 40 knots is considered for skiff operations as this is the speed at which fixed-wing aircraft cease operations. A wind speed of 40 knots over a 6.7 nautical miles fetch would generate a significant wave height of 3.8 feet with a period of 4 seconds. An experienced skiff operator would likely be able to operate in a 3.8 foot wave. Skiff travel to and from Akutan Harbor would likely not be a limiting factor of ferry operations. Additionally, the road between the community of Akutan and Akutan Harbor is currently under construction, which would negate the use of a skiff.

Figure 16: Skiff Operations Maximum Fetch Length

2.8.4.2 Ferry

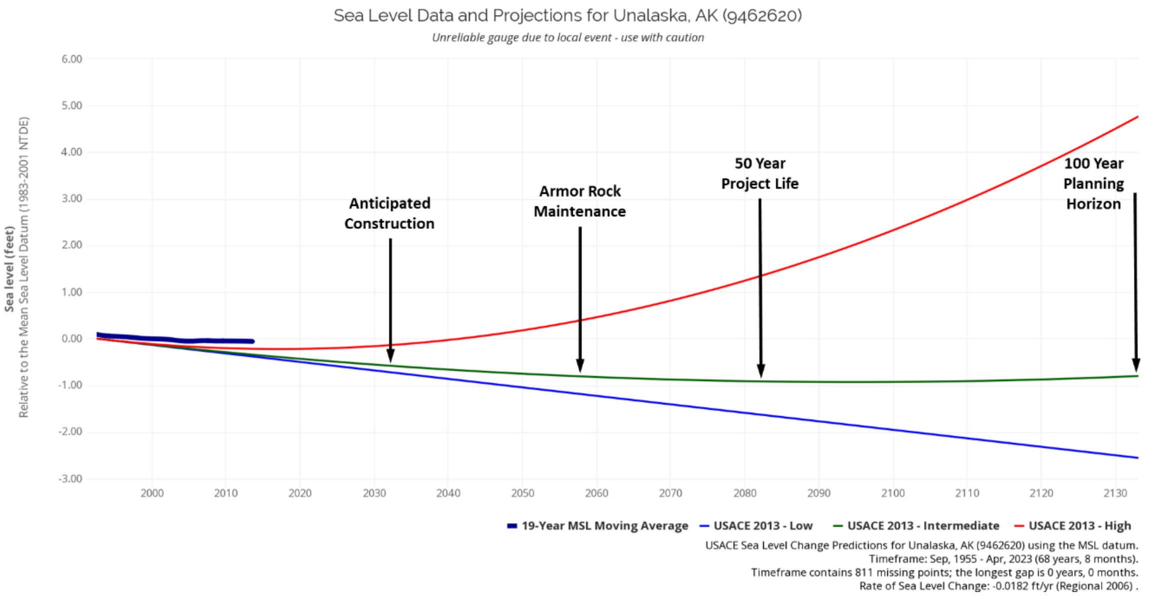
The longest fetch length for wind generated waves that would affect a ferry traveling between the community of Akutan and Akun is approximately 9.4 nautical miles. The directional band from WIS station 82327 that would affect this route is from 10° to 80° and 190° to 260°. Wind speeds of 40 knots would cause fixed-wing aircraft to cease operations. A wind speed over a 9.4 nautical miles fetch would generate a significant wave height of 4.5 feet with a period of 4.4 seconds. This is less than the prescribed maximum 5 foot wave that would cease operations of the ferry. Therefore, wind generated waves would likely not be a limiting factor for ferry operations.

Figure 17: Ferry Operations Maximum Fetch Length

2.9 Relative Sea Level Change

The Corps of Engineers requires that planning studies and engineering designs consider alternatives that are formulated and evaluated for the entire range of possible future rates of relative sea level change (RSLC). The 2013 USACE intermediate scenario is the preferred RSCL to be incorporated in project design.

The nearest tide station with the recommended 40-year period of record is at Unalaska (9462620), located approximately 35 miles southwest of the project site. Comparing tide data between Unalaska (9462620) and Surf Bay (9462711) earlier in the report indicate that the regions experience similar tides. A small rate of isostatic rebound, or the rising of land in response to the removal of the weight of glacial ice, is experienced across the Aleutians in both Akun and Unalaska. Therefore, the RSLC change results for Unalaska can be considered a good approximation for the project area on Akun.



USACE Sea Level Change Predictions for Unalaska, AK (9462620) using the MSL datum.
Timeframe: Sep, 1955 - Apr, 2023 (68 years, 8 months).
Timeframe contains 811 missing points; the longest gap is 0 years, 0 months.
Rate of Sea Level Change: -0.0182 ft/yr (Regional 2006) .

Figure 18: RSLC Projection Graphs for Unalaska

Table 11: RSCL Projection Values for Unalaska

Year	Description	USACE Low	USACE Intermediate (Feet MLLW)	USACE High
1992	USACE RSLC Projection Begins	0.00	0.00	0.00
2032	Anticipated Construction	-0.73	-0.60	-0.14
2042	Maintenance Dredging	-0.91	-0.69	+ 0.02
2052	Maintenance Dredging	-1.09	-0.77	+ 0.24
2057	Armor Rock Maintenance	-1.18	-0.81	+ 0.38
2062	Maintenance Dredging	-1.27	-0.84	+ 0.54
2072	Maintenance Dredging	-1.46	-0.89	+ 0.92
2082	50 Year Project Life	-1.64	-0.92	+ 1.37
2132	100 Year Planning Horizon	-2.55	-0.81	+ 4.72

Low and intermediate sea level change estimates predict that the isostatic rebound rate will be greater than the sea level rise rate, resulting in an overall sea level drop between anticipated construction completion in 2032 and the 50-year project life in 2082. The USACE High sea level change estimate predicts that the isostatic rebound rate will be less than the sea level rise rate. The intermediate RSCL of –0.92 feet was chosen for the project design. In order to maintain the project depth at year 50, 1 foot of dredging will be incorporated in the harbor and entrance channel design depths at construction.

3.0 WAVE ANALYSIS

3.1 Wave Hindcast

Wave analysis, like the wind analysis, was performed for this study by CEERD-HFC. The basis of the analysis is WIS, a USACE sponsored project that generates consistent, hourly, and long-term wave climatologies (Hesser, 2018). WIS point 82327 was chosen to be representative of offshore wind and wave conditions that would affect the project area at Akun. The WIS point is located approximately 30 miles from the project area (as shown in Figure 10 above).

Waves traveling through the Akun Strait (originating from 290°- 330° and 160°-220°) dictates ferry operations. Akutan and Akun islands shelter waves from other directions, except for local wind-wave generation as discussed previously.

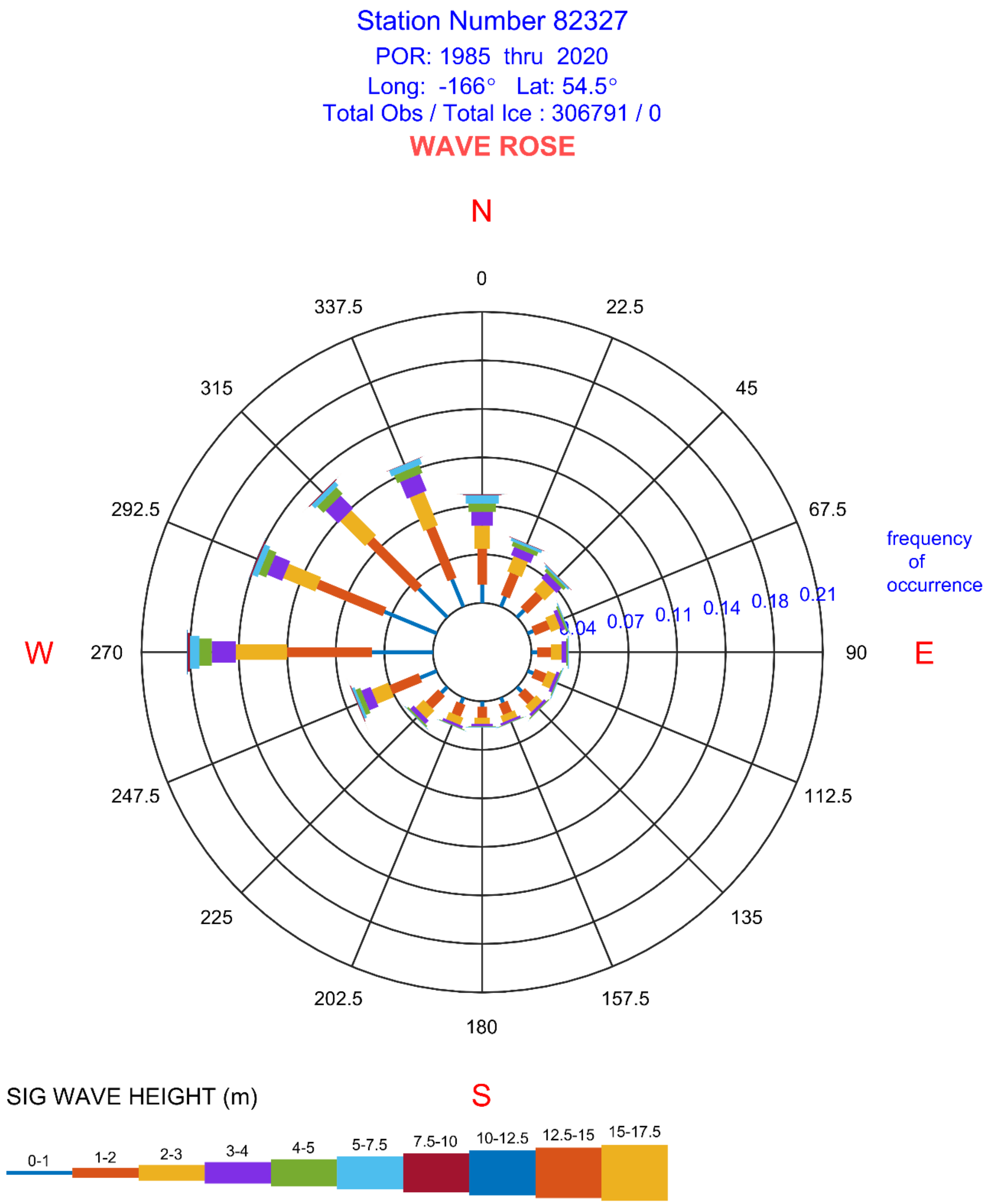
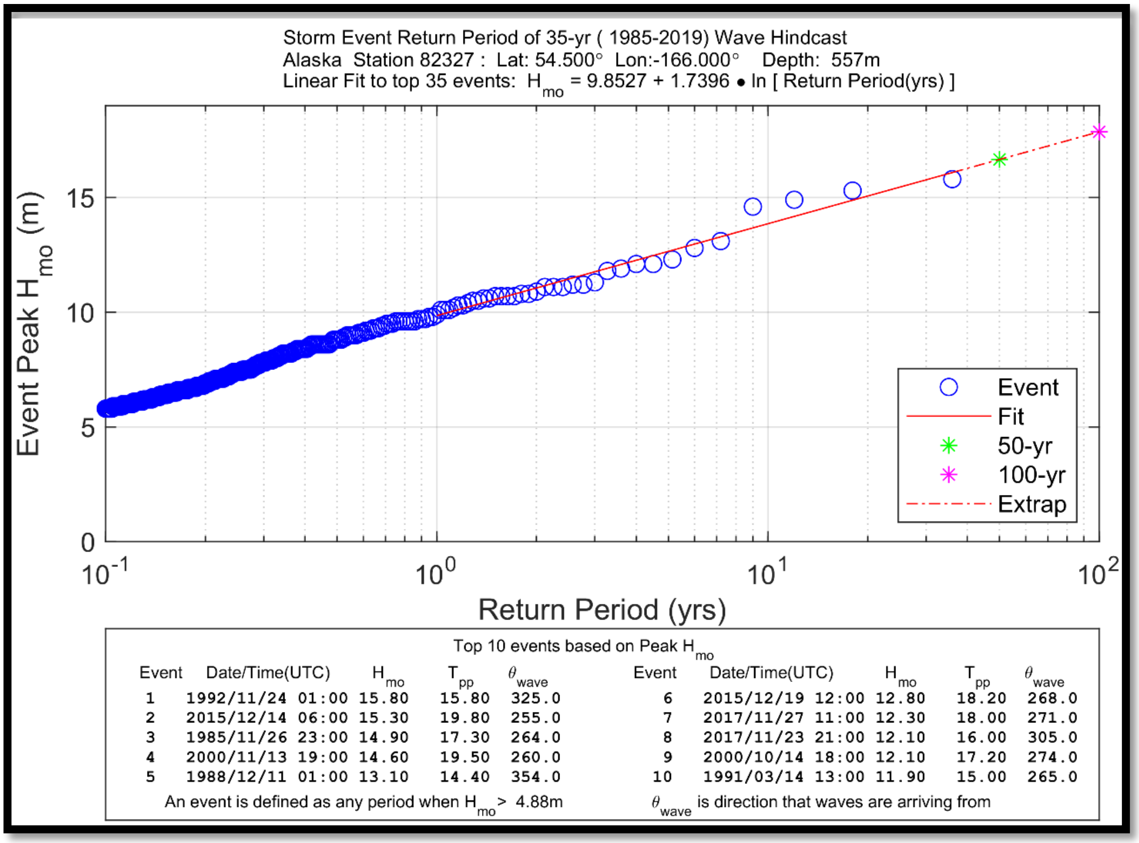


Figure 19: Wave Rose WIS Station 82327

Table 12: Directional Window (290° to 330°) for Significant Wave Height Extremes (Imperial)

Directional Window (290° to 330°) for Significant Wave Height Extremes							
Rank New	**Rank Orig**	**Peak Date**	**H_{m0} (ft)**	**T_p (s)**	**WavDir (°)**	**WndSpd (knots)**	**WndDir (°)**
1	1	1992112401	51.8	15.8	325	62.0	319
2	8	2017112321	39.7	16.0	305	45.3	313
3	16	2013030806	36.4	14.3	299	48.2	294
4	24	2002012912	35.1	13.5	326	50.9	317
5	33	2011040316	33.1	12.4	305	51.5	303
6	40	2009011701	31.8	12.8	303	46.5	296
7	44	1989011113	31.5	13.9	308	40.2	303
8	45	1985041620	31.5	12.8	327	44.7	316
9	49	2017112007	31.2	14.7	323	39.3	322
10	59	1995020602	30.2	13.4	300	39.8	288
11	61	2010030512	29.9	12.4	323	47.0	315
12	64	2001092408	29.5	13.9	292	41.0	306
13	66	1999111403	29.5	13.7	327	39.3	332
14	67	1992120515	29.5	13.6	315	40.0	311
15	86	2005110922	28.2	13.4	322	39.1	313
16	89	2010120419	27.6	13.8	299	36.9	303
17	94	1998091918	27.6	12.5	307	43.0	309
18	109	2004110314	26.2	13.4	323	34.8	310
19	117	2011102513	25.9	12.8	296	38.5	295
20	123	2004120902	25.6	12.9	316	36.0	318
21	148	2009032916	24.3	11.1	303	45.7	284
22	150	2013101312	24.0	13.0	302	35.8	301
23	151	2007041810	24.0	12.3	298	36.7	295
24	152	2003122913	24.0	11.1	294	43.5	305
25	156	1986112907	23.6	12.2	313	37.5	302
26	161	2006022802	23.3	12.2	307	35.4	324
27	170	1992032008	23.0	12.4	300	34.8	299
28	171	2015041907	23.0	12.0	328	37.3	321
29	186	1992100201	22.3	12.4	301	35.8	309
30	189	2012112719	22.3	12.4	293	34.4	322
31	193	2006040418	22.0	11.8	324	36.2	323
32	195	2011090622	22.0	12.2	315	33.6	318
33	201	2014102904	22.0	12.0	308	36.7	313
34	204	2012091615	21.7	11.3	307	38.3	292
35	207	1990011407	21.7	12.0	291	35.0	285



Top 10 events based on Peak H_{mo}

Event	Date/Time(UTC)	H_{mo}	T_{pp}	θ_{wave}	Event	Date/Time(UTC)	H_{mo}	T_{pp}	θ_{wave}
1	1992/11/24 01:00	15.80	15.80	325.0	6	2015/12/19 12:00	12.80	18.20	268.0
2	2015/12/14 06:00	15.30	19.80	255.0	7	2017/11/27 11:00	12.30	18.00	271.0
3	1985/11/26 23:00	14.90	17.30	264.0	8	2017/11/23 21:00	12.10	16.00	305.0
4	2000/11/13 19:00	14.60	19.50	260.0	9	2000/10/14 18:00	12.10	17.20	274.0
5	1988/12/11 01:00	13.10	14.40	354.0	10	1991/03/14 13:00	11.90	15.00	265.0

An event is defined as any period when H_{mo} > 4.88m θ_{wave} is direction that waves are arriving from

Figure 20: Significant Wave Height Extremes for WIS Station 82327 (All Directions)

The equation for the linear fit of the top 35 events from WIS station 82327 for all directions is shown in the top of Figure 19. This equation generates the wave height for a given return period, or recurrence interval, for the WIS location 30 miles from the project area. This equation would generate unrealistically large wave heights and should not be used. Instead, the following equation was generated by CEERD-HFC to better approximate the project area location by using spectrally windowed (290° to 330°) data. Results of the significant wave height for each annual exceedance probability (AEP) are given in Table 13 below. It does not consider depth dependent mechanisms such as wave-bottom effects, attenuation from small-scale obstructions, or depth induced wave breaking.

$$H_{m0} = 4.028 + 1.3094 \cdot \ln\{Return\ Period\ (yrs)\}$$

$$Annual\ Exceedance\ Probability\ (AEP) = \frac{1}{Return\ Period}$$

Table 13: Significant Wave Heights at the Project Site

Annual Exceedance Probability	Wave Height (feet)
1	13.2
0.2	20.1
0.1	23.1
0.04	27.0
0.02	30.0
0.01	33.0

Wave heights generated by the CEERD-HFC equation are representative of the deep water waves encountered at Akun Strait. To approximate wave heights in the project area for breakwater sizing calculations, wave heights at the Akun Strait need to be transformed using wave modeling. The 2% AEP or 50-year wave used for design is 30 feet.

3.2 Wave Modeling

Steady-State Spectral Wave (STWAVE) modeling was used to transform wave energy from WIS station 82327 to the breakwater and harbor alternatives. STWAVE is a spectral wave energy propagation model that includes refraction, diffraction, and shoaling, but does not include reflection. It should be noted that STWAVE is the Hydraulic, Hydrologic and Coastal (HH&C) Community of Practice (CoP) preferred model for modeling coastal processes.

3.2.1 Model Bathymetry

In order to optimize the bathymetric grid sizes for model runs, wave data was ran from a coarse grid to a fine grid as shown in Figure 20 below. Model bathymetry was obtained from NOAA charts for the coarse grid, 2015 Stantec survey for the fine grid at the project area, and 2022 Golder survey for the project area land-water interface. The coarse grid consists of 50 meters by 50 meters (164 feet by 164 feet) cells and transmits the WIS wave data from deep water oriented at 302°, as this would be the worst-case scenario of waves hitting directly perpendicular to the structure from the Bering Sea. The fine grid's northern boundary is where the wave transmitted by the coarse grid begins to interact with the ocean bottom and experience a decrease in wave height. It consists of 2 meters by 2 meters (6.6 feet by 6.6 feet) cells oriented at 310°.

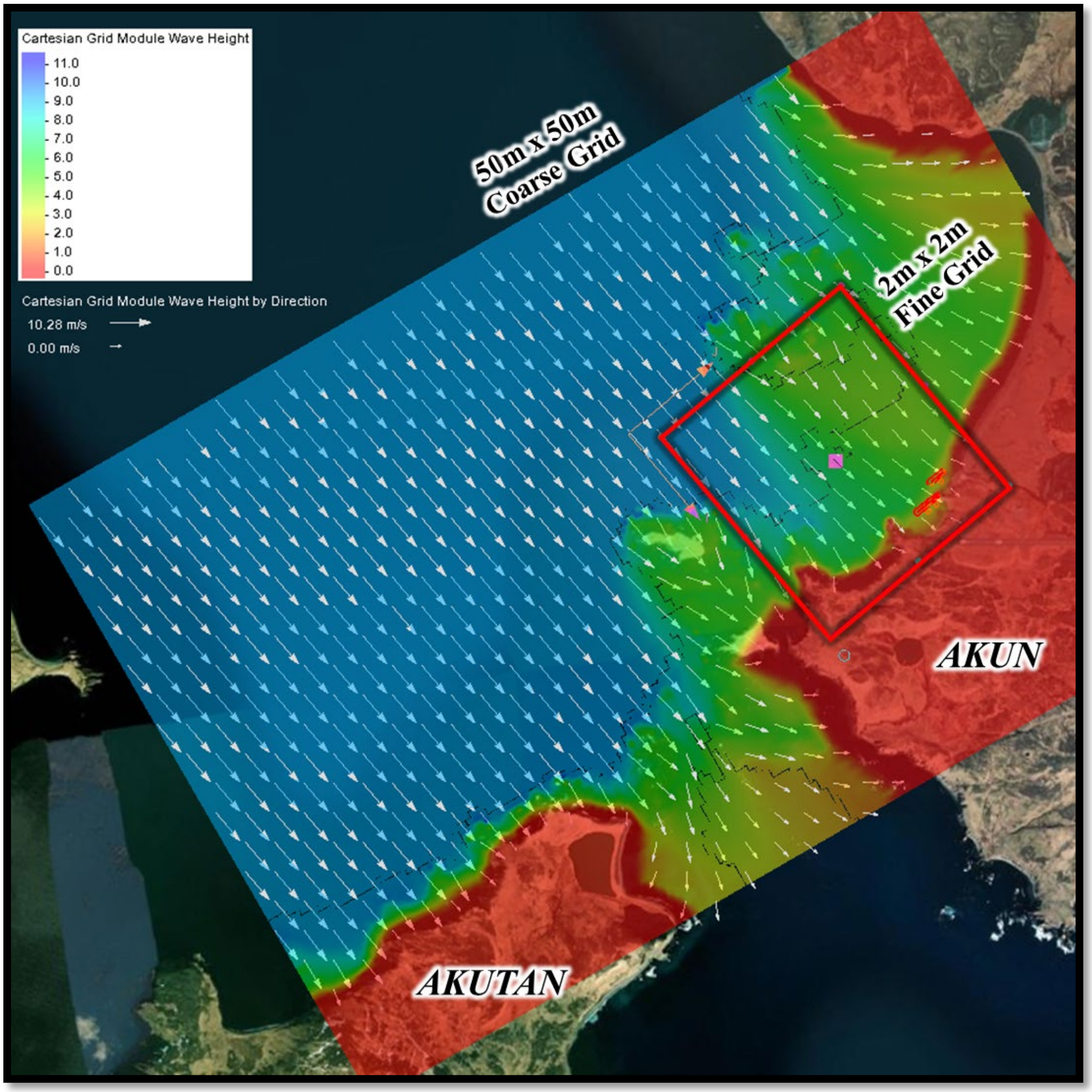


Figure 21: STWAVE Coarse and Fine Grids - Wave Height and Direction, Without Project Condition

Model runs are in half-plane mode with propagation of the boundary conditions only, no wind propagation. Results of the wave height and direction for the without project condition are shown in Figure 20 and then zoomed in on the project area in Figure 21.

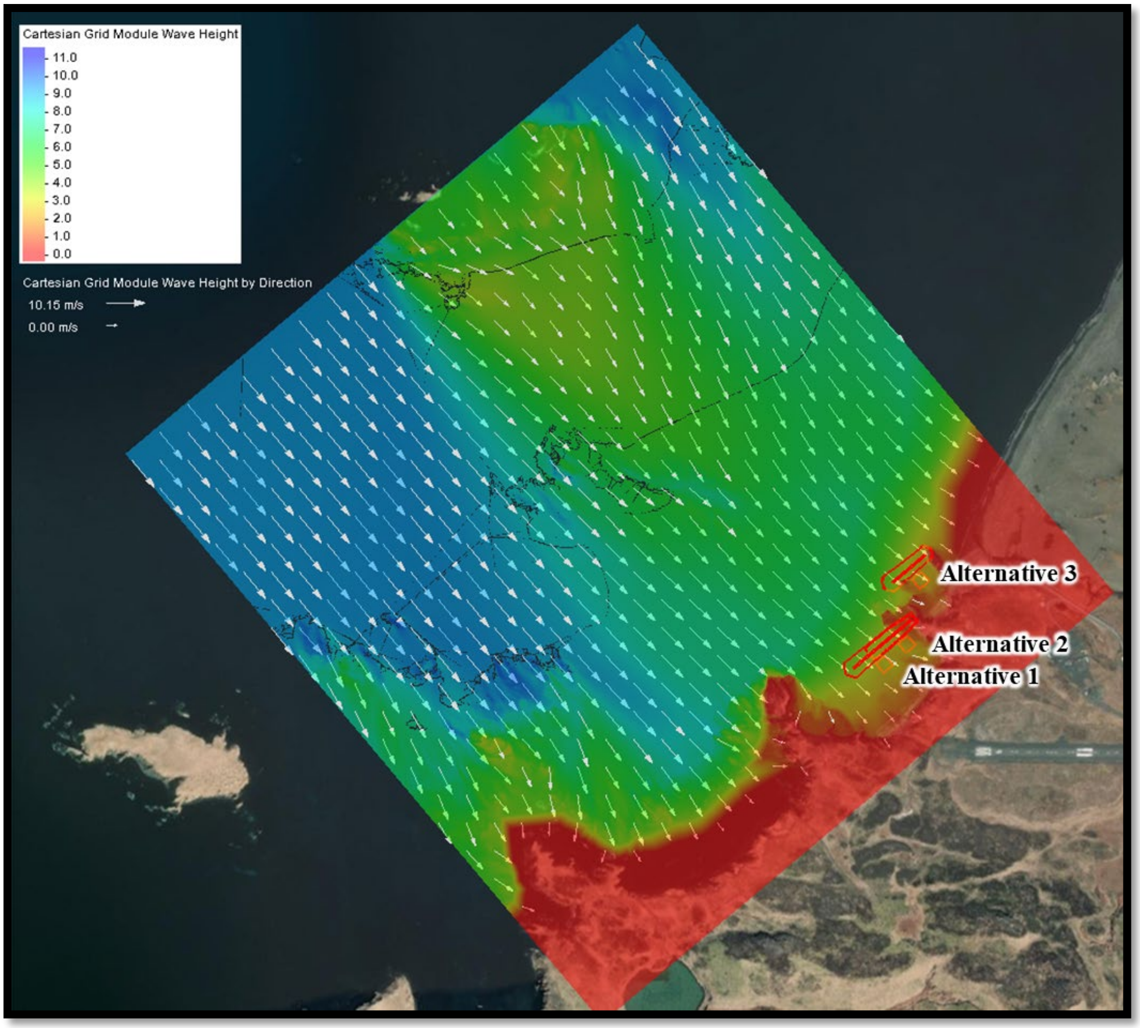


Figure 22: STWAVE Fine Grid - Wave Height and Direction, Without Project Condition

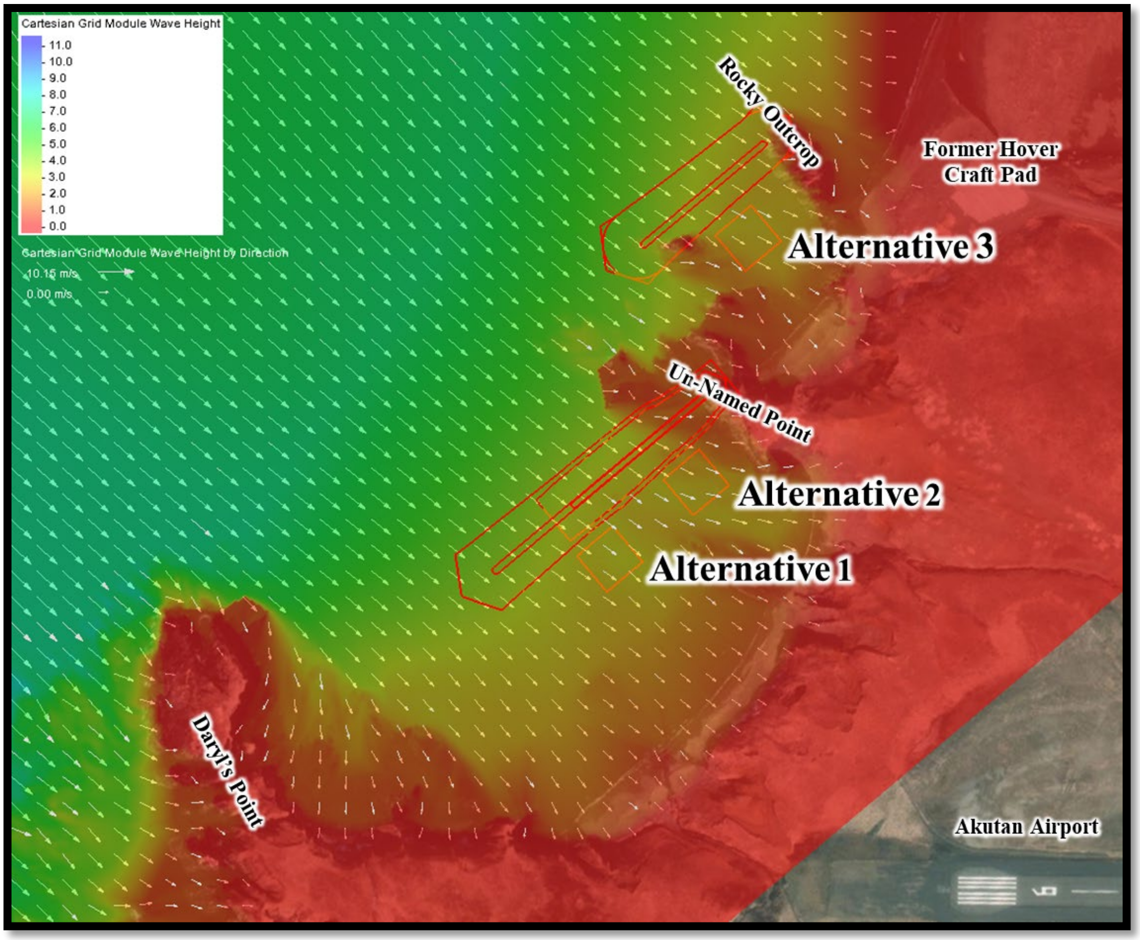


Figure 23: STWAVE Fine Grid Closeup on Alternavies - Wave Height and Direction, Without Project Condition

3.2.2 Water Level

The design wave and total water level are used to inform breakwater design. The total water level to be modeled was determined using the following equation:

$$Total\ Water\ Level = Tide + Wave\ Setup + Storm\ Surge + RSLC$$

3.2.2.1 Tide

The tide used for wave modeling was MHHW of 3.76 feet.

3.2.2.2 Wave Setup

Wave setup is an increase in water level due to breaking waves in the surf zone. The proposed breakwater is located in water depths beyond the surf zone and influence of wave setup. Wave setup was not considered for water level determination.

3.2.2.3 Storm Surge

Storm surge is an increase in water level due to low atmospheric pressure and wind driven transport of seawater over relatively large and shallow unobstructed waters. Storm surge can produce short term increases in water level considerably over normal tidal levels. There is no known storm surge model or study near the project area. The best approximation is NOAA AEP curves at Unalaska (9462620) tidal station. The AEP curves model extreme water levels during storms known as storm tides, which are a combination of astronomical tide, storm surge, and wave setup. As MHHW tide is included in the water level and wave setup is not expected, the AEP curves are a good approximation for storm surge. The 2% AEP is 2.66 feet (0.81 meter) and 1% AEP is 2.76 feet (0.84 meter) as read from Figure 22. The 2% AEP prediction of 2.66 feet was used for the breakwater design water level calculation.

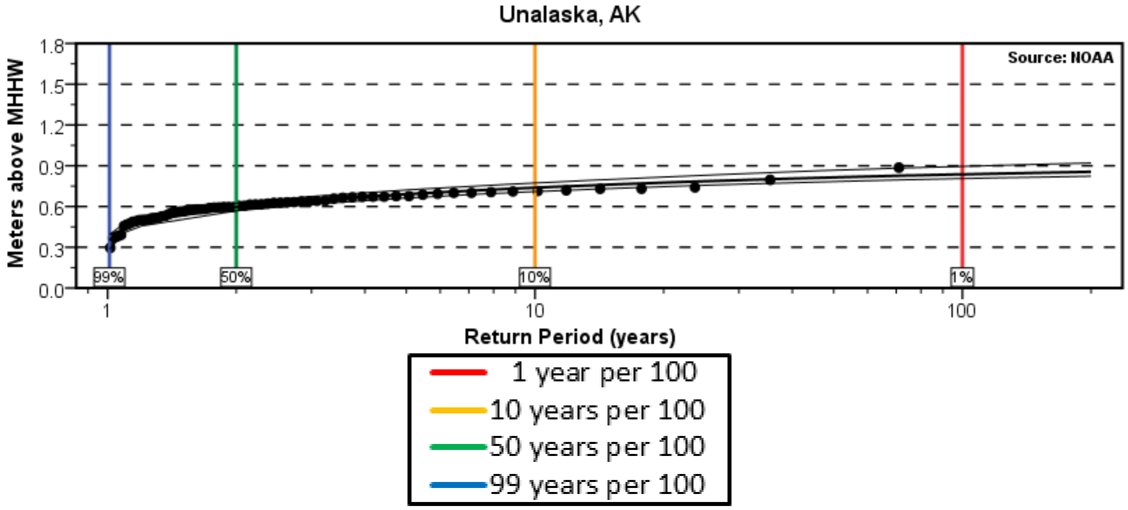


Figure 24: NOAA AEP Curves for Unalaska, AK (NOAA, 2023)

3.2.2.4 Sea Level Change

As described in the section 2.9 Sea Level Change, the RSLC intermediate estimate predicts a change in water level of -0.92 feet over the 50-year design life of the project. Therefore, the sea level at the time of project construction at year 0 was used for modeled water level, a value of 0.0 feet.

3.2.2.5 Total Water Level

The total water level including a MHHW tide of 3.76 feet, storm surge of 2.66 feet, and relative sea level change of 0.0 feet is approximately 6.42 feet MLLW. The total water level of 6.42 feet MLLW was inputted in STWAVE modeling when modeling the design wave. These calculations were used in designing the breakwater length, crest height, crest width, and stone size.

Table 14: Total Water Level for Breakwater Design

Description	Water Level (feet)
Tide (MHHW)	3.76
Wave Setup	0.00
Storm Surge	2.66
RSLC	0.00
Total Water Level	6.42

3.2.3 Wave Modeling Results

STWAVE was used to transmit the 2% AEP WIS wave of 30.0 feet from deep water to the project area. The total water level modeled was 6.42 feet. The design wave for each alternative was determined by measuring for the highest wave value just offshore of the toe of the breakwater. The wave will begin to break at this point due the sudden decrease in water depth due to the breakwater structure at the toe. Breaking waves at the toe of the breakwater would be the worst case from a design perspective and would drive the armor stone size for the breakwater. The design waves heights produced in STWAVE for the three alternatives are found in Table 15.

Table 15: STWAVE Results - Design Wave

Alternative	2% AEP Wave (feet)	Still Water Level (feet MLLW)	Design Wave (feet)
Alternative 1	30.0	6.42	16.4
Alternative 2	30.0	6.42	12.5
Alternative 3	30.0	6.42	15.0

4.0 DESIGN CRITERIA

4.1 Design Vessel

The design vessel of this study is based upon two factors, regularly available vessels in the region and minimum size requirements to safely operate trips between Akutan and Akun in conditions that allow aircraft to land in Akun. The design vessel chosen for this study is the F/V Magnus Martens, a 58-foot long twin screw steel monohull with a 26-foot beam and an 8-foot draft that operates across Alaska, including in the Aleutians. During the Charette, local fisherman stated that a 58-foot vessel would be the minimum recommended length to cross Akun Strait safely. It is anticipated that the ferry vessel would be a converted seiner/crabber/trawler type vessel.

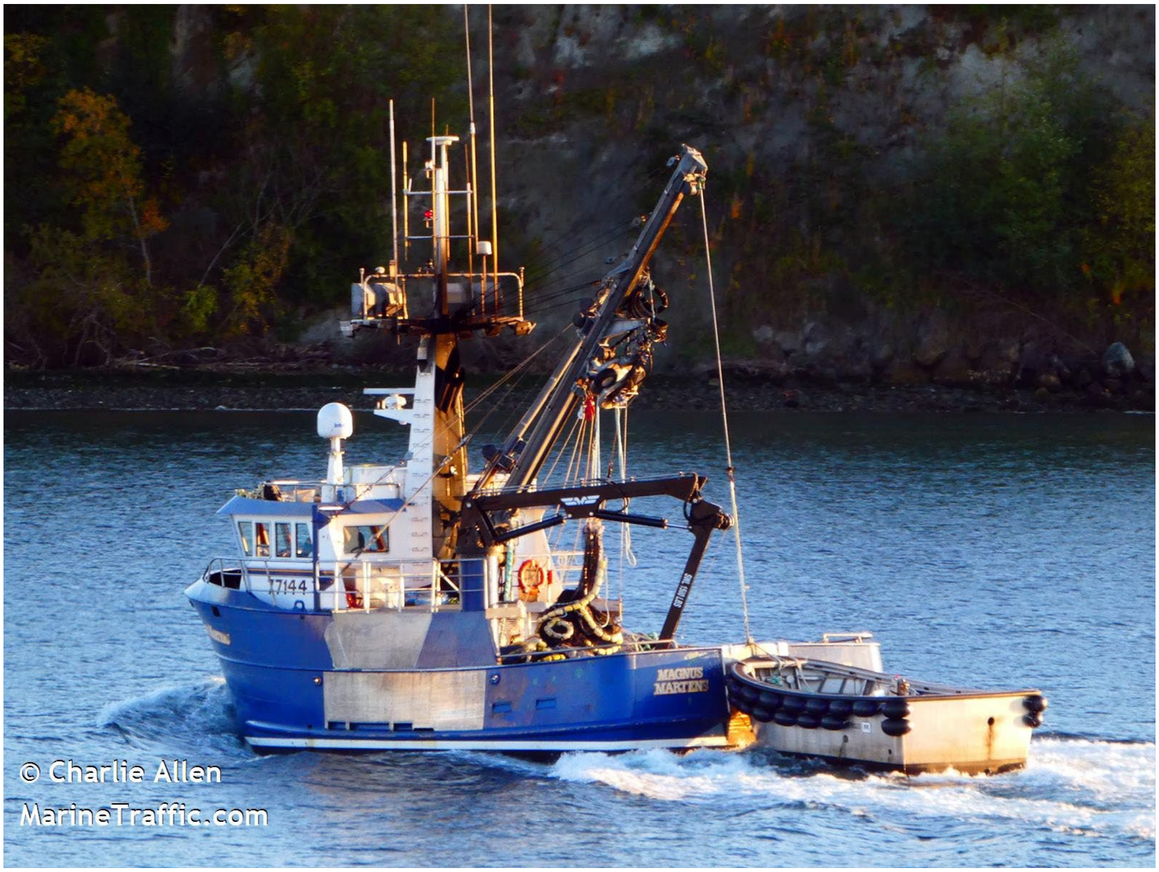


Figure 25: Design Vessel F/V Magnus Martens

Table 16: Design Vessel F/V Magnus Martens Parameters

Ship Paramenter	Dimensions (feet)
Length Over All (LOA)	58
Beam	26
Loaded Draft	8

Initial designs considered a design vessel up to 95 feet. Feedback during the Charrette was that this size of vessel would make the crossing through the Akun Strait most comfortable for passengers. The size of vessel was gradually reduced to 58 feet in order to minimize the harbor requirements for a vessel that was able to operate in the same parameters that fixed-wing aircraft land at Akutan airport.

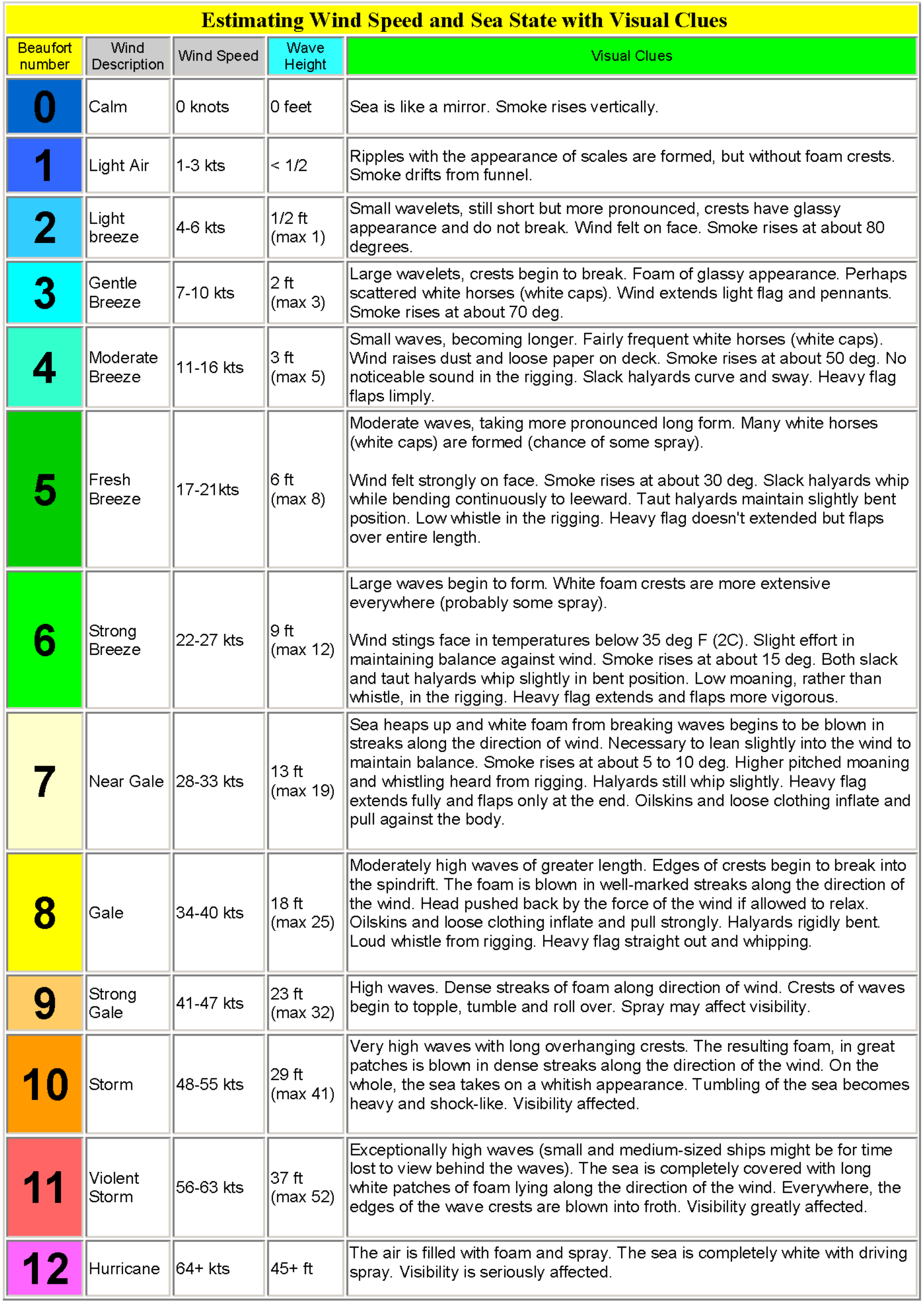
Note that many similar 58 foot fishing vessels in the area have drafts greater than 8 feet ranging up to 13 feet. A shallower draft of 8 feet allows the ferry to travel faster, reducing the amount of time passengers are exposed to waves that induce motion sickness. But a shallower draft vessel will experience greater motion in the waves which affects passenger comfort. The shallower draft design vessel of 8 feet was chosen based on similar drafts of fishing vessels in the area and to optimize harbor dredging depths.

The Aleutians East Borough (AEB) has indicated that they do not want to purchase a ferry vessel and will be contracting for ferry services, similarly to the current contract for the helicopter. Fishing vessels in the 58 foot range are commonly available, and it is likely the ferry contractor will purchase a used vessel and repurpose it to carry passengers and light freight.

4.1.1 Operational Conditions

Comparisons will be made henceforth using the Beaufort Sea State (BSS), as described in Table 17. This design vessel can be expected to conduct operations in Beaufort Sea State 3 (BSS3) with a windspeed of 7 to 10 knots and a maximum wave height of 3 feet and survive in SS4 with a windspeed of 11 to 16 knots and a maximum wave height of 5 feet (Eling, 2023). Wave conditions originating from 290°- 330° and 160°- 220° would filter through the Akun straight and impact the ability of the ferry to operate for the percent of time shown in the figure below.

Table 17: Beaufort Sea State Scale (NWS, 2023)



Estimating Wind Speed and Sea State with Visual Clues

Beaufort number	Wind Description	Wind Speed	Wave Height	Visual Clues
0	Calm	0 knots	0 feet	Sea is like a mirror. Smoke rises vertically.
1	Light Air	1-3 kts	< 1/2	Ripples with the appearance of scales are formed, but without foam crests. Smoke drifts from funnel.
2	Light breeze	4-6 kts	1/2 ft (max 1)	Small wavelets, still short but more pronounced, crests have glassy appearance and do not break. Wind felt on face. Smoke rises at about 80 degrees.
3	Gentle Breeze	7-10 kts	2 ft (max 3)	Large wavelets, crests begin to break. Foam of glassy appearance. Perhaps scattered white horses (white caps). Wind extends light flag and pennants. Smoke rises at about 70 deg.
4	Moderate Breeze	11-16 kts	3 ft (max 5)	Small waves, becoming longer. Fairly frequent white horses (white caps). Wind raises dust and loose paper on deck. Smoke rises at about 50 deg. No noticeable sound in the rigging. Slack halyards curve and sway. Heavy flag flaps limply.
5	Fresh Breeze	17-21kts	6 ft (max 8)	Moderate waves, taking more pronounced long form. Many white horses (white caps) are formed (chance of some spray). Wind felt strongly on face. Smoke rises at about 30 deg. Slack halyards whip while bending continuously to leeward. Taut halyards maintain slightly bent position. Low whistle in the rigging. Heavy flag doesn't extended but flaps over entire length.
6	Strong Breeze	22-27 kts	9 ft (max 12)	Large waves begin to form. White foam crests are more extensive everywhere (probably some spray). Wind stings face in temperatures below 35 deg F (2C). Slight effort in maintaining balance against wind. Smoke rises at about 15 deg. Both slack and taut halyards whip slightly in bent position. Low moaning, rather than whistle, in the rigging. Heavy flag extends and flaps more vigorous.
7	Near Gale	28-33 kts	13 ft (max 19)	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of wind. Necessary to lean slightly into the wind to maintain balance. Smoke rises at about 5 to 10 deg. Higher pitched moaning and whistling heard from rigging. Halyards still whip slightly. Heavy flag extends fully and flaps only at the end. Oilskins and loose clothing inflate and pull against the body.
8	Gale	34-40 kts	18 ft (max 25)	Moderately high waves of greater length. Edges of crests begin to break into the spindrift. The foam is blown in well-marked streaks along the direction of the wind. Head pushed back by the force of the wind if allowed to relax. Oilskins and loose clothing inflate and pull strongly. Halyards rigidly bent. Loud whistle from rigging. Heavy flag straight out and whipping.
9	Strong Gale	41-47 kts	23 ft (max 32)	High waves. Dense streaks of foam along direction of wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.
10	Storm	48-55 kts	29 ft (max 41)	Very high waves with long overhanging crests. The resulting foam, in great patches is blown in dense streaks along the direction of the wind. On the whole, the sea takes on a whitish appearance. Tumbling of the sea becomes heavy and shock-like. Visibility affected.
11	Violent Storm	56-63 kts	37 ft (max 52)	Exceptionally high waves (small and medium-sized ships might be for time lost to view behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Everywhere, the edges of the wave crests are blown into froth. Visibility greatly affected.
12	Hurricane	64+ kts	45+ ft	The air is filled with foam and spray. The sea is completely white with driving spray. Visibility is seriously affected.

To calculate the design vessel expected operational conditions, WIS point 82327 wave and wind conditions originating from 290°- 330° would filter through the Akun straight and impact the ability of the ferry to operate for the percent of time shown in Table 18 below. Statistics do not consider wind, fog, and maintenance that may also affect operations.

Table 18: Design Vessel Expected Operational Conditions

58 Foot Ferry	
Likely Operation	**Cease Operation**
Seas 3 feet or less	Seas greater than 3 feet,
Max wave height 5 feet or less	Max wave height greater than 5 feet,
Winds 20 knots or less	Winds greater than 20 knots
78%	22%

**Statistics are based on significant wave heights and winds generated by WIS point 82327 and do not consider wind, fog, and maintenance that may also affect operations.*

The proposed harbor alternatives assume the ferry vessel will permanently moor on Akutan island. Passengers and freight will be transported to and from the Akutan airport on Akun island, returning at the end of each trip to Akutan island.

4.2 Breakwaters

4.2.1 Design Wave

The design wave was developed for the three alternatives by transmitting the 2% AEP deepwater wave of 30.0 feet from Akun Strait to the toe of each breakwater using STWAVE modeling.

Table 19: Design Wave

	Design Wave (0.0 feet MLLW)
Alternative 1	16.4
Alternative 2	12.5
Alternative 3	15.0

4.2.2 Stone Sizing

Breakwater stone size was calculated using Hudon’s equation, where M_{50} is the medium mass of rock, ρ_s is the density of rock, p_w is the density of water, H is the wave height, K_D is the stability coefficient, and α is the slope angle.

$$M_{50} = \frac{\rho_S H^3}{K_D \left(\frac{\rho_s}{p_w} - 1\right)^3 \cot \alpha}$$

With p_s of 165lb/ft^3, p_w of 64 lb/ft^3, H of 12.5 feet, K_D of 3.5 for special placement, and α of 2 for a 2 horizontal to 1 vertical (2:1) slope, the medium weight of armor stone is 6 tons. Ice is not present at the project area and was not considered for armor stone sizing.

Table 20: Breakwater Armor Stone Weight

	Armor Stone (tons)
Alternative 1	13
Alternative 2	6
Alternative 3	10

4.2.3 Breakwater Dimensions

4.2.3.1 Crest Height

CEM run-up calculations were initially used to determine breakwater height. The following equations determine the runup height with 2% exceedance level for a permeable rock armored slope with irregular head-on waves.

$$R_{2\%} \begin{cases} = 0.96\xi_{om} \times H_s & for\ 1.0 < \xi_{om} \le 1.5 \\ = 1.17(\xi_{om})^{0.46} \times H_s & for\ 1.5 < \xi_{om} \le 3.1 \\ = 1.97 \times H_s & for\ 3.1 < \xi_{om} < 7.5 \end{cases}$$

where ξ_{om} is the mean surf-similarity parameter and is dependent on the mean wave period, significant wave height, and slope of the structure, and H_s is the significant wave height. For alternative 2 with a wave height of 12.5 feet and period of 12 seconds, the run-up with 2% exceedance level was calculated to be 24.6 feet. Added to the total water level, this results in a breakwater crest elevation of 32.7 feet. A breakwater of this height is not feasible, and an overtopping breakwater design was pursued.

The overtopping breakwater crest height was determined using the EurOtop equation below (Van der Meer, 2018). A maximum mean overtopping discharge q value of 50 liters/s per meter length of breakwater was allowed. At q = 50 l/s/m, structural damage is anticipated to begin (Figure 25). H_s is the significant wave height, which is equal to the design wave height calculated for each alternative. R_c is the freeboard, or the difference between the crest of the breakwater and the total water level. γ_f is the influence factor for the permeability and roughness of the slope, 0.40 for a 2 rock armor layer with a permeable core. γ_β is the influence factor for oblique wave attack, 1.0 for worst-case perpendicular wave attack.

$$q = \left[0.1035 \times \exp\left(-\left(1.35\frac{R_c}{H_s\gamma_f\gamma_\beta}\right)^{1.3}\right)\right]\sqrt{gH_s^3}$$

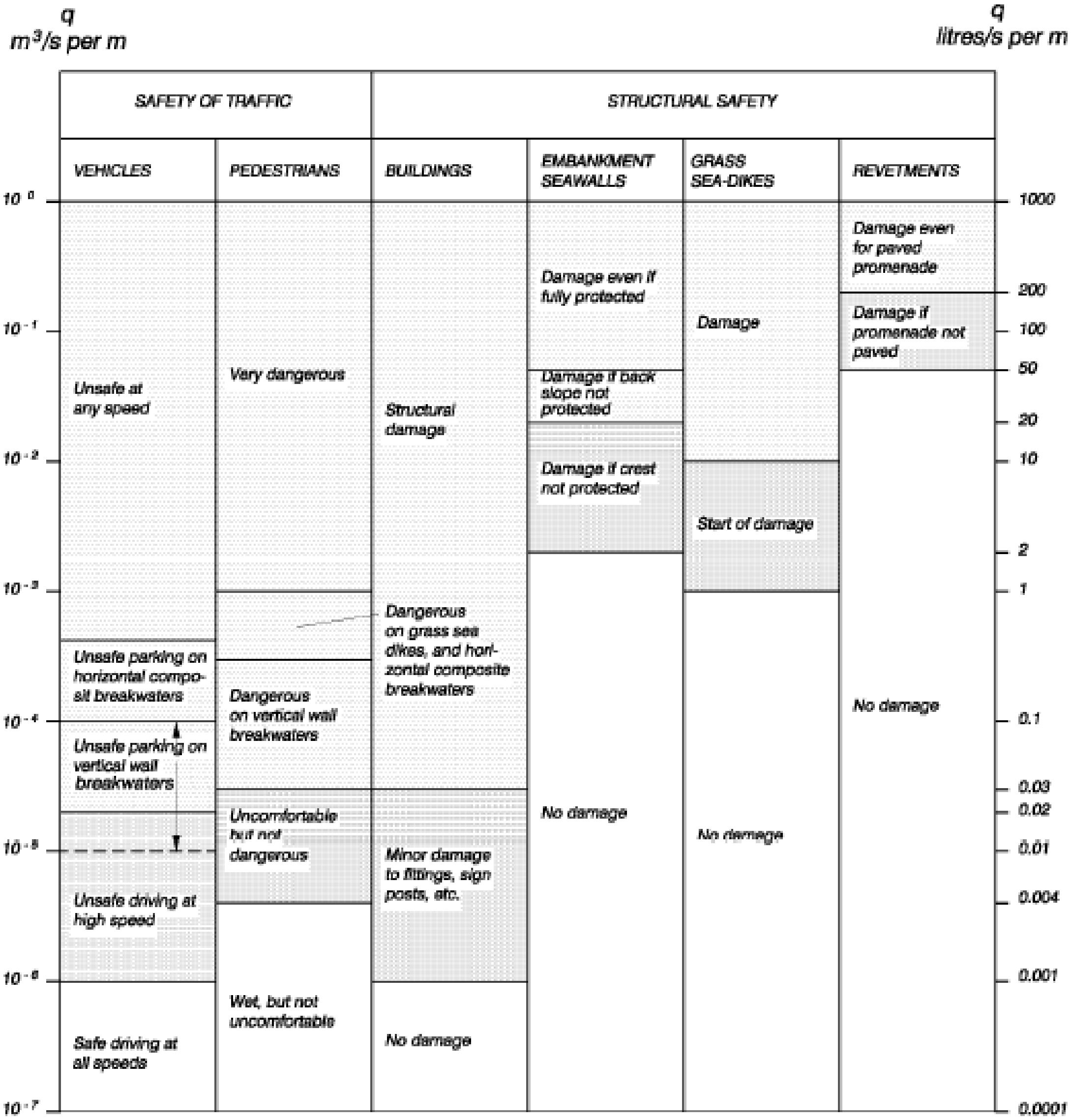


Figure 26. CEM Table VI-5-6 Critical Values of Average Overtopping Discharges (USACE, Coastal Engineering Manual, 2008).

Table 21: Breakwater Crest Heights

	Crest Height (0.0 feet MLLW)	
	Non-Overtopping	*Overtopping*
Alternative 1	40.4	20.0
Alternative 2	32.7	17.0
Alternative 3	37.6	19.0

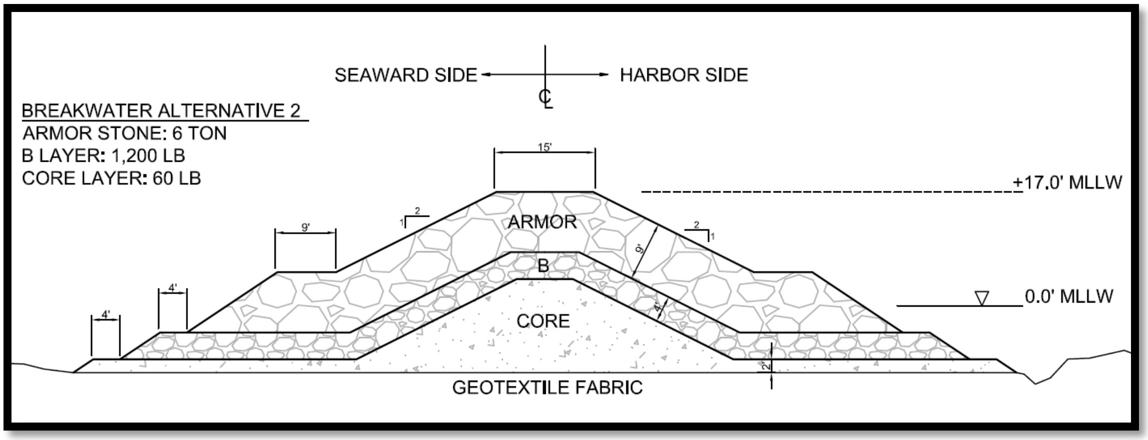


Figure 27: Breakwater Typical Cross Section (Alternative 2)

4.3.2.2 Crest Width and Armor Stone Layer Thickness

Breakwater crest width is equal to the combined width of three armor stones. Breakwater armor stone layer thickens is equal to the combined width of two armor stones.

Table 22: Breakwater Crest Widths

	Crest Width (feet)		**Armor Stone Layer Thickness** (feet)
	Non-Overtopping	*Overtopping*	*Non-Overtopping and Overtopping*
Alternative 1	16.6	19.0	11.5
Alternative 2	12.7	15.0	9.0
Alternative 3	15.2	17.0	11.0

4.3.2.3 Breakwater Length

Breakwater length was determined by assuming an initial length and then integrating the geometry of the breakwater into the STWAVE model bathymetry. The model was rerun with the breakwater and checked to ensure that a 1 foot or less wave was in the harbor basin footprint. Actual wave heights of up to 2 feet in the harbor should be expected due to the limitations in STWAVE modeling at small wave heights. The 2 foot maximum wave height in the basin is intended to protect mooring infrastructure.

Table 23: Breakwater Lengths

	Length (feet)
Alternative 1	715
Alternative 2	450
Alternative 3	400

4.2.4 Life-Cycle Breakwater Design

Armor stone for the proposed breakwaters at Akun was sized using the 2% AEP design wave forces expected to impact the structure. This was determined to be the most cost-effective means of protection for port alternatives considered. Rock for the project would likely be barged to the project location. Replacement costs are estimated to be relatively high because the project location is very remote and mobilization costs are substantial. A 1% AEP design would reduce the frequency and magnitude of needed maintenance, however design conditions for these events are not well known due to the period of record of data available at the site and there is less certainty that basing the design on a lower frequency event would produce a structure that would be capable of withstanding events of greater severity than those observed and studied. A 2% AEP design provides the optimum balance between minimizing maintenance requirements and the cost of procuring the stone for repairs.

Maintenance of breakwater armor stone is estimated at 5 percent replacement every 25 years.

4.3 Channel and Basin Widths

Considerations for channel design follow the standards of USACE EM1110-2-1613 Hydraulic Design of Deep Draft Navigation Projects and EM 1110-2-1615 Hydraulic Design of Small Boat Harbors and were checked against globally used PIANC guidance (USACE, 2008).

4.3.1 Entrance Channel

Section 3-11 of EM 1110-2-1615 Hydraulic Design of Small Boat Harbors was used to design the entrance channel and turning basin widths. The design vessel is a 58-foot long with 26-foot beam twin screw steel monohull and is assumed to have good controllability. The section of the entrance channel is designed at 180% of the vessel beam, and the 40° bend in the entrance channel is 440% of the vessel beam. This was rounded to 60 feet for strait sections and 120 feet for 40° bends for design. Note that most 58-foot fishing vessels in Alaska have beams less than 26-feet, typically ranging from 18 to 24 feet. This would allow a 24-foot beam ferry vessel with poor controllability to safely navigate the entrance channel.

Table 24: Minimum Channel Element Widths (Committee on Tidal Hydraulics, 1965)

Minimum Channel Widths Needed in Percent of Beam			
Location	**Vessel Controllability**		
	Very Good	*Good*	*Poor*
Maneuvering Lane, Straight Channel	160	180	200
Bend, 26-degree Turn	325	370	415
Bend, 40-degree Turn	385	440	490
Vessel Clearance	80	80	80
Bank Clearance	60	60 plus	60 plus

4.3.2 Turning Basin

Section 3-14 of EM 1110-2-1615 Hydraulic Design of Small Boat Harbors recommends the turning basin be designed based on observation of vessel turning radius. Because the ferry vessel will be contracted and the turning radius is unknown, PIANC guidance was utilized. PIANC recommends the turning basin to be twice the length of the design vessel, or 120 by 120 feet. Since ship simulation was not performed for this study, it was deemed appropriate to use the PIANC turning basin dimensions.

The mooring basin is located within the dimensions of the turning basin, as only the ferry vessel will utilize the mooring basin. In the rare instance that another vessel is utilizing the mooring basin, the conservatively sized turning basin should provide enough room for the design vessel to maneuver.

4.3.3 Circulation

The circulation aspects of the proposed harbors at Akun were evaluated based on guidance given in the Coastal Engineering Manual Part II Chapter 7. Tidal variation, storm surge, wave driven currents, and wind stresses are factors that would affect water circulation in the proposed harbor. The harbor basin design is square, 120 feet by 120 feet, for all alternatives. This results in a very high spatial average exchange coefficient of 0.48 to 0.5 (Figure 27). Additionally, pollutants in the harbor are expected to be a low concern. Anticipated usage of the harbor is one ferry vessel making one to two trips daily with no permanent mooring. Circulation issues with the proposed harbor design are not anticipated.

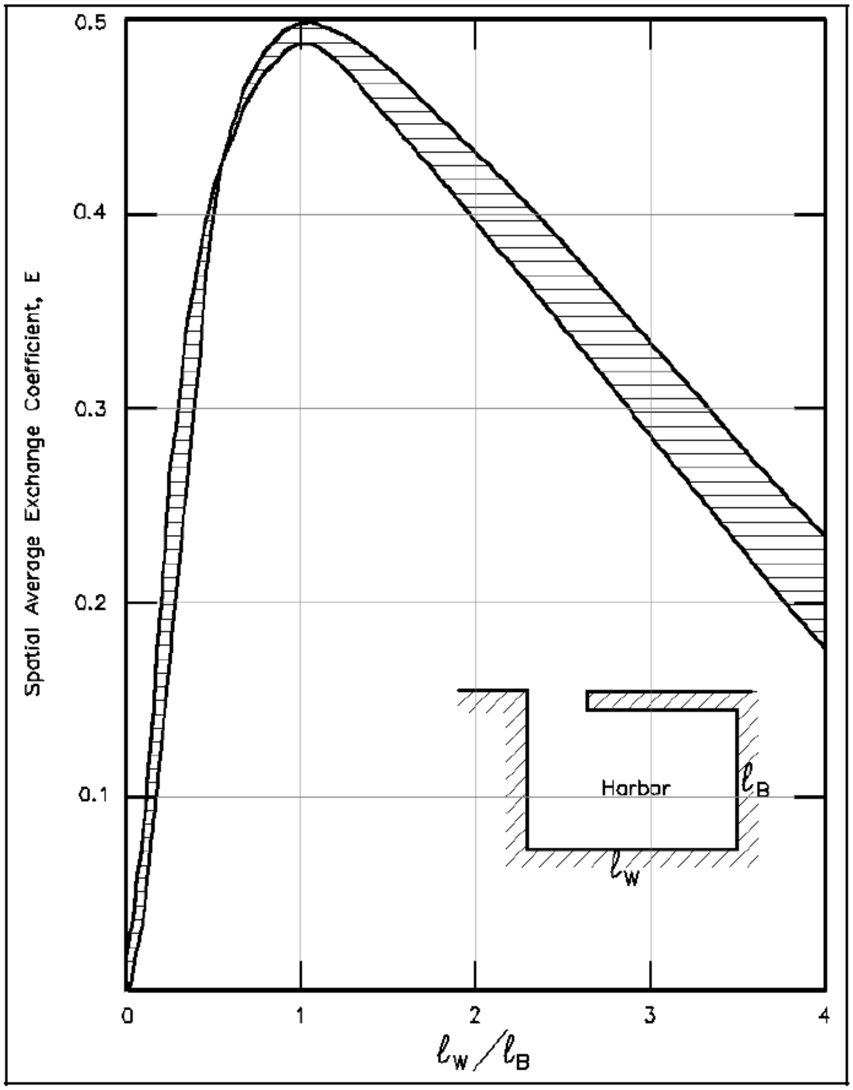


Figure 28: Exchange Coefficients – Rectangular harbor (USACE, 2008)

4.4 Channel and Basin Depths

A vessel moving in the entrance channel and turning basin must maintain clearance between its hull and channel bottom. Navigational design parameters were analyzed including squat, safety clearance, and vessel motion due to waves. Storm surge was not included as it increases water depth that would benefit depth calculations. An allowance for RSLC was included. Minimum gross underkeel clearance was calculated from the sum of the depth requirement from each design parameter.

Considerations for channel design follow the standards of the CEM and were checked against globally used PIANC guidance (USACE, 2008).

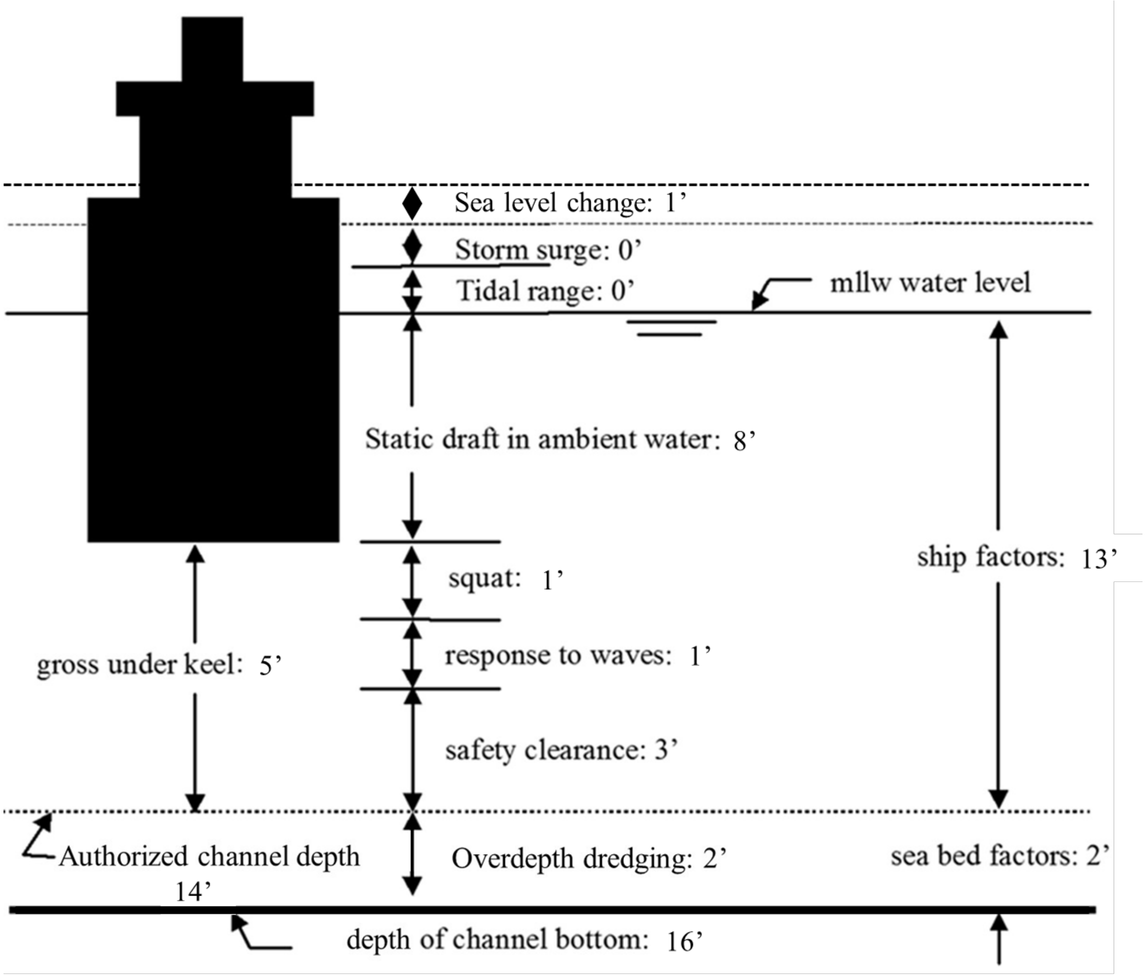


Figure 29: Channel Design Parameters

4.4.1 Environmental Factors

4.4.1.1 Tide.

The harbor is designed to allow access at tides above 0.0 feet MLLW.

4.4.1.2 Relative Sea Level Change

From Section 2.9 Relative Sea Level Change, the intermediate RSCL of –0.92 feet was chosen for the project design. In order to maintain the project depth at year 50, 1 foot of dredging will be incorporated in the harbor and entrance channel design depths at construction.

4.4.1.3 Set-Down

Set-down is a lowering of the water surface elevation due to wind stresses. The lowest observed water level at Unalaska (9462620) is -2.78 feet which indicates that set-down can occur in the area, but information is not available for how often they occur. Set-down was not included in the design depth as the ferry would likely not operate during the strong wind conditions associated with set-down.

4.4.2 Ships Factors

4.2.2.1 Squat

Vessel draft increases when vessel sailing depth adjusts to the energy balance between hydrostatic and kinetic energy due to the fluid velocity around and under the vessel hull. It is pulled down into the water column by the hydrodynamic pressure gradient. This phenomenon and related vertical hydrodynamic effects are defined here as "squat," which varies with vessel speed, water depth beneath the keel, and the ratio of the vessel cross-section area to the cross-section area of the channel.

Ship squat is difficult to accurately predict, with the best available method being imperial formulas. USACE guidance for the Hydraulic Design of Small Boat Harbors (EM 1110-2-1615 section 3-12) describes ship squat based on the vessel's blockage ratio and the Froude number. The channel's dimensionless blockage ratio S is defined as

$$S = \frac{A_s}{A_c}$$

where A_s is the cross-sectional area of the ship and A_c is the cross-sectional area of the channel. A beam of 26 feet multiplied by a draft of 8 feet results in an A_s value of 28 feet^2. A channel depth of 14 feet multiplied by a width of 120 feet results in an A_c value of 1,680 feet^2. Therefore S is equal to 0.12.

The Froude number F is defined as

$$F = \frac{V_s}{\sqrt{gH_c}}$$

where V_s is vessel speed in feet/sec, g is acceleration due to gravity at 32.2 ft/sec^2, and H_c is the channel water depth in feet. With V_s ranging from 4 to 8 knots (6.8 to 13.5 feet/sec) and a channel depth of 14 feet, dimensionless squat is read from Figure 29 below.

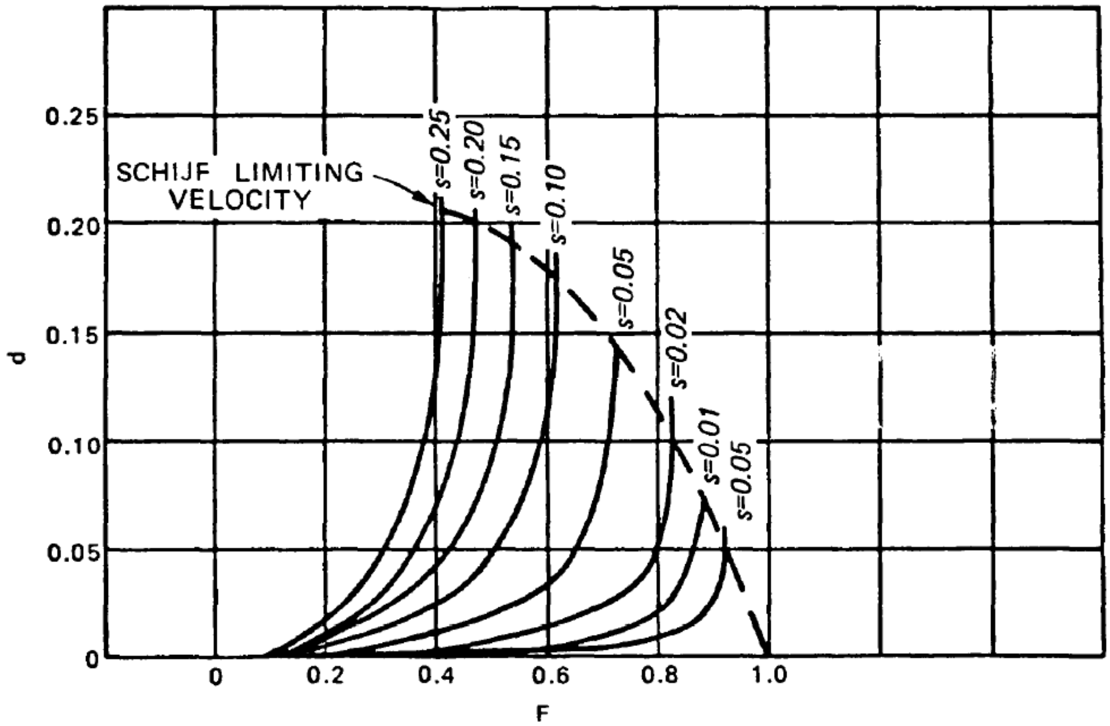


Figure 30: Dimensionless Squat (EM 1110-2-1615 Figure 3-10)

Dimensionless squat was multiplied by the depth of channel water (14 feet) to produce ship squat. Results for EM 1110-2-1615 squat calculations are shown in Table 25 below.

Table 25: Squat Calculations

Vessel Speed	**Squat**		
	EM 1110-2-1615	*EM 1110-2-1613*	*PIANC*
(knots)	(feet)	(feet)	(feet)
4	0.3	0.4	0.1
5	0.4	0.7	0.1
6	1.0	1.0	0.2
7	1.8	1.4	0.3
8	2.5	1.8	0.4

USACE guidance for the Hydraulic Design of Deep Draft Navigation Projects (EM 1110-2-1613 section 6-3) was also used to check squat using the Norrbin equation

$$z_{max} = \frac{C_B B T V^2}{4.573 L h}$$

where z_{max} is ship squat in feet, C_B is block coefficient, B is max beam, T is fully loaded draft, V is ship velocity in knots, L is length of vessel, and h is channel depth. C_B coefficients range from 0.5 for fine form ships to 0.9 for very full tankers and bulk carriers, with 0.5 used for the design vessel (see Table 26, tuna seiner).

Computations for prediction of squat assume a typical container vessel C_B of 0.5, B of 26 feet, T of 8 feet, V of 4 to 8 knots, L of 58 feet, and h of 14 feet. Results for EM 1110-2-161 squat calculations for are shown in Table 25 above.

Table 26: Block Coefficients from EM 1110-2-1613

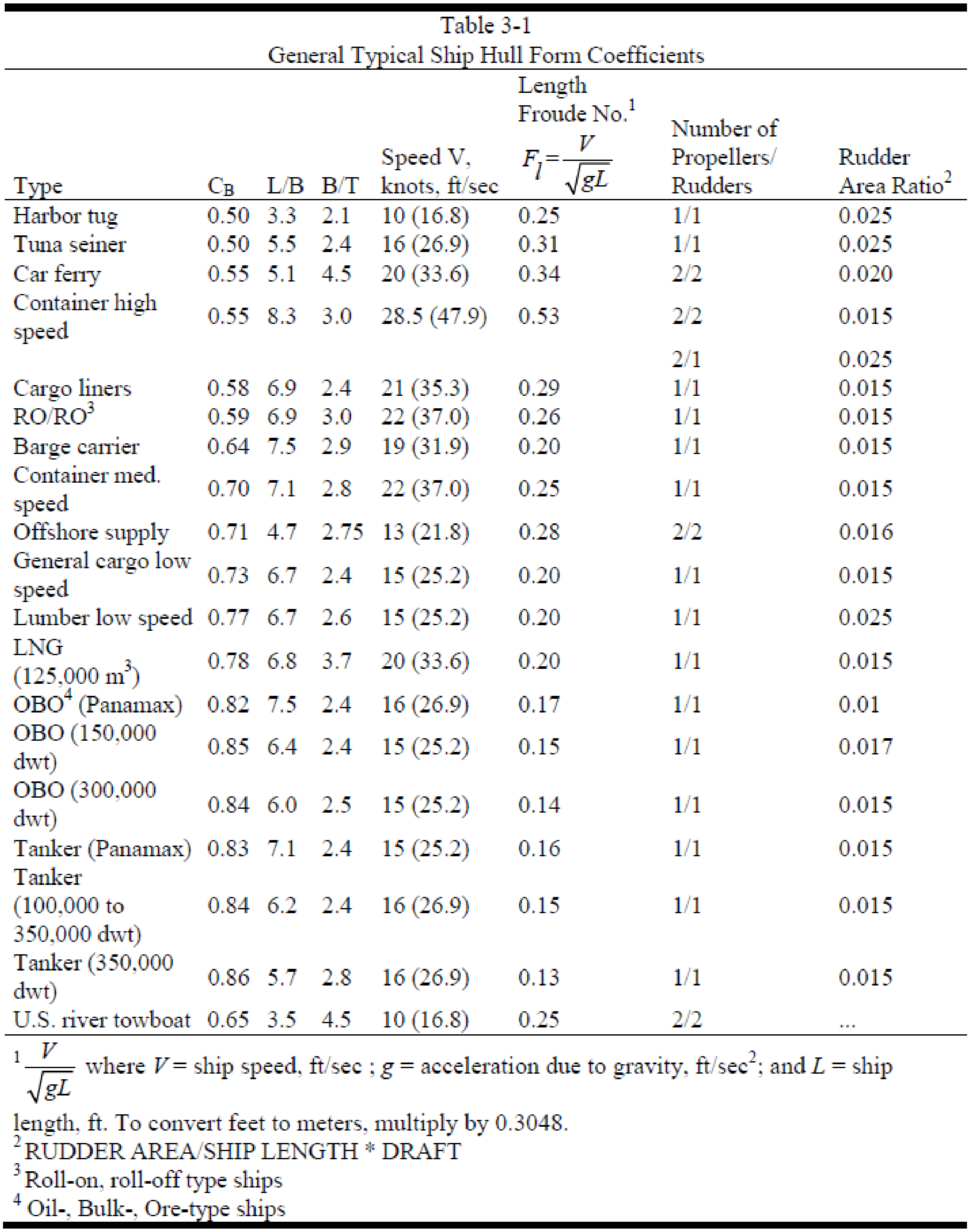


Table 3-1
General Typical Ship Hull Form Coefficients

Type	C_B	L/B	B/T	Speed V, knots, ft/sec	Length Froude No.[1] $F_l = \frac{V}{\sqrt{gL}}$	Number of Propellers/ Rudders	Rudder Area Ratio[2]
Harbor tug	0.50	3.3	2.1	10 (16.8)	0.25	1/1	0.025
Tuna seiner	0.50	5.5	2.4	16 (26.9)	0.31	1/1	0.025
Car ferry	0.55	5.1	4.5	20 (33.6)	0.34	2/2	0.020
Container high speed	0.55	8.3	3.0	28.5 (47.9)	0.53	2/2	0.015
						2/1	0.025
Cargo liners	0.58	6.9	2.4	21 (35.3)	0.29	1/1	0.015
RO/RO[3]	0.59	6.9	3.0	22 (37.0)	0.26	1/1	0.015
Barge carrier	0.64	7.5	2.9	19 (31.9)	0.20	1/1	0.015
Container med. speed	0.70	7.1	2.8	22 (37.0)	0.25	1/1	0.015
Offshore supply	0.71	4.7	2.75	13 (21.8)	0.28	2/2	0.016
General cargo low speed	0.73	6.7	2.4	15 (25.2)	0.20	1/1	0.015
Lumber low speed	0.77	6.7	2.6	15 (25.2)	0.20	1/1	0.025
LNG (125,000 m^3)	0.78	6.8	3.7	20 (33.6)	0.20	1/1	0.015
OBO[4] (Panamax)	0.82	7.5	2.4	16 (26.9)	0.17	1/1	0.01
OBO (150,000 dwt)	0.85	6.4	2.4	15 (25.2)	0.15	1/1	0.017
OBO (300,000 dwt)	0.84	6.0	2.5	15 (25.2)	0.14	1/1	0.015
Tanker (Panamax)	0.83	7.1	2.4	15 (25.2)	0.16	1/1	0.015
Tanker (100,000 to 350,000 dwt)	0.84	6.2	2.4	16 (26.9)	0.15	1/1	0.015
Tanker (350,000 dwt)	0.86	5.7	2.8	16 (26.9)	0.13	1/1	0.015
U.S. river towboat	0.65	3.5	4.5	10 (16.8)	0.25	2/2	...

[1] $\frac{V}{\sqrt{gL}}$ where V = ship speed, ft/sec ; g = acceleration due to gravity, ft/sec^2; and L = ship length, ft. To convert feet to meters, multiply by 0.3048.
[2] RUDDER AREA/SHIP LENGTH * DRAFT
[3] Roll-on, roll-off type ships
[4] Oil-, Bulk-, Ore-type ships

USACE guidance value was checked against PIANC guidance recommended Barrass (B3) equation

$$S_{Max,B3} = \frac{C_B V_k^2}{100/K}$$

where $S_{Max,B3}$ is ship squat, C_B is the block coefficient, V_k is ship speed, and K is a dimensionless coefficient. K is defined as

$$K = 5.74S^{0.76}$$

where S is the channel's dimensionless blockage factor, previously calculated as 0.12. Therefore K is equal to 1.17. For a C_B previously established as 0.5 and a V_k of 4 to 8 knots, results PIANC squat calculations are shown in Table 25 above.

As a check, USACE guidance (EM 1110-2-1615 Section 3-12 b.) recommends a smaller vessel generalization for squat of 1 foot in entrance channels. An allowance for vessel squat of 1 foot was chosen for design, which equates to a maximum ferry speed of 6 knots in the entrance channel and mooring and turning basins.

4.2.2.2 Response to Waves

Vessel response to waves, or the vertical movement of pitch, roll, and heave, is difficult to estimate accurately and is still being researched. Best available USACE guidance (EM 1110-2-1613) estimates the effect of pitch, roll, and heave using the Noble equation

$$P_{avg} = 0.57 + 0.99\left(\frac{H_S T_\emptyset}{T_e}\right)$$

where P_{avg} is average ship motion in waves, H_S is significant wave height, $T_\emptyset$ is natural ship pitch period, and T_e is encounter period. The natural pitch period for the design vessel is not known but is estimated at 4 seconds based on a similar study of a 65 foot fishing vessel in Newfoundland, Cananda (Akinturk, Cumming, & Bass, 2007). An offshore significant wave of 5 feet with a 8 second period was modeled in STWAVE to find the wave height at the entrance channel and basin at the ferry cease operation condition. Modeled water level was MHHW of 3.76 feet. Results were a 5 foot 8 second period wave at the entrance channel and 0.5 foot 8 second period wave in the basin. The vessel speed was calculated for 4 to 8 knots.

Utilizing Figure 30 below, waves originating from the Bering Sea to the north would have an encounter angle Θ, or the difference between the wave angle and ship heading, of 180° for the inbound ferry heading to Akun and 0° for the outbound ferry heading to Akutan. Outbound vessels travel in head seas, or against the direction of wave propagation, which causes a larger ship motion due to waves than inbound vessels. Therefore, outbound ship motion due to waves was used for calculations. Vessel speed V_k multiplied by the dimensionless factor F is the input and wave period of encounter is the output. Using the Noble equation with a 5-foot and 0.5-foot significant wave height, natural ship period of 4 seconds, and a wave encounter period for outbound ferry ranging from 4 to 8 knots, the ship response to waves is given in Table 27 below.

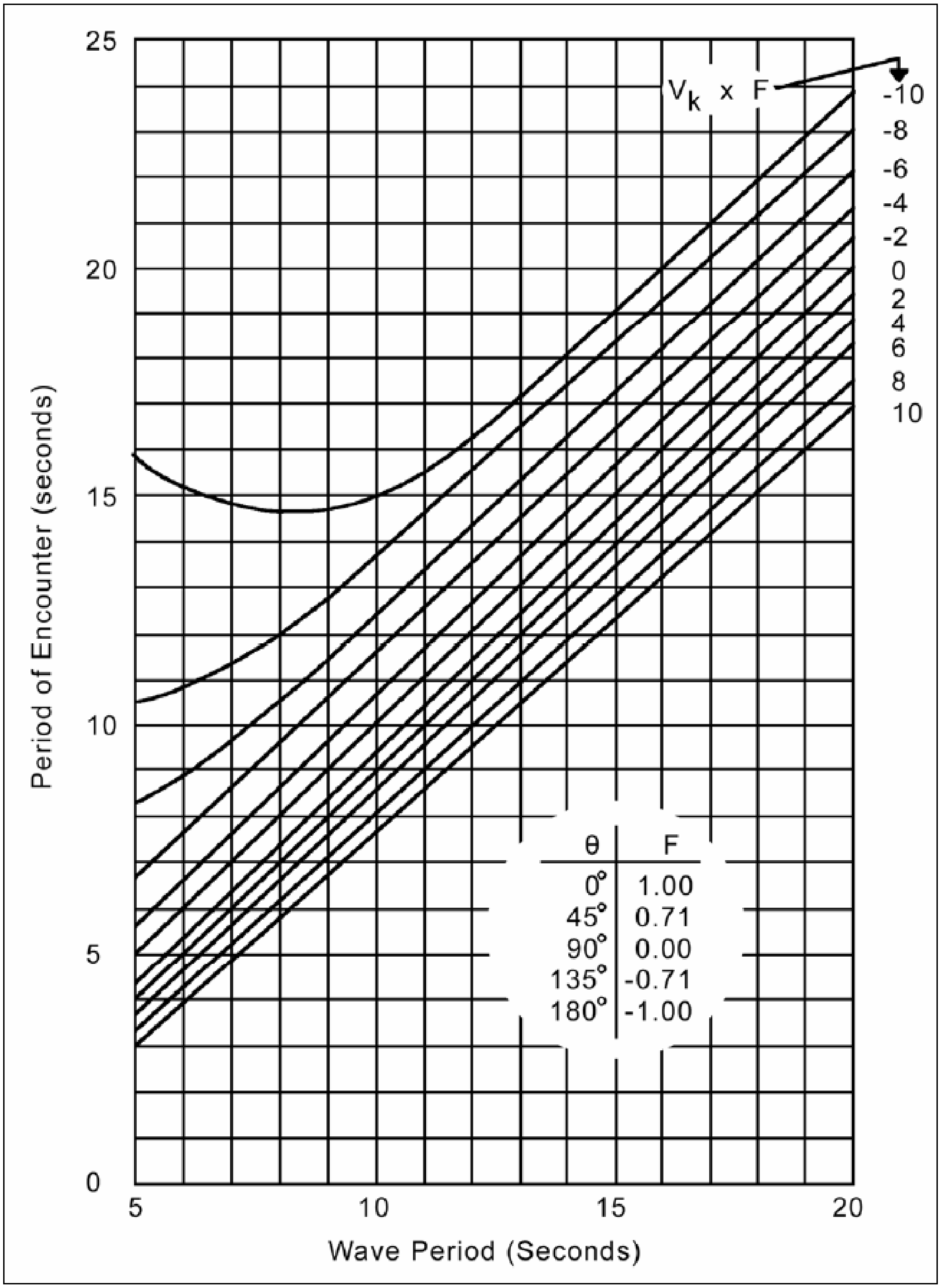


Figure 31: EM 1110-2-1613 Wave Encounter Period (Figure 6-15)

Table 27: Vessel Motion Due to Waves

Vessel Speed	Motion Due to Waves			
	Basin		Entrance Channel	
	USACE	*PIANC*	*USACE*	*PIANC*
(knots)	(feet)	(feet)	(feet)	(feet)
4	0.85	10.0	3.4	10.0
5	0.86	10.0	3.5	10.0
6	0.87	10.0	3.6	10.0
7	0.88	10.0	3.7	10.0
8	0.89	10.0	3.8	10.0

A second method of evaluating wave-induced motions is the trigonometric method in PIANC guidance. It is a simplistic and conservative method that assumes that all wave components would occur in phase for a value twice the significant wave height. Using a 5-foot significant wave at the entrance channel and a 0.5-foot wave in the basin, the effects of pitch, roll, and heave are 10 feet and 1 feet respectively with results shown in Table 27 above.

USACE guidance (EM 1110-2-1615 Section 3-12 c.) recommends a smaller vessel generalization for ship response to waves of one-half the design wave height. This equates to 0.25 feet for the mooring and turning basin, and 2.5 feet for the entrance channel. These allowances were deemed too small to be considered for design.

An allowance for vessel motion due to waves of 1 foot for the mooring and turning basin and 4 feet for the entrance channel chosen for design. This is for a maximum vessel speed of 6 knots as established in the squat calculation of 3.6 feet, but is rounded up to 4 feet due to the uncertainty associated with calculating ship motion due to waves.

4.4.3 Safety Clearance

USACE guidance (EM 1110-2-1613) suggests a minimum net underkeel clearance of 2 feet; however, for hard bottom conditions such as rock, consolidated sand or clay, 3 feet of net underkeel clearance is recommended. Based on bedrock being present in the dredging area, a safety factor of 3 feet was used for this analysis.

4.4.4 Gross Underkeel Clearance

The subtotal of squat, response to waves, RSLC, and safety clearance for the entrance channel and turning basin provides a gross underkeel clearance of 6.0 feet for the mooring and turning basin and 9.0 feet for the entrance channel. This results in a design depth of -14 feet MLLW and -17 feet MLLW respectively. USACE guidance (EM 1110-2-1613 Section 6-4) recommends the PIANC rule of thumb for preliminary design of entrance channel depths of 1.3 times the maximum shift draft, or a design depth of -10.4 feet MLLW. The entrance channel design depth far surpasses the rule of thumb.

Dredging equipment and procedures for blasting the entrance channel and turning basin cannot provide a smoothly excavated bottom at a precisely defined elevation. Two feet of allowable overdepth dredging was added to for a maximum dredge depth of -16 feet MLLW for the mooring and turning basin and -19 feet MLLW for the entrance channel.

Table 28: Design Parameters for Gross Underkeel Clearance Calculation

Design Parameter	Depth Allowance	
	Basin (feet)	*Entrance Channel* (feet)
Storm Surge	0	0
Tidal Range	0	0
Relative Sea Level Change	1	1
Vessel Draft	8	8
Squat	1	1
Response to Waves	1	4
Safety Clearance	3	3
Design Depth	14	17
Allowable Overdepth	2	2
Max Payline	16	19

4.5 Dredging

4.5.1 Dredging Limits

Dredging limits were determined based on vessel maneuvering characteristics as a function of length, beam, turning radii, and wind conditions. Side slopes of 2H:1V were assumed based on the rocky material anticipated, and further geotechnical analysis will likely allow for even steeper side slopes.

A minimum offset bench width distance of 15 feet horizontal between the top of the dredge cut slope and the toe of any causeway or breakwater structure is recommended. For purposes of dredging adjacent to the proposed dock faces, the required depth can abut to the dock faces.

The maximum dredging depth determined for the site was to -16 feet MLLW. Previous studies have indicated a need to drill and blast 2 feet below the design depth to produce an efficient pattern to loosen the material for excavation. Dredging tolerances were assumed to be 2 feet due to the coarse nature of the material around the island and the potential need for blasting to remove it. Payment includes dredging allowable overdepth to a maximum of -16 feet MLLW. Note that quantities for all 3 alternatives were calculated based on a previous dredge depth of -13 feet MLLW. Since the update in depth from -13 feet MLLW to -16 feet MLLW affects all three alternatives equally, it was not a factor of the TSP selection.

4.5.2 Dredging Quantities

Initial dredging quantities will vary with channel depth. Table 29 displays dredge quantities associated with each alternative. Alternative 1 was laid out beyond the anticipated bedrock and would likely not require blasting. Alternatives 2 and 3 are located within known bedrock prisms and will likely require blasting. The quantities presented include grading a 2:1 sideslope and the previous dredge depth of -13 feet MLLW.

Table 29: Estimated Dredging Quantities

	Initial Dredging (cy)	**Maintenance Dredging** (cy)
Alternative 1	8,700	870
Alternative 2	9,840	980
Alternative 3	8,180	820

4.6 Channel Navigation

4.6.1 Navigation Aids

As part of the construction of the project, concrete navigation marker bases would be constructed at locations determined by the U.S. Coast Guard, typically at the heads of the new breakwaters. Coordination with the U.S. Coast Guard Aids to Navigation Office will be conducted to ensure adequate base construction to support installation of navigational aids.

4.6.2 Allowable Wave Heights

The design wave height inside the harbor is 2 feet to minimize damage to the dock and other harbor infrastructure. This allowable wave height is also to protect the ferry vessel. The ferry is expected to moor at Akutan Harbor, but may occasionally need to moor for up to several days at Akun if severe weather prevents the ferry from crossing back to Akutan.

4.7 Local Service Facilities

For each of the three alternatives, it is assumed that the local service facilities would be constructed under the same contract for the Federal features of the project. Local service facilities include the non-Federal dredging at the mooring area, docks, mooring dolphins and bollards, and access roads. Upland staging and laydown areas are also local service facilities. The non-Federal dredging portions of the project are represented by the area adjacent to the proposed dock faces out to an offset distance of approximately one and a half vessel beams in width (40 feet) and one vessel length (60 feet).

4.8 Dredge Material Placement

Material will be generated both from the road cut to access Alternatives 1 and 2, and the dredging of the entrance channel and turning basin for all alternatives. It is anticipated that the dredge material, especially blasted rock, will be of good quality and could be utilized by the sponsor. In which case an uplands placement area will be identified for dredge material storage rather than in water disposal. If in water disposal of dredge material is required, a preferred disposal area will be identified by the Environmental team based on biological productivity levels identified at each site.

5.0 SITE SELECTION

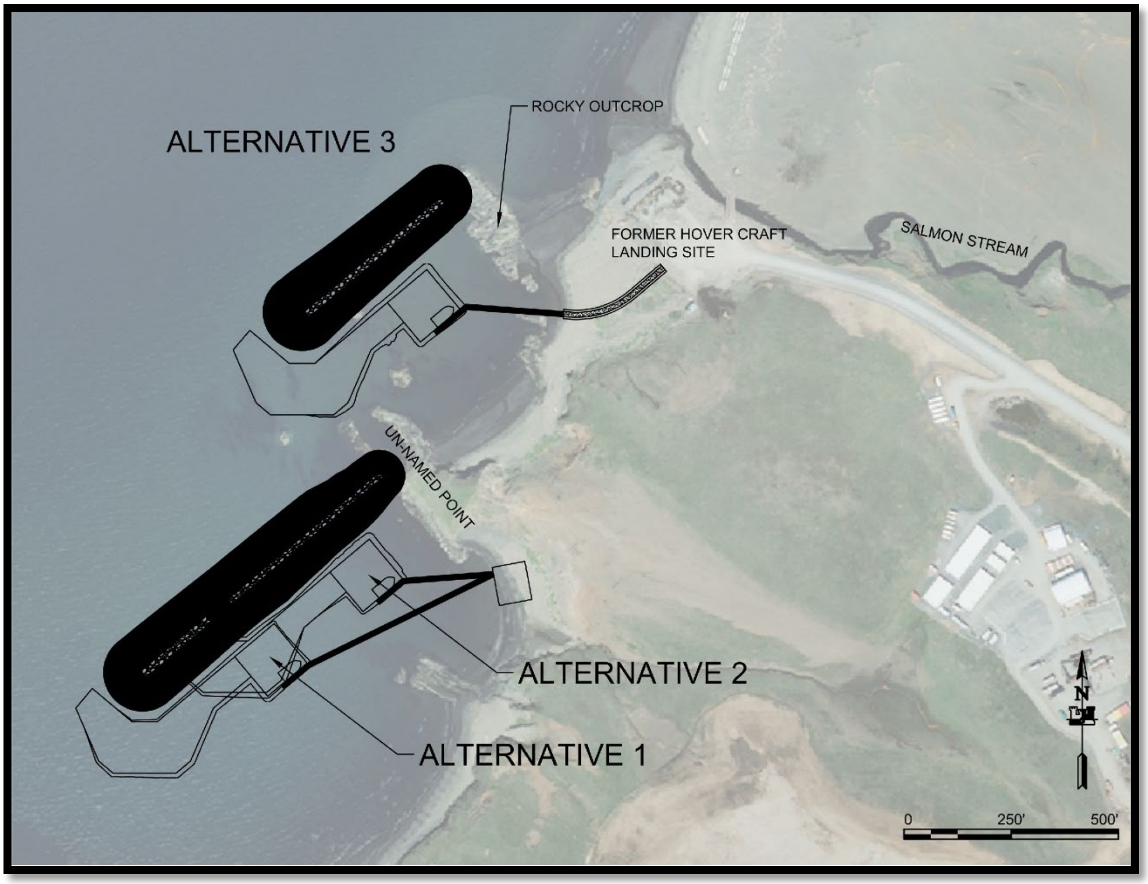


Figure 32: Alternatives 1-3 Overview

5.1 Features for All Alternatives

5.1.1 Akutan Facilities

The facility upgrades on Akutan island will be the same for alternatives 1-3. At this time, it is assumed that the ferry vessel will moor in Akutan Harbor. Before each ferry trip, crew to pilot the vessel will board a skiff at the City Dock in Akutan and travel 2 miles to the ferry at Akutan Harbor, or use the road from the harbor to the City once constructed. The vessel and crew will travel back to the City Dock where passengers and freight will board the vessel. The ferry will then travel to the proposed harbor on Akun and offload passengers and freight to meet a connecting flight on a fixed wing aircraft. The ferry will travel back to Akutan City Dock with any passenger and crew from Akun. Once all runs for the day are completed, the ferry will be moored at Akutan Harbor, and crew will take a skiff or the road once constructed back to the Akutan City Dock.

Upgrades will need to be applied to the Akutan City Dock in order to accept the ferry vessel. At a minimum, the catwalk with mooring dolphins could be replaced to the appropriate elevation for easy boarding of the ferry vessel. If the road to the harbor is constructed first, the ferry will be able to dock at Akutan harbor.

5.1.2 Akun Facilities

The facility upgrades on Akun will vary for each alternative based on the length of road needed to reach existing infrastructure.

5.1.3 Updated Design Features

The design depth of the three alternatives was deepened after the cost estimate and economic analysis was performed. The “updated design” depth is reflected in the Hydraulics and Hydrology Appendix, and is shown in Table 30 - Table 33. The original design depth used for the cost estimate and economic analysis is listed as “presented in report” in Table 30 - Table 33. Since the updated design affected all three alternatives equally, it was not necessary to update the cost estimate and economic analysis for the TSP.

5.2 Alternative 1

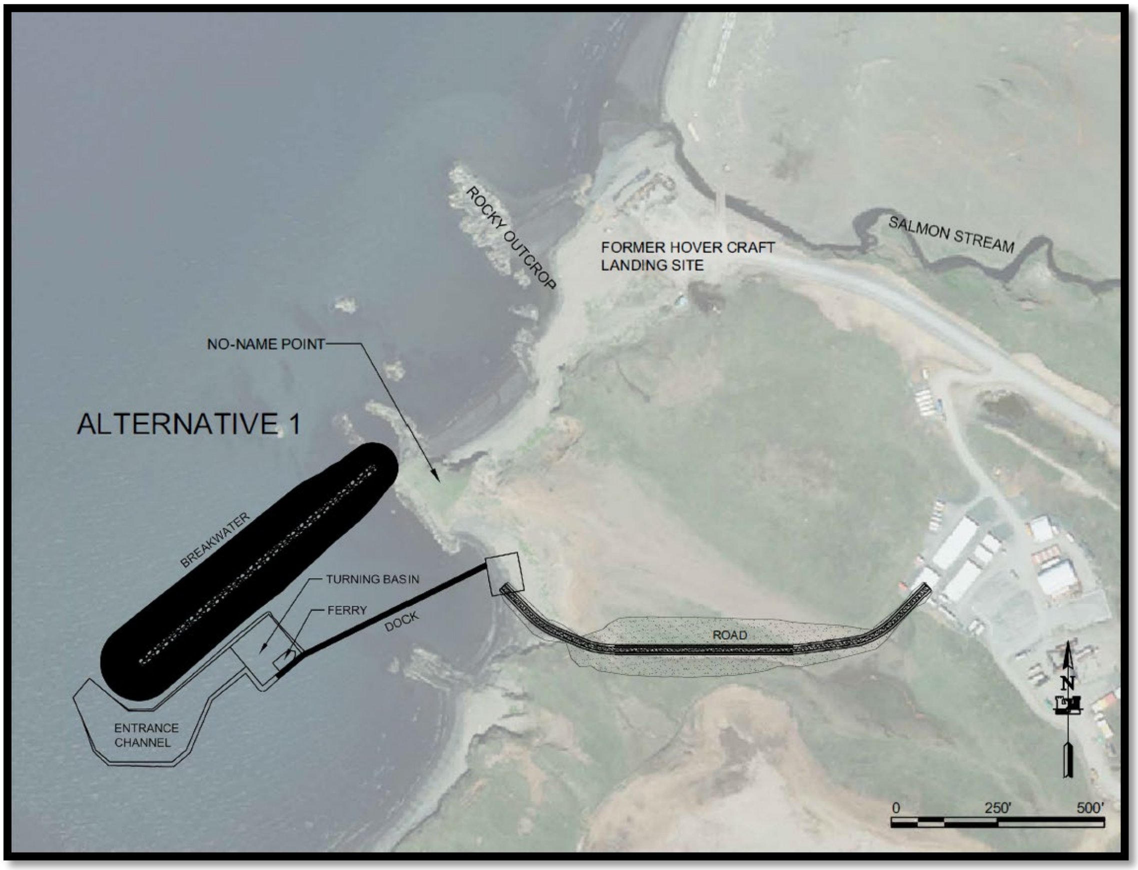


Figure 33: Alternative 1 Concept Plan

5.2.1 Harbor

The harbor would be sized to accommodate a design vessel with a length of 58 feet and a draft of 8 feet. The 715-foot-long rubble mound breakwater would protect a 120 foot by 120 foot turning basin. Both the entrance channel and turning basin would have a dredge depth of -14 feet MLLW. It is anticipated that blasting would not be required for the turning basin or entrance channel in this location. The entrance channel would have a minimum width of 60 feet to a maximum width of 120 feet when turning around the nose of the breakwater.

Table 30: Alternative 1 Features

		Unit	Alternative 1	
			Presented in Report	*Updated Design*
Breakwater	**Armor Stone Weight**	(tons)	13	-
	Armor Stone Thickness	(feet)	11.5	-
	Crest Height	(feet MLLW)	20	-
	Crest Width	(feet)	19	-
	Length	(feet)	715	-
Entrance Channel	**Width Straight**	(feet)	60	-
	Width 40° Bend	(feet)	120	-
	Depth	(feet MLLW)	-13	-17
Turning Basin	**Width**	(feet)	120	-
	Length	(feet)	120	-
	Depth	(feet MLLW)	-13	-14
Quantities	**Armor Stone**	(cubic yards)	33,600	-
	Harbor Dreding	(cubic yards)	8,700	24,210
	Road Excavation	(cubic yards)	45,000	-

Alternative ` explores the tradeoff of having the harbor located in deeper water to utilize soft material dredging equipment rather than blasting. The cost savings of avoiding blasting are not expected to outweigh having a larger breakwater with heavier armor stone and a longer dock to reach the mooring basin. Only a slight decrease in dredge quantity is realized by alternative 1 as it is located in a similar depth as the harbor in alternative 2.

Figure 34: Looking West From Un-Named Point Towards Daryl's Point (Alternatives 1&2)

5.2.2 Local Service Facilities

Local service facilities required would include a 560 foot long by 12-foot-wide pile-supported dock, 60 foot by 40-foot mooring basin with mooring dolphins, uplands with an area of approximately 0.15 acres for loading/unloading freight from dock, and a 1,100 foot long by 12-foot-wide road connecting the harbor areas with the existing pad to the south of the hotel.

Alternatives 1 and 2 would share the same road alignment. The road would have an average grade of 8.5 percent and cut through the valley up to the pad containing Surf Bay Inn. The road consists of a 12-foot wide surface with 6 inches of aggregate surface over 2 feet of borrow material. Two shoulders are graded out 5 feet from the edge of road with a 2 horizontal on 1 vertical (2H:1V) slope, before sloping upward to existing ground at a 2H:1V slope.

Figure 35: Looking East Towards Proposed Road Alignment Through Valley (Alternatives 1&2)

5.2.3 Accessibility

The harbors in alternatives 1 and 2 are anticipated to accessible during the same conditions that a 58-foot ferry would be able to safely make the crossing through Akun Strait (Table 31). The approach to the entrance channel is open and not constrained by rock pinnacles.

Table 31: Operational Conditions Comparison

	58 Foot Ferry		
	Likely Operation Seas under 3 feet	**Possible Operation** Seas 3 to 5 feet	**Cease Operation** Seas 5+ feet
Alternatives 1 & 2	78%	85%	15%
Alternative 3	71%	77%	23%

5.2.4 Akutan Facilities

The facility upgrades on Akutan island will be the same for all three alternatives. At this time, it is assumed that the ferry vessel will moor in Akutan Harbor. Before each ferry trip, crew to pilot the vessel will board a skiff at the City Dock in Akutan and travel 2 miles to the ferry at Akutan Harbor. The vessel and crew will travel back to the City Dock where passengers and freight will board the vessel. The ferry will then travel to the proposed harbor on Akun and offload passengers and freight to meet a connecting flight on a fixed wing aircraft. The ferry will travel back to Akutan City Dock with any passenger and crew from Akun. Once all runs for the day are completed, the ferry will be moored at Akutan Harbor, and crew will take a skiff back to the Akutan City Dock.

Upgrades will need to be applied to the Akutan City Dock in order to accept the ferry vessel. At a minimum, the catwalk with mooring dolphins could be replaced to the appropriate elevation for easy boarding of the ferry vessel.

5.3 Alternative 2 (TSP)

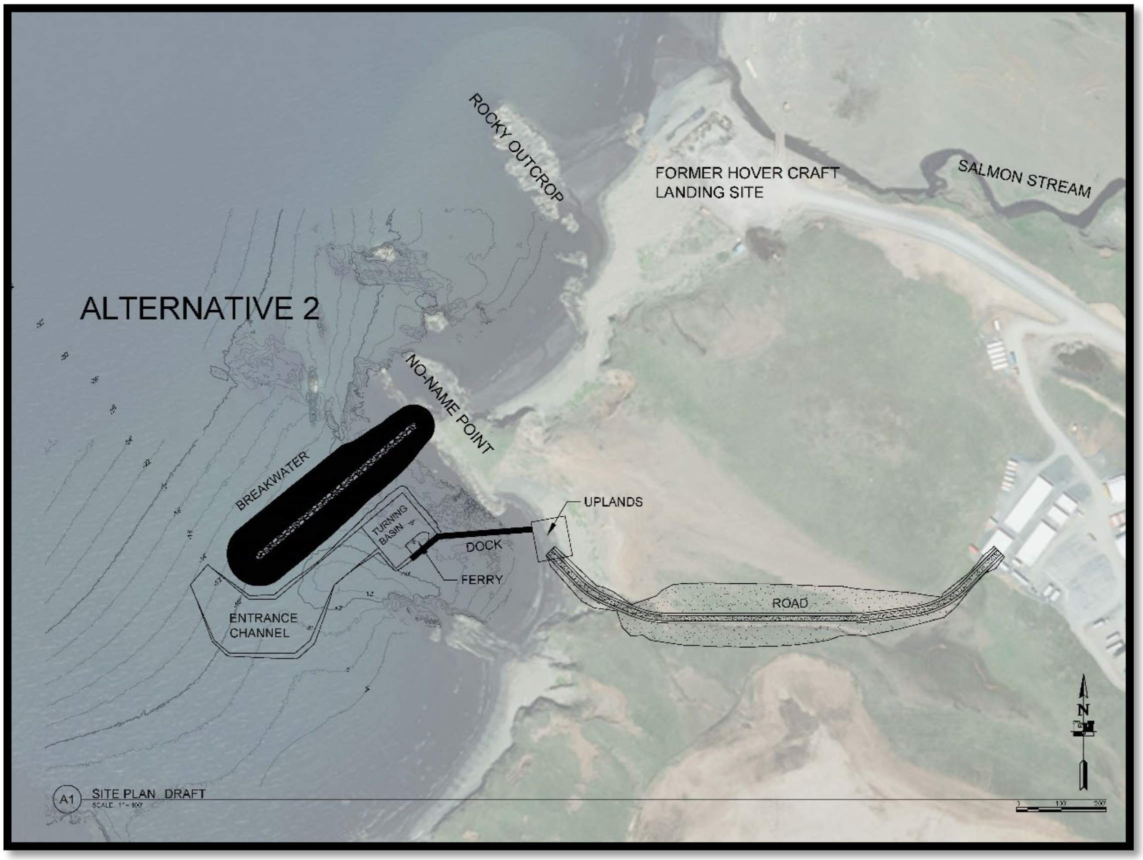


Figure 36: Alternative 2 Concept Plan

5.3.1 Harbor

The harbor would be sized to accommodate a design vessel with a length of 58 feet and a draft of 8 feet. The 450-foot-long rubble mound breakwater would protect a 120-foot by 120-foot turning basin. Both the entrance channel and turning basin would have a dredge depth of -13.0 feet. It is anticipated that blasting would be required for the turning basin or entrance channel in this location. The entrance channel would have a minimum width of 60 feet to a maximum width of 120 feet when turning around the nose of the breakwater.

Table 32: Alternative 2 Features

		Unit	Alternative 2	
			Presented in Report	*Updated Design*
Breakwater	**Armor Stone Weight**	(tons)	6	-
	Armor Stone Thickness	(feet)	9	-
	Crest Height	(feet MLLW)	17	-
	Crest Width	(feet)	15	-
	Length	(feet)	450	-
Entrance Channel	**Width Straight**	(feet)	60	-
	Width 40° Bend	(feet)	120	-
	Depth	(feet MLLW)	-13	-17
Turning Basin	**Width**	(feet)	120	-
	Length	(feet)	120	-
	Depth	(feet MLLW)	-13	-14
Quantities	**Armor Stone**	(cubic yards)	14,000	-
	Harbor Dreding	(cubic yards)	9,840	25,350
	Road Excavation	(cubic yards)	45,000	-

Alternative 2 attempts to optimize quantities of dredging for the entrance channel and turning basin by bringing them closer to shore than alternative 1. This also decreases both the length, height, and armor stone size required for the breakwater. Dock length also decreases as the mooring basin is located closer to shore. Road access is the same as alternative 1.

5.3.2 Local Service Facilities

Local service facilities required would include a 290 foot long by 12-foot-wide pile-supported dock, 60 foot by 40-foot mooring basin with mooring dolphins, uplands with an area of approximately 0.15 acres for loading/unloading freight from dock, and a 1,100 foot long by 12-foot-wide road connecting the harbor areas with the existing pad to the south of the hotel.

Alternatives 1 and 2 would share the same road alignment. The road would have an average grade of 8.5 percent and cut through the valley up to the pad containing Surf Bay Inn. The road consists of a 12-foot wide surface with 6 inches of aggregate surface over 2 feet of borrow material. Two shoulders are graded out 5 feet from the edge of road with a 2 horizontal on 1 vertical (2H:1V) slope, before sloping upward to existing ground at a 2H:1V slope.

5.3.3 Accessibility

The harbors in alternatives 1 and 2 are anticipated to accessible during the same conditions that a 58-foot ferry would be able to safely make the crossing through Akun Strait (Table 31). The approach to the entrance channel is open and not constrained by rock pinnacles.

Table 31: Operational Conditions Comparison

	58 Foot Ferry	
	Likely Operation	**Cease Operation**
	Seas under 3 feet	Seas 5+ feet
Alternatives 1 & 2	78%	15%
Alternative 3	71%	23%

5.4 Alternative 3

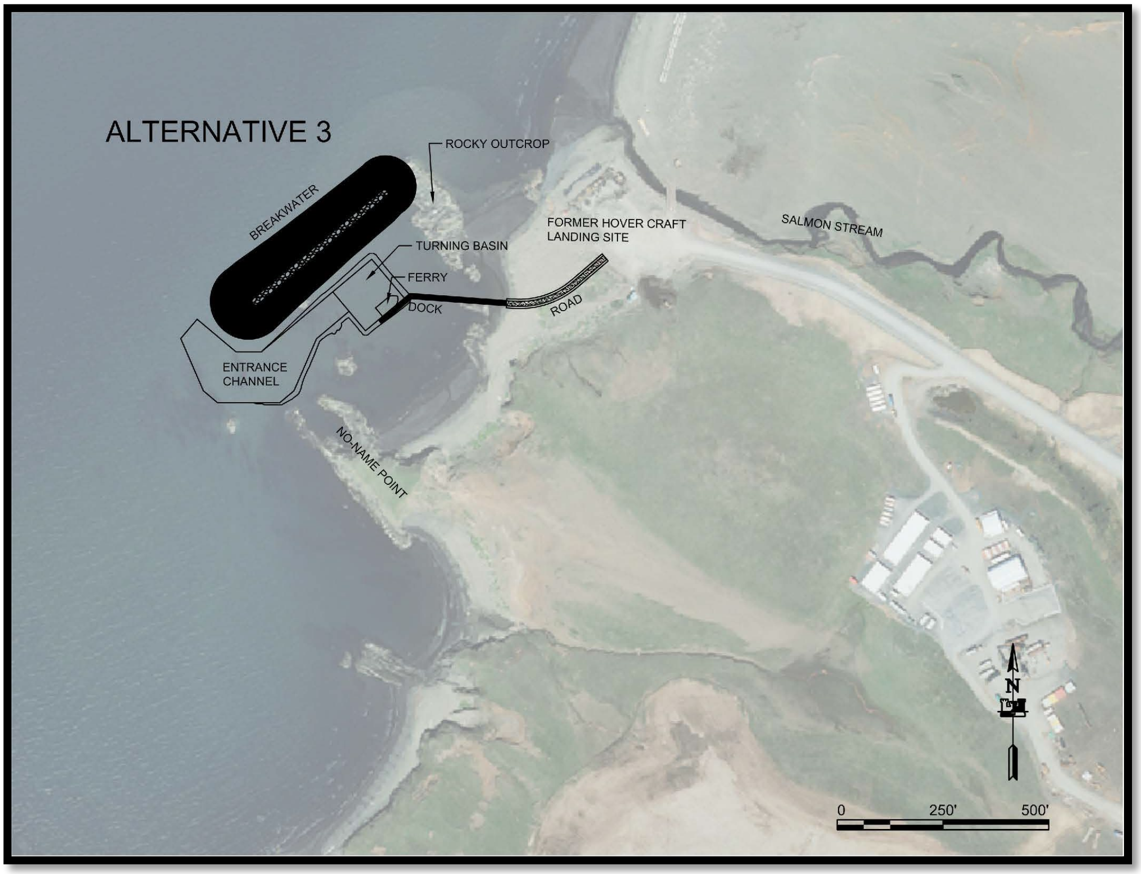


Figure 37: Alternative 3 Concept Plan

5.4.1 Harbor

The harbor would be sized to accommodate a design vessel with a length of 58 feet and a draft of 8 feet. The 400-foot-long rubble mound breakwater would protect a 120 foot by 120-foot turning basin. Both the entrance channel and turning basin would have a dredge depth of -13.0 feet. It is anticipated that blasting would be required for the turning basin or entrance channel in this location. The entrance channel would have a minimum width of 60 feet to a maximum width of 120 feet when turning around the nose of the breakwater.

Table 33: Alternative 3 Features

		Unit	Alternative 3	
			Presented in Report	*Updated Design*
Breakwater	**Armor Stone Weight**	(tons)	10	-
	Armor Stone Thickness	(feet)	11	-
	Crest Height	(feet MLLW)	19	-
	Crest Width	(feet)	17	-
	Length	(feet)	400	-
Entrance Channel	**Width Straight**	(feet)	60	-
	Width 40° Bend	(feet)	120	-
	Depth	(feet MLLW)	-13	-17
Turning Basin	**Width**	(feet)	120	-
	Length	(feet)	120	-
	Depth	(feet MLLW)	-13	-14
Quantities	**Armor Stone**	(cubic yards)	18,400	-
	Harbor Dreding	(cubic yards)	8,180	23,690
	Road Excavation	(cubic yards)	600	-

Alternative 3 explores the trade-off of locating the harbor closer to the existing road infrastructure of the former hover craft landing site verses a less optimal harbor location. This harbor location is anticipated to be less accessible than alternatives 1 and 2 due to the proximity of rocky outcrops. Additionally, this location is much closer to the salmon stream and has a much greater potential for disturbance of this resource as compared to the other alternatives.

Figure 38: Looking North From Un-Named Point Towards Rocky Outcrop (Alternative 3)

5.4.2 Local Service Facilities

Local service facilities required would include a 325 foot long by 12-foot-wide pile-supported dock, 60-foot by 40-foot mooring basin with mooring dolphins, uplands at the existing hovercraft pad for loading/ unloading freight from dock, and a 270 foot long by 12-foot-wide road connecting the existing hovercraft pad.

The shoreline along alternative 3 is flanked by narrow headlands of volcanic rock (Golder, 2022). This provides some natural protection but will make dredging difficult as the rock extends under the water surface throughout the area.

5.4.3 Accessibility

The harbor in alternative 3 is anticipated to less accessible than alternatives 1 and 2 (Table 31). The approach to the entrance channel is constrained by un-named point to the south and rock pinnacles to the west. It is anticipated that a 15 to 20 knot wind from the northwest (270°-360°) would present an unsafe condition for a ferry vessel in the approach channel for alternative 3.

Table 31: Operational Conditions Comparison

	58 Foot Ferry		
	Likely Operation Seas under 3 feet	**Possible Operation** Seas 3 to 5 feet	**Cease Operation** Seas 5+ feet
Alternatives 1 & 2	78%	85%	15%
Alternative 3	71%	77%	23%

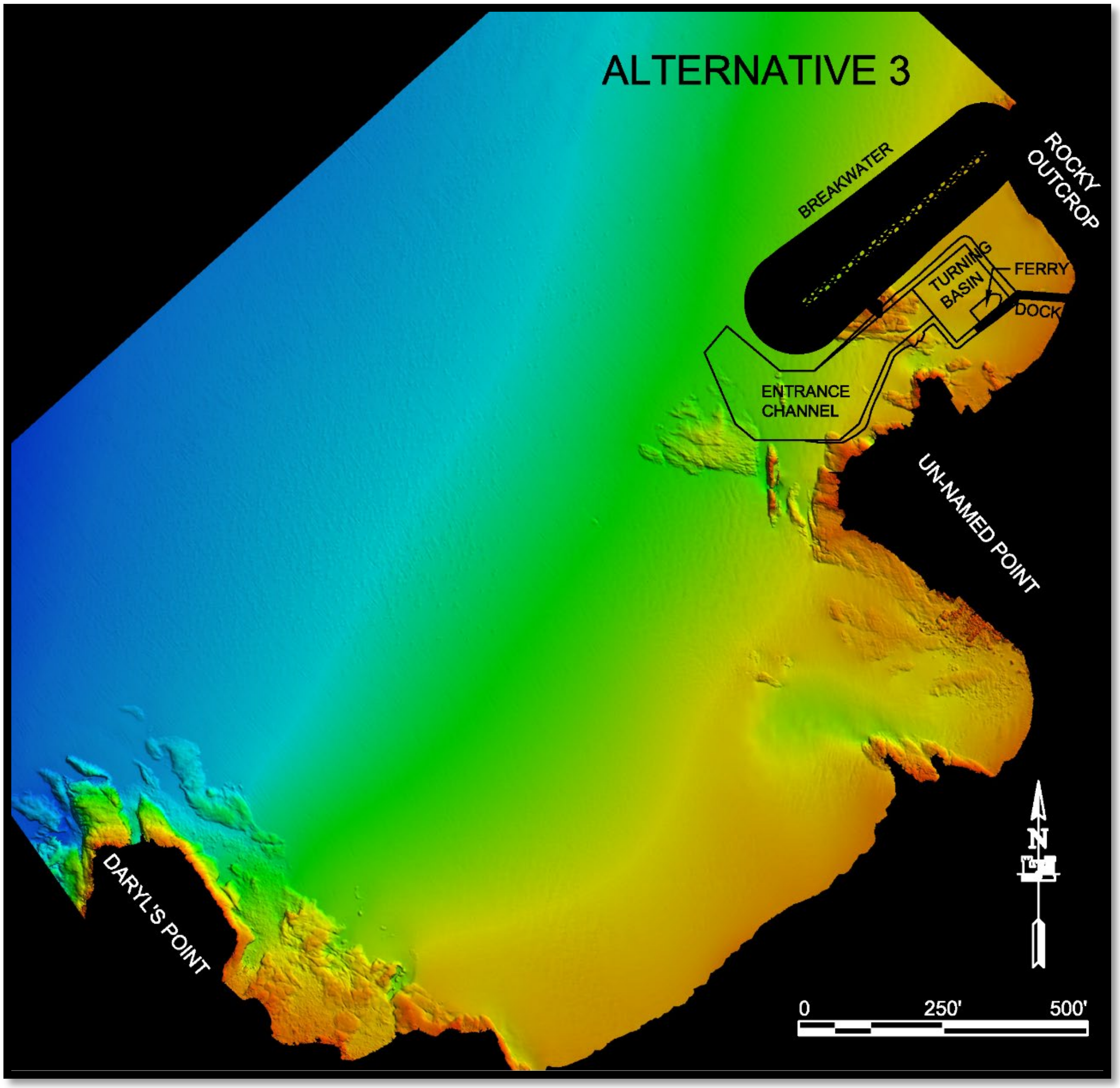


Figure 39: Alternative 3 Concept Plan – 2015 Stantec Survey

6.0 CHANNEL MAINTENANCE

The non-Federal operator of the harbor would be responsible for operation and maintenance of the completed mooring areas and local service facilities portion of the project. The Federal Government would be responsible for maintenance of the breakwaters, entrance channels and maneuvering basin portions of the project. The Alaska District, U.S. Army Corps of Engineers would visit the site(s) periodically to inspect the breakwaters and perform hydrographic surveys at 3- to 5-year intervals for the dredged areas. The hydrographic surveys would be used to verify whether the predicted maintenance dredging was warranted for the entrance channel and maneuvering areas. Maintenance requirements for breakwaters would be determined from the surveys and inspections. Local and Federal dredging requirements, if necessary, would probably be combined, so there would be only a single mobilization and demobilization cost.

The breakwaters were designed to be stable for the 2% AEP predicted wave conditions and no significant loss of stone from the rubblemound structures is expected over the life of the project. Stone quality is strictly specified in construction contracts to control stone degradation. However, it is anticipated that up to 5 percent of the armor stone could need to be replaced every 25 years. This results in an average of 2,000 cubic yards of Armor Rock required for replacement for the three alternatives at year 25.

Maintenance dredging would be conducted on an estimated 10-year cycle. The entrance channel and turning basin would require dredging of approximately 900 cubic yards. A dredged material management plan would be developed for the project in which a long-term disposal option would be identified. For purposes of this study, it is assumed that the entrance channel and maneuvering area material would be disposed of in the offshore. Clamshell bucket dredging equipment with a scow barge would likely be used for maintenance dredging. Dredged material characteristics should be easier to remove than construction dredging of the area and no blasting would be required for maintenance.

7.0 RISK AND UNCERTAINTY

7.1 Construction Considerations

The harbor construction is anticipated to take three years to complete. The type of dredge equipment used to perform the work will not be specified in the contract. It is anticipated that the bidders on the project will have experience blasting since it will likely be used in this project. To attract a number of bidders, it is recommended that the project be advertised early to interest dredging contractors in bidding on this project. In-water work will likely occur during the summer due to frequent winter storms. The work season length, remote site location, and wave climate are just some of the conditions that a contractor would need to consider when proposing on this contract.

7.2 Future Work to be Completed in PED

To more accurately determine the amount of blasting required for the selected plan, borings are required to ground-truth the geophysical investigation that was performed during the Feasibility Study and recalculate quantities if necessary.

A phase resolving numerical model would be required in PED in order to determine a more accurate design wave and wave conditions inside the harbor. It is not anticipated that a physical model will be necessary for the completion of PED.

7.3 Resiliency

ECB-2018-2 describes resilience principles to be implemented in the engineering and construction community of practice (USACE, Implementation of Resilience Principles in the Engineering & Construction Community of Practice, 2018). Wind, wave, and currents in and around Akun are not anticipated to change in the 50-year project life. The anticipated changing condition at the site is a relative sea level change of -0.92 feet MLLW. The breakwater stone is designed for this increased wave height, and the increased water depth would benefit underkeel clearances.

REFERENCES

"LICENCIAS", D. ". (2013). *"PIPER NAVAJO PA-31-310" "CC–AJB".* Dirección General de Aeronáutica Civil.

Akinturk, A., Cumming, D., & Bass, D. (2007). *Mapping motion responses for the Newfoundland fishing fleet.* St. John's: NRC Publications Archive.

Center, W. R. (2023). *Cold Bay, Alaska*. Retrieved from Western Regional Climate Center: https://wrcc.dri.edu/cgi-bin/clilcd.pl?ak25624

Center, W. R. (2023). *DUTCH HARBOR, ALASKA (502587)*. Retrieved from Western Regional Climate Center: https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?ak2587

Drewes, H., Fraser, G. D., Snyder, G. L., & Barnett Jr., H. F. (1961). *Geology of Unalaska Island and Adjacenet Insular Shelf, Aleutian Islands, Alaska.* Washington D.C.: U.S. Department of the Interior.

Eling, D. (2023). *Ferry Notional Sizing, Acquisition Cost, and Recurring Annual Costs Estimates.* Bristol: Bristol Harbor Group.

Golder. (2022). *Geophyiscal Survey Report Akutan Harbor Navigation Improvements.* Golder Associates USA Inc.

Hesser, D. T. (2018). Wave Information Studies. Vicksburg, MS, USA.

Jensen, R. (2022). *Akun-Akutan Island Study: Wind and Wave Estimates used for Ferry Operation and Planning Desing of New Harbor on Akun Island.* CEERD-HFC.

Miller, D. L., Phillips, W. T., & Wilson, S. Y. (2005). *Geotechnical Exploration Akutan Airport Master Plan.* Anchorage: Duane Miller & Associates.

NAVFAC. (2013). *Preliminary Assessment Report for Naval Defense Sea Area: Unalaska Island.* Silverdale: Naval Facilities Engineering Command Northwest.

NOAA. (2023, 06 13). *Tides & Currents*. Retrieved from Annual Exceedance Probability Curves 9462620 Unalaska, AK: https://tidesandcurrents.noaa.gov/est/curves.shtml?stnid=9462620

NWS, N. W. (2023). *Beaufort Scale*. Retrieved from Estimating Wind Speed and Sea State: https://www.weather.gov/pqr/beaufort

Pan, F. a. (1999). Gap Winds and Wakes: SAR Observations and Numerical Simulations. *J. Atm. Sciences*, pp. Vol. 56, No. 7, 905-923.

Peterson, M. (2003). *Hydraulic Design: Navigation Improvements Akutan, Alaska.* Anchorage: USACE.

PIANC. (2014). *Harbour Approach Channels Design Guidelines.* Brussels: The World Association for Waterborne Transport Infrastructure.

Sepez, J., Package, C., Malcolm, P. E., & Poole, A. (2007, December 20). Unalaska, Alaska: Memory and Denial in the Globalization of the Aleutian Landscape. *Polar Geography*, pp. 193-209.

Survey, U. C. (2017, September 26). *Historical Map & Chart Collection*. Retrieved from https://historicalcharts.noaa.gov/historicals/preview/image/9008-9-1937

United States Army Corps of Engineers. (2002, April 30). Coastal Engineering Manual. *(EM 1110-2-1100)*. Department of Army.

USACE. (2008). *Coastal Engineering Manual.* Washington, DC: EM 1110-2-1100.

USACE. (2018). *Implementation of Resilience Principles in the Engineering & Construction Community of Practice.* ECB-2018-02.

Van der Meer, J. W. (2018). *Manual on wave overtopping of sea defenses and related structures. An overtopping manual largely based on European research, but for worldwide application.* EurOtop.

Wendler, G. C. (2014, August). Recent Sea Ice Increase and Temperature Decrease in the Bering Sea Area, Alaska. *Theoretical and Applied Climatology*, pp. 393-398.

Zautner, J. (2017). *Extreme Value Analysis.* 14th Weather Squadron.