FAA. 2022. AC 150/5300-13B – Airport Design. February 14, 2023. Accessed November 3, 2023 at: https://www.faa.gov/documentLibrary/media/Advisory_Circular/150-5300-13B-Airport-Design.pdf

FAA. 2023a. Alaska Aviation Weather Cameras: Scammon Bay. Accessed November 3, 2023, at https://weathercams.faa.gov/

FAA. 2023b. Terminal Area Forecast (TAF). Accessed November 3, 2023, at https://taf.faa.gov/

Federal Emergency Management Agency (FEMA). 2023. Declared Disasters. Alaska. Accessed December 27, 2023, at https://www.fema.gov/locations/alaska

Flagstad, L., M. A. Steer, T. Boucher, M. Aisu, and P. Lema. 2018. Wetlands across Alaska: Statewide wetland map and assessment of rare wetland ecosystems. Alaska Natural Heritage Program, Alaska Center for Conservation Science, University of Alaska Anchorage. 151 pages. Accessed November 1, 2023 from https://accscatalog.uaa.alaska.edu/dataset/alaska-vegetation-and-wetland-composite

Giefer, J., and S. Graziano. 2023. Catalog of waters important for spawning, rearing, or migration of anadromous fishes – Interior Region, effective June 15, 2023, Alaska Department of Fish and Game, Special Publication No. 23-02, Anchorage.

HDR. 2022a. Coastal Report - Scammon Bay Airport Improvements Feasibility Study. Prepared for the Alaska Department of Transportation and Public Facilities, Central Region.

HDR. 2022b. Hydrology and Hydraulics Report - Scammon Bay Airport Improvements Feasibility Study. Prepared for the Alaska Department of Transportation and Public Facilities, Central Region.

Huntington, H.P., M. Nelson, L.T. Quakenbush. 2017. Traditional knowledge regarding marine mammals near Scammon Bay, Alaska. Final report to the Eskimo Walrus Commission, the Ice Seal Committee, and the Bureau of Ocean Energy Management for contract #M13PC00015. 10pp Accessed November 1, 2023, at https://www.adfg.alaska.gov/static/research/programs/marinemammals/pdfs/boem_2019_79_M13PC00015_ice_seal_tracking_appendices.pdf

National Marine Fisheries Service (NMFS). 2023. Alaska Endangered Species and Critical Habitat Mapper Web Application. Accessed on November 3, 2023, at https://www.fisheries.noaa.gov/resource/data/alaska-endangered-species-and-critical-habitat-mapper-web-application

National Oceanic and Atmospheric Administration (NOAA). 2023. Storm Events Database. Accessed on October 23, 2023, at https://www.ncdc.noaa.gov/stormevents/textsearch.jsp?q=Scammon+Bay+Flood

U.S. Bureau of Transportation Statistics (USBTS). 2023. T-100 Domestic Market Data. Accessed on November 3, 2023, at https://www.transtats.bts.gov/

U.S. Fish and Wildlife Service (USFWS). 2023. IPaC Information for Planning and Consultation. Accessed November 3, 2023, at https://ipac.ecosphere.fws.gov/.

APPENDIX C: COASTAL REPORT – SCAMMON BAY AIRPORT IMPROVEMENTS FEASIBILITY STUDY (HDR 2022A)

Coastal Report – Scammon Bay Airport Improvements Feasibility Study

Project Number: CFAPT00691
AIP: 3-02-0255-003-2023

Alaska Department of Transportation and Public Facilities, Central Region

Scammon Bay, Alaska

December 19, 2022

Prepared by:
HDR

STATE OF ALASKA
49TH
DONALD L. MCPHERSON
No. CE 13591
PROFESSIONAL ENGINEER
12-19-2022

This page intentionally left blank.

Contents

Tables

Figures

Acronyms and Abbreviations

AEP	Annual Exceedance Probability
ASOS	Automated Surface Observing System
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute
DMVA	Department of Military and Veterans' Affairs
DOT&PF	State of Alaska Department of Transportation and Public Facilities
FEMA	Federal Emergency Management Agency
H&H	Hydrology and Hydraulic
HD FM	Hydrodynamic Flexible Mesh
ft	feet
IfSAR	Interferometric Synthetic Aperture Radar
in	inches
LiDAR	Light Detection and Ranging
m	meter
mm	millimeter
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
RSLR	relative sea-level rise
s	second
SCM	Scammon Bay State Airport (International Air Transport Association's airport code)
SW	Spectral Wave
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

This page was intentionally left blank.

1. Introduction

1.1 Project Overview

This Coastal Report is prepared for the State of Alaska Department of Transportation and Public Facilities (DOT&PF) Central Region as part of a larger feasibility study to assess improvements to the airport at Scammon Bay (project).

The project is at the Scammon Bay State Airport (SCM), which is a state-owned, public use airport. The airport consists of one runway and one seaplane landing area. The DOT&PF proposes various airport improvements to enhance safety, improve infrastructure, and bring the airport to Federal Aviation Administration standards. These improvements consist primarily of repairing elements that have been damaged by flooding or have otherwise deteriorated, including:

- Increasing the elevation of the runway, taxiway, apron, and access road
- Shifting the runway away from the Kun River
- Replacing the culvert under the runway
- Placing erosion protection adjacent to the Kun River and airport embankments
- Making various building and aviation-specific additions and replacements
- Obtaining additional right-of-way

1.2 Scope of Coastal Analyses

The project involves providing coastal engineering and hydrology and hydraulic (H&H) recommendations to guide a larger feasibility study regarding the various airport improvements to better protect SCM from flooding and scour. Recommended improvements to the airport specific to coastal engineering are detailed within this report. Details on H&H analysis to support this project are provided under separate cover (HDR, 2022).

The coastal analyses for this project include a review of readily available background information, site visit performed in May 2021, storm surge analysis, and wind wave analysis. Details of these analyses are discussed herein.

1.3 Organization of Report

This report is organized as follows:

- Section 2 discusses existing general conditions.
- Section 3 discusses data used in coastal analysis.
- Section 4 discusses the design criteria.
- Section 5 discusses the coastal analysis.

- Section 6 presents the coastal engineering design recommendations.
- Section 7 presents the summary.
- Section 8 presents the references cited.

All elevations provided are based on the North American Vertical Datum of 1988 (NAVD88) unless otherwise specified.

2. General Conditions

2.1 General Physical Characteristics

The project site is located in the community of Scammon Bay in the Kusilvak Census Area, in Western Alaska. Scammon Bay has a population of 594 (U.S. Census Bureau 2020) and covers 299 acres (see Figure 1). The airport is located at the northeast edge of the community. The Scammon Bay community sits at the meeting point of the base of the Askimuk mountain range and flat, intertidal wetlands. Wetlands, ponds, and connecting streams dominate the area to the north and east.

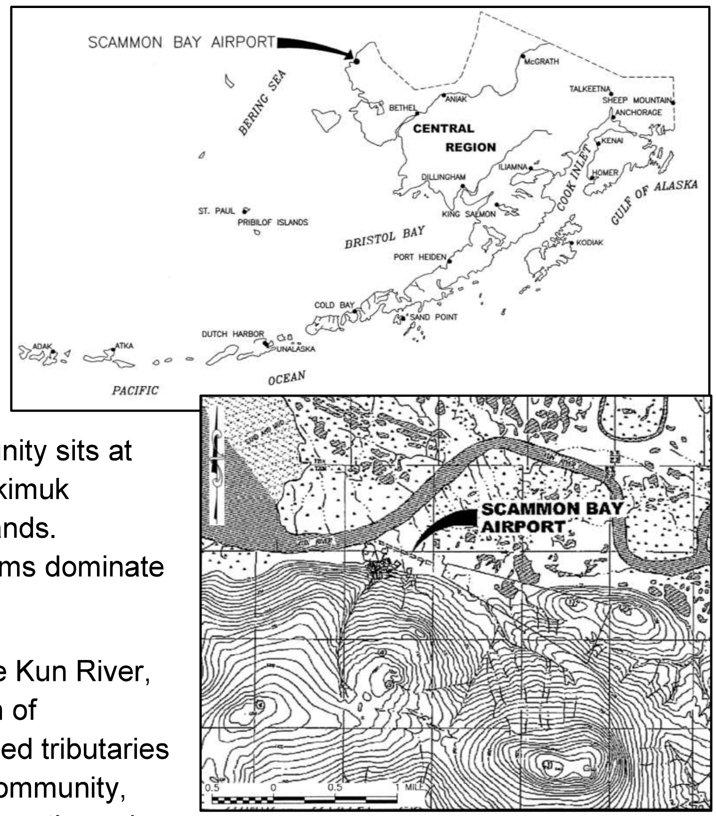


Figure 1: Location and Vicinity Map

Recreated from DOT&PF 2004 and 2013

The airport sits on the south bank of the Kun River, a perennial stream with a bankfull width of approximately 900 feet. Several unnamed tributaries of the Kun River are located near the community, one of which flows underneath the runway through a singular culvert. Tidal influence is evident in the tributary by the nearly vertical stream banks that are 2–3 feet in depth. The tributary's confluence is located approximately 2 miles from the mouth of the Kun River.

2.1.1 Runway 10/28 and Seaplane Landing Area 4W/22W

The airport consists of one Type A, gravel runway designated as 10/28, and one seaplane landing area designated as 4W/22W. The runway is located at the northeast edge of the community, sits at an elevation between +10 and +17.5 feet NAVD88, and runs northwest to southeast at a +0.19 percent slope. It is encompassed by intertidal wetlands with the unnamed perennial stream that runs through a culvert under the runway from south to north. One access road connects the runway to the community. The seaplane landing area is located at the northwest edge of the community.

2.1.2 Runway Culvert

The existing structure is a 48-inch-diameter, 405-foot-long, smooth interior wall, corrugated, high-density polyethylene culvert that runs under the runway. It was installed with a 0.1 percent slope, with an inlet invert elevation of +4.0 feet NAVD88 and an outlet invert elevation of +3.6 feet NAVD88. Additional information on the condition of the existing culvert can be found in the accompanying *Hydrology and Hydraulics Report* (HDR, 2022).

3. Data Used for Coastal Analysis

3.1 Metocean Data

Meteorological and oceanic (metocean) data were gathered from readily available sources. For data not available at Scammon Bay, data from the nearest reasonable location were used. The following provides details on metocean data used for the coastal analysis.

3.1.1 Water Level

Tidal datum information from the National Oceanic and Atmospheric Administration (NOAA) is available for the Kun River near Scammon Bay (Station 9467124) and is shown in Table 1. This information comes from a historical short-term tide station that collected water level data from July 24, 2020, to October 22, 2020 (approximately 3 months).

Table 1: Kun River Tidal Datums (NOAA Station ID: 9467124)

Datum	Elevation (feet from MLLW)	Elevation (feet, based on NAVD88)
Mean Higher High Water (MHHW)	6.47	6.77
Mean High Water (MHW)	5.70	6.00
Mean Tide Level (MTL)	3.29	3.59
Mean Sea Level (MSL)	3.20	3.50
Mean Low Water (MLW)	0.88	1.18
Mean Lower Low Water (MLLW)	0	0.30
NAVD88	-0.30	0

Source: NOAA 2021c
Notes: NAVD88 = North American Vertical Datum of 1988.

Long-term water level data for Scammon Bay are not available; thus, review/prediction of relative sea-level rise (RSLR) over time is not possible near the project site. The nearest location to Scammon Bay with a long-term water level dataset is Nome, Alaska, approximately 180 miles to the north. The Nome tide station has measured RSLR at a rate of 0.15 inch per year with a confidence interval of +/- 0.11 inch per year (3.89 millimeter [mm]/year with a 95 percent confidence interval of +/- 2.88 mm/year). Figure 2 shows the long-term trend plot developed by NOAA (NOAA 2021d). Assuming a similar RSLR at Scammon Bay, the increase in sea level over a 50-year period would be 0.64 feet.

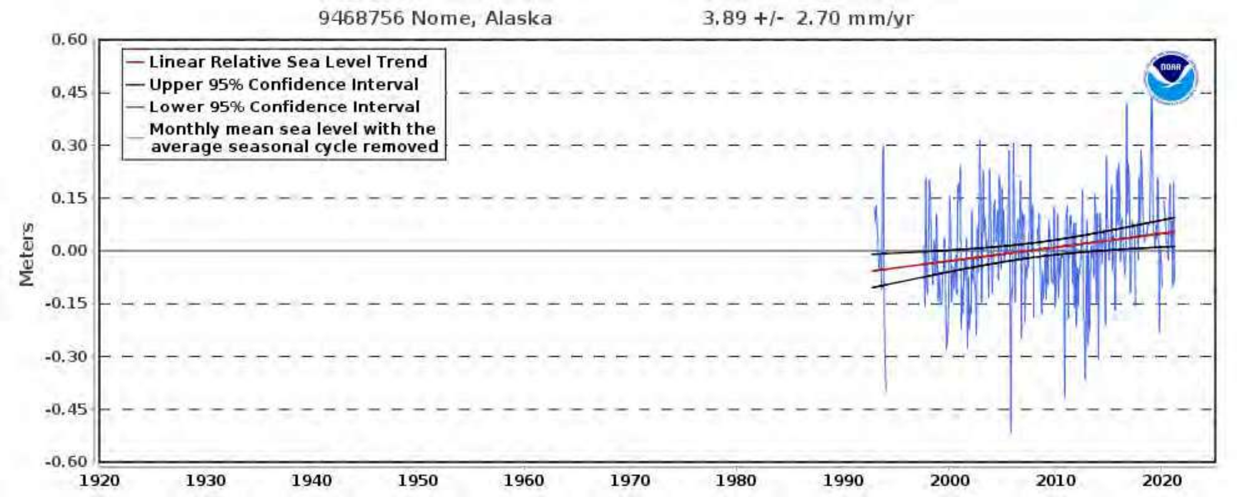


Figure 2: Relative Sea-Level Rise at Nome, AK

Source: NOAA 2021d

Statistical storm surge water level predictions in western Alaska were developed by the U.S. Army Corps of Engineers (USACE) in *Storm-Induced Water Level Prediction Study for the Western Coast of Alaska* (USACE 2009). The study provides statistical storm surge water levels at 17 locations in Western Alaska. The two nearest locations to Scammon Bay for statistical storm surge elevations are Agcklarok, Alaska, and Hooper Bay, Alaska, approximately 50 miles northeast and 30 miles southwest of Scammon Bay, respectively (Figure 3). Storm surge predictions for Agcklarok and Hooper Bay are shown in Table 2.

Table 2: Probabilistic Storm Surge Elevations for Agcklarok, AK, and Hooper Bay, AK

Return Period (years)	Agcklarok Surge Level (feet)	Hooper Bay Surge Level (feet)
5	4.8	6.5
10	6.7	8.1
15	7.4	8.4
20	7.8	8.6
25	8.3	8.8
50	10.1	10.0
100	12.1	11.5

Note: Storm surge elevations are reported independent of tidal influence.
Source:USACE 2009

Figure 3: Statistical Storm Surge Data Source Locations

3.1.2 Wind

Historic wind direction and speed information starting in 2010 at the project site is available via the Scammon Bay Automated Surface Observing System (ASOS). ASOS wind observations are reported as 2-minute averages. These durations were converted to 1-hour averaged wind speeds for wind-generated wave simulations (see Section 5.2). An extreme value analysis using these data was performed to determine statistical wind speeds and associated wind directions at Scammon Bay. An example of the statistical wind speed that includes data for "all directions" is shown on Figure 4. The wind direction data were binned to the nearest 10 degrees. The 1-hour wind speed duration was chosen based on the large fetch that would occur during a flooding event in which the surrounding flats are considered open water.

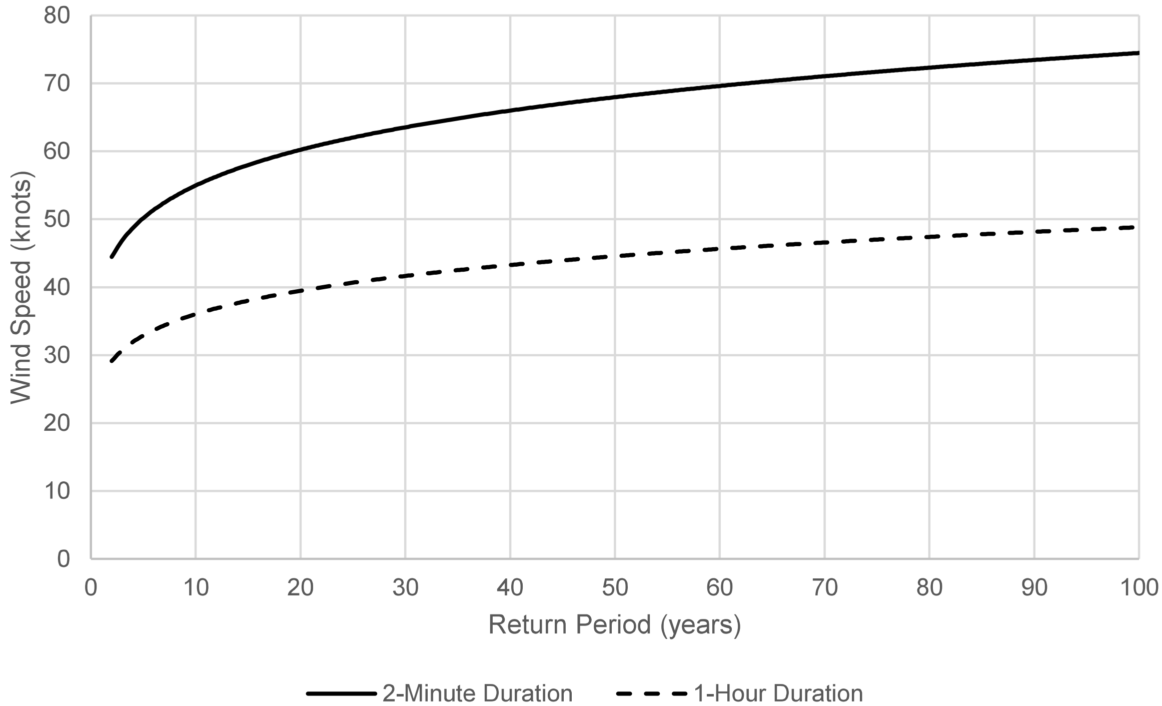


Figure 4: Statistical Wind Speeds for All Directions at Scammon Bay

3.1.3 Waves

Wave data are not available for Scammon Bay during a flooding event. Therefore, wave conditions were determined using MIKE 21 Spectral Wave (SW) software, a two-dimensional depth-averaged spectral wave numerical model. The model simulates wind-generated wave conditions at the project site. Additional wave information based on model results is presented in Section 5.2.

3.1.4 Sea Ice

Historic data from the University of Alaska Fairbanks indicate that Scammon Bay (coastal water body) typically contains at least 80 percent sea ice in January, February, and March, and contains variable levels of sea ice during all other months excluding August, September, and October (UAF 2021).

3.2 Elevation Data

3.2.1 Topography

The topographic data in the form of Digital Elevation Models (DEMs) were obtained using a combination of readily available Interferometric Synthetic Aperture Radar (IfSAR) data (USGS 2019) and Light Detection and Ranging (LiDAR) data (State of Alaska Division of Geological & Geophysical Surveys 2021).

3.2.2 Bathymetry

Bathymetric information in the offshore area to the west of Scammon Bay was gathered from NOAA National Geodetic Data Center datasets (NOAA 2021a) and NOAA Navigation Chart

16240 (NOAA 2021b). The chart reported depths in feet below mean lower low water. These data were then converted to NAVD88 using the relationship provided in Table 1.

Readily available bathymetric data for the Kun River or its tributaries were not found. Therefore, elevation data for the Kun River and three of its unnamed tributaries were estimated using a combination of channel width, estimated bankfull discharge, bathymetric maps of the Yukon River for comparison, and engineering judgement.

4. Design Criteria

Design criteria for coastal recommendations utilize a 50-year return period (2 percent annual exceedance probability [AEP]) for water level (for both concurrent and non-coastal conditions) and 100-year return period (1 percent AEP) for wind-generated waves. Design life duration is assumed to be 50 years.

5. Coastal Analysis

A coastal analysis was performed that consisted primarily of developing a storm surge numerical model and a wave numerical model. The purpose of these models was to better understand potential storm surges and wave conditions that affect the design of runway elevation and erosion mitigation.

5.1 Storm Surge Analysis

A storm surge analysis was performed to approximate potential water surface elevations and current speed/direction at the SCM due to an extreme flood event. The analysis was performed using the MIKE 21 Hydrodynamic Flexible Mesh (HD FM) numerical model. The model was developed to simulate a 50-year (2 percent AEP) and 100-year (1 percent AEP) representative storm surge events.

5.1.1 Storm Surge Model Description

MIKE 21 HD FM, developed by the Danish Hydraulic Institute (DHI), is software used for developing two-dimensional hydrodynamic models based on a flexible (unstructured) mesh. Models developed with MIKE 21 HD FM simulate water level variations and flows in coastal areas, estuaries, and floodplains (DHI 2017a). The flexible mesh module allows for higher-resolution elements at locations requiring better resolution of the hydrodynamics (e.g., near the project site and nearby flow paths).

5.1.2 Model Domain and Mesh

The model domain for the MIKE 21 HD FM storm surge simulations includes offshore, upland (which contains the project site), and backland areas. The offshore area applies coastal surge elevations that subsequently flow through the entire model domain. The backlands area is intended to provide added area/volume for surge inundation to flow to avoid unrealistic boundary effects impacting the project site (i.e., acts as a hydraulic storage area).

The mesh contains 50,524 elements and 27,385 nodes. The backlands area has a relaxed mesh resolution to improve model computation efficiency. The offshore and uplands areas have finer resolution with elements decreasing in size along flow paths and near the project site. Bed resistance information in the form of Manning's M values (reciprocal of Manning's n) were applied to the domain. A Manning's M value of 32 meter$^{1/3}$/second was assigned to the offshore area and a Manning's M value of 20 meter$^{1/3}$/second was assigned to the upland and backland areas.

Primary sources of elevation data used to create the mesh are summarized in Table 3.

Table 3: Elevation Data Summary

Data Source	Source Datum and Units	Model Location
IfSAR, Y-K Delta 2016 LiDAR Scammon 2015 elevation data	Horizontal: UTM Zone 3, meters Vertical: NAVD88, meters	Project area
Alaska Yukon Delta Base Order 2018 D18 Digital Elevation Model	Horizontal: Alaska Albers, meters Vertical: NAVD88, meters	All other upland and backland areas
NOAA Navigation Chart 16240	Horizontal: WGS 1984, degrees Vertical: Depth at MLLW, feet	Offshore area

Note: The horizontal and vertical datums used for the project are UTM Zone 3, Meters and NAVD88, Meters respectively. Source datum/units were converted to these project datums. IfSAR = Interferometric Synthetic Aperture Radar, Y-K Delta = Yukon-Kuskokwim Delta, LiDAR = Light Detection and Ranging, UTM = Universal Transverse Mercator, NAVD88 = North American Vertical Datum of 1988, NOAA = National Oceanic and Atmospheric Administration, WGS = World Geodetic System, MLLW = mean lower low water.

Figure 5 provides a view of the entire model domain. The colors represent bathymetry/topography elevations. Figure 6 and Figure 7 provide enlarged views of the mesh showing the finer resolution for the project site and flow paths.

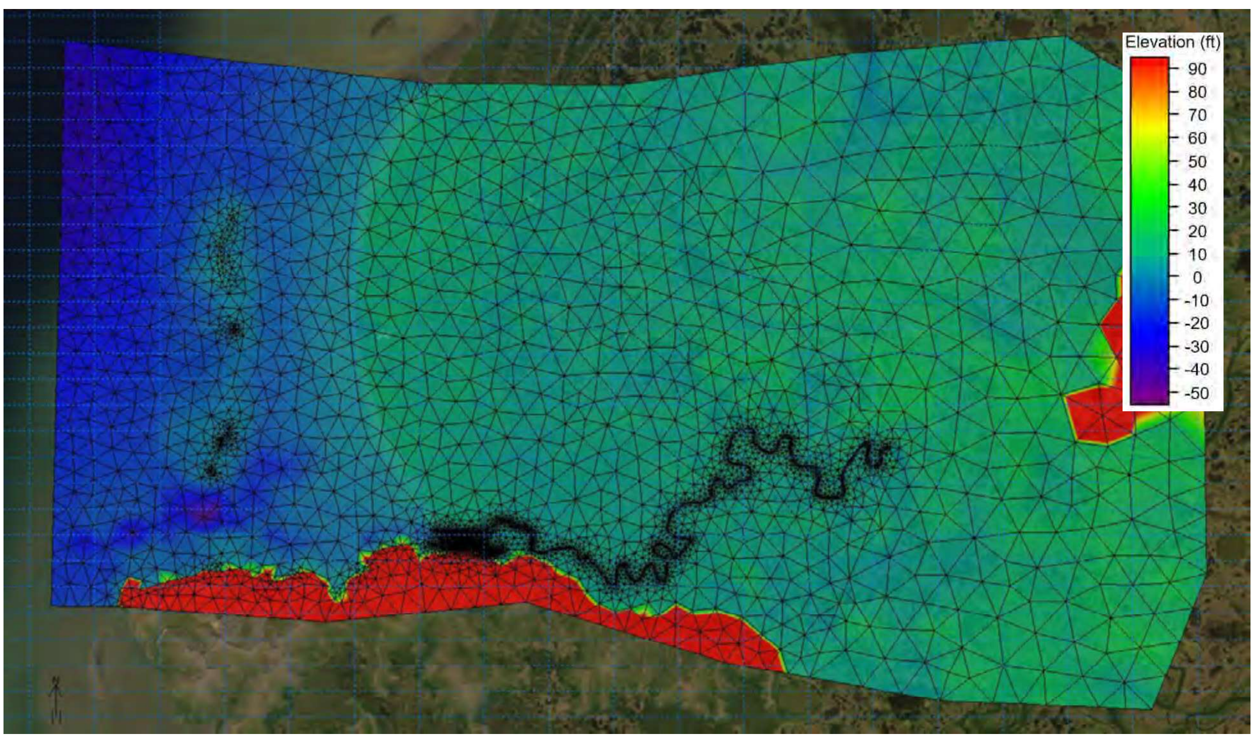


Figure 5: MIKE 21 HD FM Storm Surge Model Mesh - Full Domain

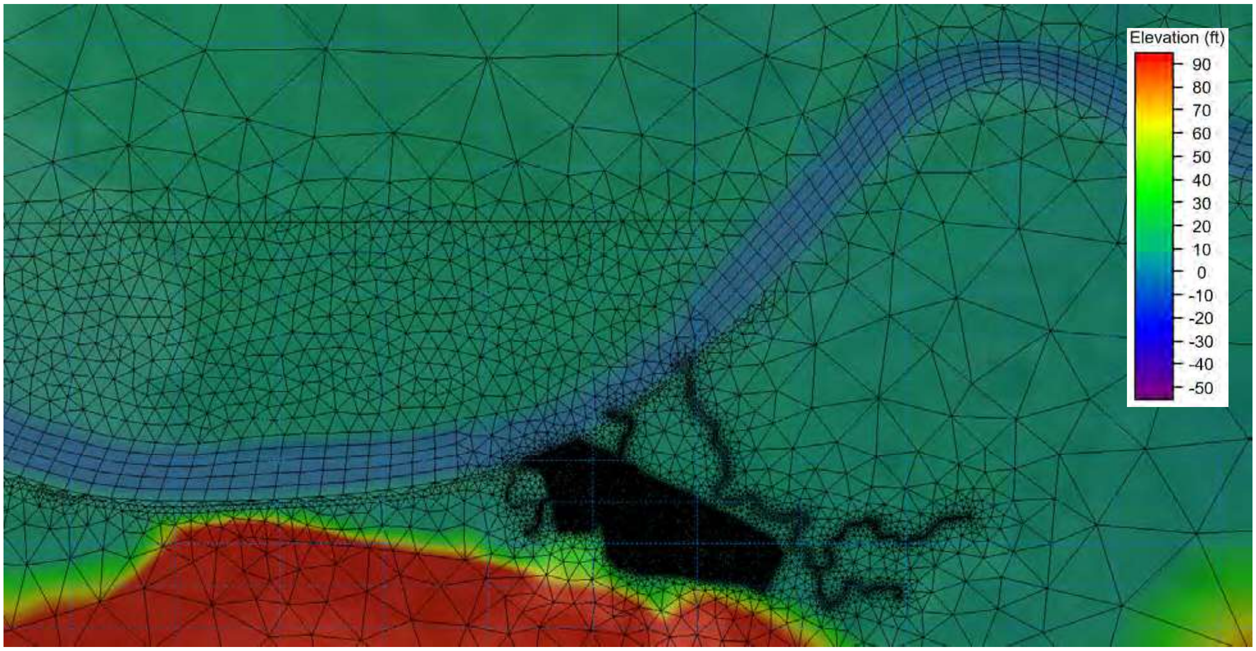


Figure 6: MIKE 21 HD FM Storm Surge Model Mesh - Enlarged View Showing the Kun River and Scammon Bay

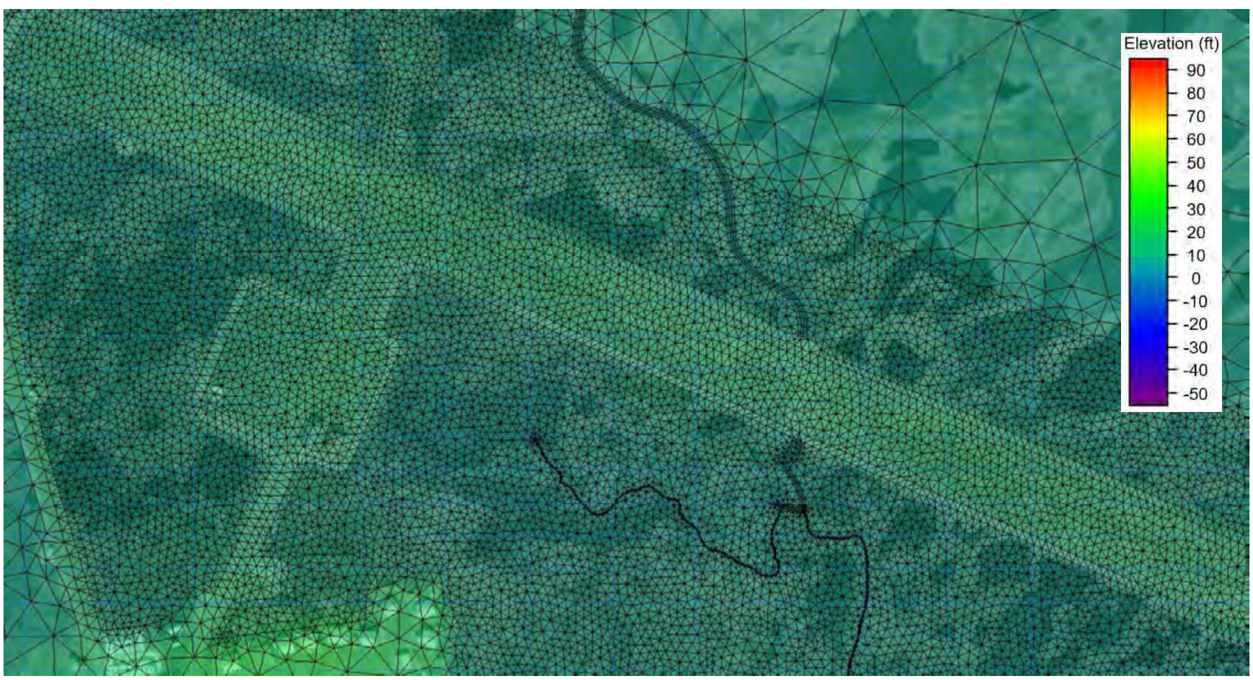


Figure 7: MIKE 21 HD FM Storm Surge Model Mesh - Enlarged View Showing Project Area

5.1.3 Storm Surge Model Boundary Conditions

The storm surge model was forced using both a storm surge hydrograph that was applied to the offshore boundary as well as a flow rate for the Kun River applied upstream of the runway. The storm surge hydrograph combined typical tides, anticipated RSLR, and a statistical storm surge in which the peak surge occurs at a high tide.

Statistical Storm Surge Development: Historic storm surge events identified by USACE (2009) in Nome were evaluated for shape, duration, and season of occurrence. Several events identified by USACE took place during the month of February. These storm surges were not included in the analysis, as sea ice is understood to dampen the effects of coastal storm surges (Barnhart et al. 2014).

All surges were analyzed independent of tidal influence. A representative storm surge unit hydrographic was developed that combined the fast rise of a storm surge observed with the fastest fall (receding water level) of a storm surge observed and maintained a peak level duration of a typical storm surge for Western Alaska. The intent of combining the fastest storm surge rise and fall was to simulate the higher end of current speeds near the runway during a flood event both as the storm surge enters and as it recedes. The unit storm surge hydrograph was scaled using the USACE (2009) 50- and 100-year storm surge heights for the Agcklarok location (see Section 3.1.1). Surge heights from the Agcklarok location were applied in lieu of the Hopper Bay location, as they were found to be more conservative.

Typical Tides: Typical tide data were gathered from NOAA Station 9467124 Kun River (NOAA 2021e). Based on review of Western Alaska storm surge occurrences as well as local anecdotal data, the fall season (September, October, and November) was found to be the most likely time of year for storm surge occurrence. Thus, the typical tide used for the boundary condition utilizes the NOAA tidal predictions during this period. Figure 8 shows the predicted tides for the fall 2021 at the Kun River NOAA station. The highest seasonal tide during this period was identified and used in the storm surge hydrograph.

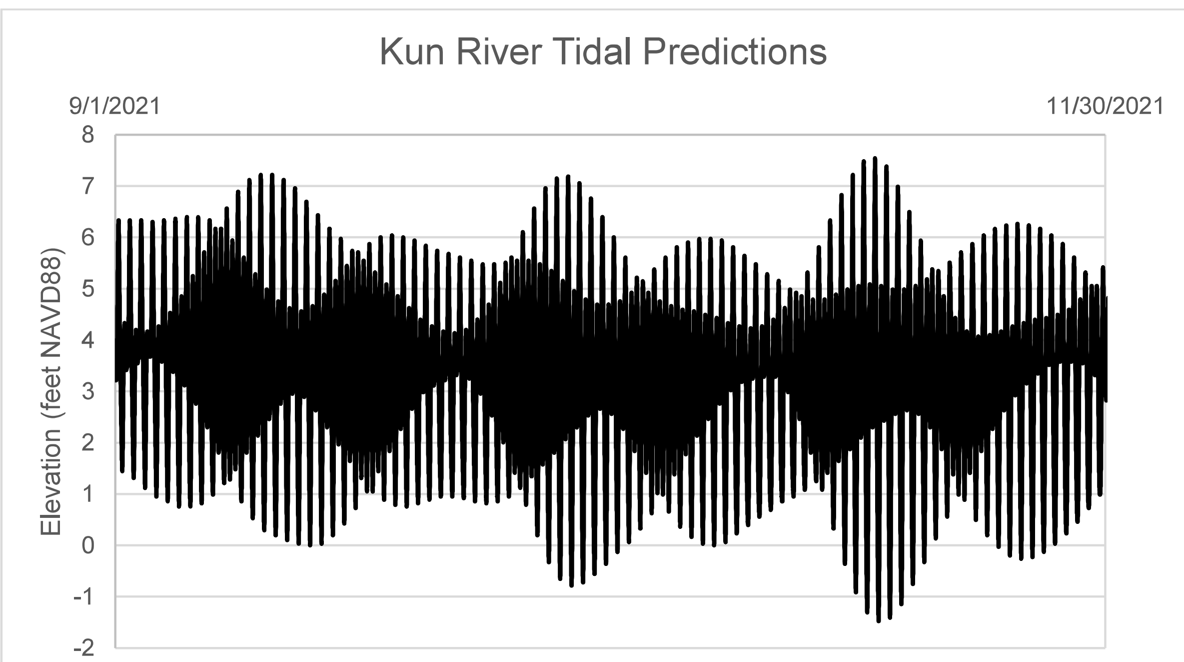


Figure 8: Kun River Tidal Prediction - Fall 2021

Combined Storm Surge Hydrograph: The representative storm surge was superimposed over the tidal predictions such that the peak of the surge coincided with the largest predicted tide.

The surge was set to begin following 2 days of normal tide to allow the model to ramp up and establish typical hydrodynamic conditions prior to the introduction of a storm surge. To account for RSLR, the storm surge hydrograph was increased by 0.64 foot representing potential sea level rise increase over a 50-year project duration. Figure 9 shows the design 100-year return period coastal surge with the typical tide and isolated surge components. All water level information was applied to the domain's western boundary in the offshore area (see Section 5.1.2).

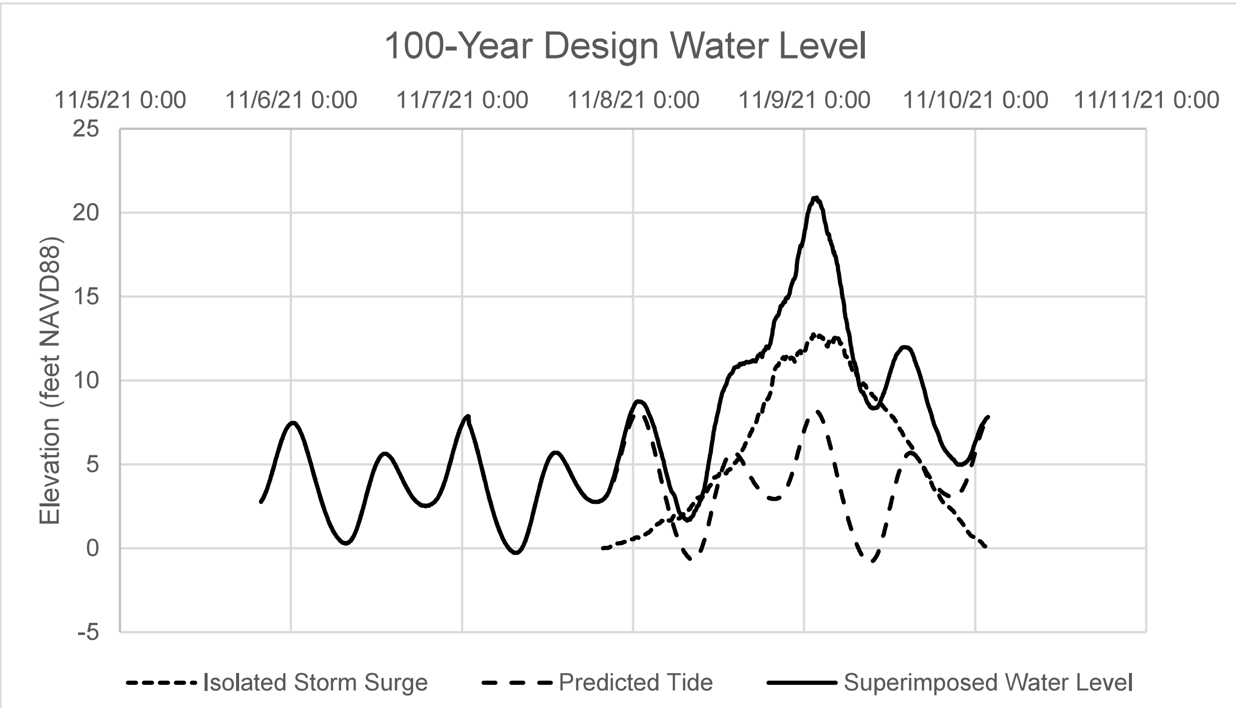


Figure 9: 100-year Return Period Storm Surge Hydrograph with Predicted Tide and Isolated Representative Surge Components

<u>*Kun River:*</u> Flow from the Kun River was included along the model boundary approximately 45 miles upstream of the runway terminal. The storm surge models assumed that the Kun River was flowing at base flow (40 percent bankfull flow). A sensitivity check comparing flood elevations at SCM during the 2 percent AEP storm surge with base flow with the concurrent 2 percent AEP storm surge and 2 percent AEP extreme runoff event as well as the 2 percent AEP runoff event with no storm surge, was performed. Design discharges for the Kun River are in Appendix B of the in the accompanying *Hydrology and Hydraulics Report* (HDR, 2022). Results of this sensitivity check showed that the additional discharge from the Kun River had a minimal effect on modeling results. The concurrent surge/riverine flood event raised water surface elevations by 0.003 feet at its peak, and the riverine event with no storm surge yielded flood elevations that did not reach the runway in most locations.

5.1.4 Storm Surge Model Limitations and Assumptions

The model developed for the coastal surge assessment at Scammon Bay is intended to be a simplistic approximation of surge inundation due to a 50-year and 100-year return period storm surge at SCM. Thus, the following limitations and assumptions should be noted:

- The model is not calibrated. Field hydrodynamic data required for calibration have not been collected. DHI recommended defaults are used for model parameters. This approach is expected to provide conservative peak water levels.
- The culvert that runs beneath the Scammon Bay Airport Runway was defined by its characteristics detailed in the 2013 Scammon Bay Airport Flood Permanent Repairs Department of Military and Veterans' Affairs (DMVA)/FEMA project plans, which are assumed to be representative of the existing culvert.
- Given that little information on bed resistance is available in the domain, bed resistance values used were assumed constant in each area and were determined by ocular estimation. This is unlikely to be the case in nature, but it provides more realistic results than neglecting roughness entirely.
- RSLR information was obtained from Nome and is assumed to be representative of the RSLR at Scammon Bay.
- Storm surge elevations were obtained from Agcklarok and are assumed to be representative of storm surge elevations at Scammon Bay.
- The shape of storm surge events was obtained from Nome and is assumed to be representative of the shape of storm surge events at Scammon Bay.
- Only one representative surge was used to determine inundation. A sensitivity analysis using different surge slopes was not performed. The surge hydrograph used was assumed to be conservative and is expected to provide higher-end values of current speed.
- Peak surge was aligned to occur simultaneously with a high tide event with the intent to represent a conservative surge elevation. A sensitivity analysis of storm surge effects at different tidal phases was not performed.
- The Kun River was assumed to be flowing at base flow (40 percent bankfull flow). Flow from other streams in the model domain were excluded and were assumed to have minimal impact of results.

5.1.5 Storm Surge Model Simulations

Two model simulations were performed: a 50-year return period (2 percent AEP) storm surge event and a 100-year return period (1 percent AEP) storm surge event. The storm surge input used for the 100-year return period model is shown on Figure 9. The storm surge input for the 50-year return period event is the same, with the peak surge elevation adjusted to match the 50-year maximum surge height provided in Table 2. The model simulations ran for 1,020 timesteps, with each timestep representing 6 minutes. The total simulation time for both models was approximately 4 days (102 hours).

5.1.6 Storm Surge Model Results

Storm surge model results were reviewed for surge inundation and potential impacts near the SCM runway, taxiway, and access road. The storm surge models resulted in a near-complete inundation of the runway and taxiway from both the 50-year and 100-year events. Maximum water surface elevation and current speeds are summarized in Table 4. The higher current speeds in the model are associated with breaching of the roadway as this area is flooded. Assuming that the improved runway is above the surge elevation, this rate of current speed is not anticipated. The fastest current speed observed not associated with a breach (current traveling around the runway/wind cone areas) is also provided since this is anticipated to be more representative of storm surge current speeds under the Future With Project condition. Figure 10 shows maximum predicted water surface elevations for the 50-year storm surge event.

Table 4: Storm Surge Model Water Elevations Results, Current Results, and Reference Elevations

Location	Elevation (feet NAVD88)
Reference Elevations	
Runway Centerline – Southeast End	+17.4 feet
Runway Centerline – At Culvert	+12.7 feet
Runway Centerline – At Taxiway	+13.5 feet
Center of Taxiway	+13.1 feet
50-Year Max Water Surface Offshore	+18.9 feet
100-Year Max Water Surface Offshore	+20.9 feet
Model Results Elevations	
50-Year Max Water Surface Elevation Near SCM	+16.1 feet
100-Year Max Water Surface Elevation Near SCM	+18.4 feet
Model Results Current	
Maximum Current Speed (breaching roadway)	7.5 feet/second
Maximum Current Speed, West Runway Terminal	4.1 feet/second
Maximum Current Speed, East Runway Terminal	2.2 feet/second
Maximum Current Speed, Culverts (either side)	2.2 feet/second

Note: NAVD88 = North American Vertical Datum of 1988

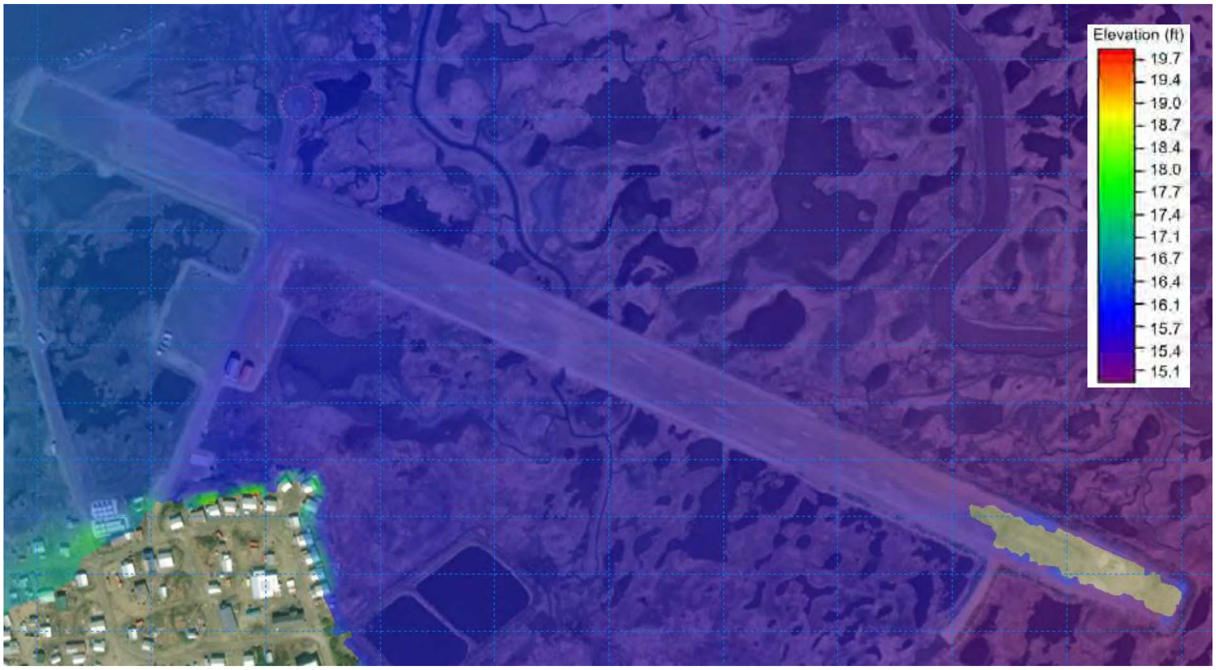


Figure 10: Peak Water Surface Elevation Results for the 50-Year Storm Surge Event

5.2 Wave Analysis

A wave analysis was conducted to determine potential wave conditions at the Scammon Bay Airport that coincide with a flooding event. MIKE 21 SW numerical model software was used to simulate wave conditions at the project site.

5.2.1 Wave Model Description

The MIKE 21 SW numerical model was used to assess wind-generated wave height and period at the project site. MIKE 21 SW, developed by DHI, is software used for developing two-dimensional spectral wave models based on a flexible (unstructured) mesh. Models developed with MIKE 21 SW simulate wind-generated waves and swell (DHI 2017b). The flexible mesh module allows for higher resolution at areas of interest (e.g., near the runway embankment) while relaxing the resolution away from the project site to increase computation efficiency.

5.2.2 Model Domain and Mesh

The model domain for the MIKE 21 SW simulations includes an approximately 30-mile fetch centered at SCM in all directions that are not obstructed by the Askimuk Mountains. The mesh contains 29,873 elements and 15,229 nodes. Mesh elements increase in size as radial distance from SCM increases. Mesh elements along the runway embankment have a fine resolution allowing for multiple (approximately three) elements per wave length. Features with potential to influence wave conditions, such as nearby roads and detention ponds, were also defined with increased resolution.

Primary sources of elevation data used to create the mesh are the same as those for the MIKE 21 HD FM and are summarized in Table 3.

Figure 11 provides a view of the entire model domain. The colors represent different elevations. Figure 12 and Figure 13 provide enlarged views of the mesh showing the finer resolution for the project site.

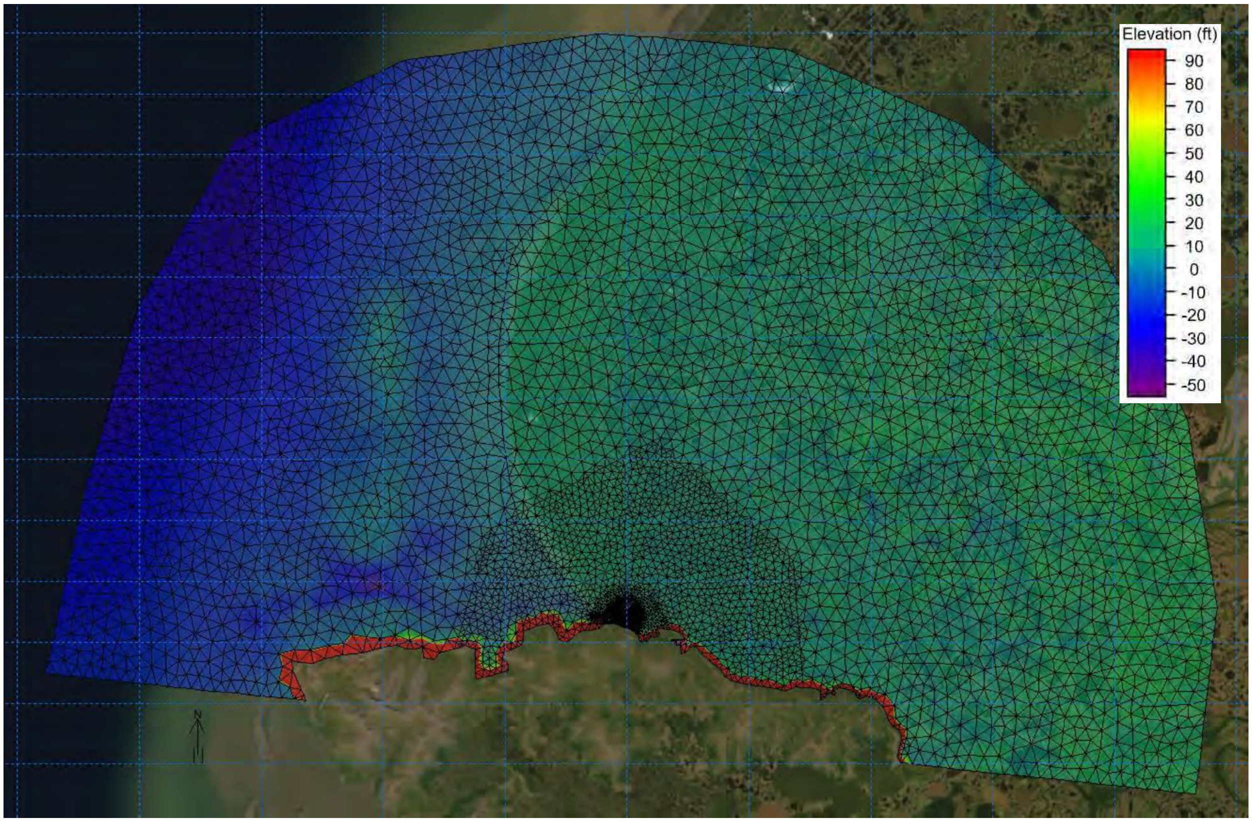


Figure 11: MIKE 21 SW Wave Model Mesh - Full Domain

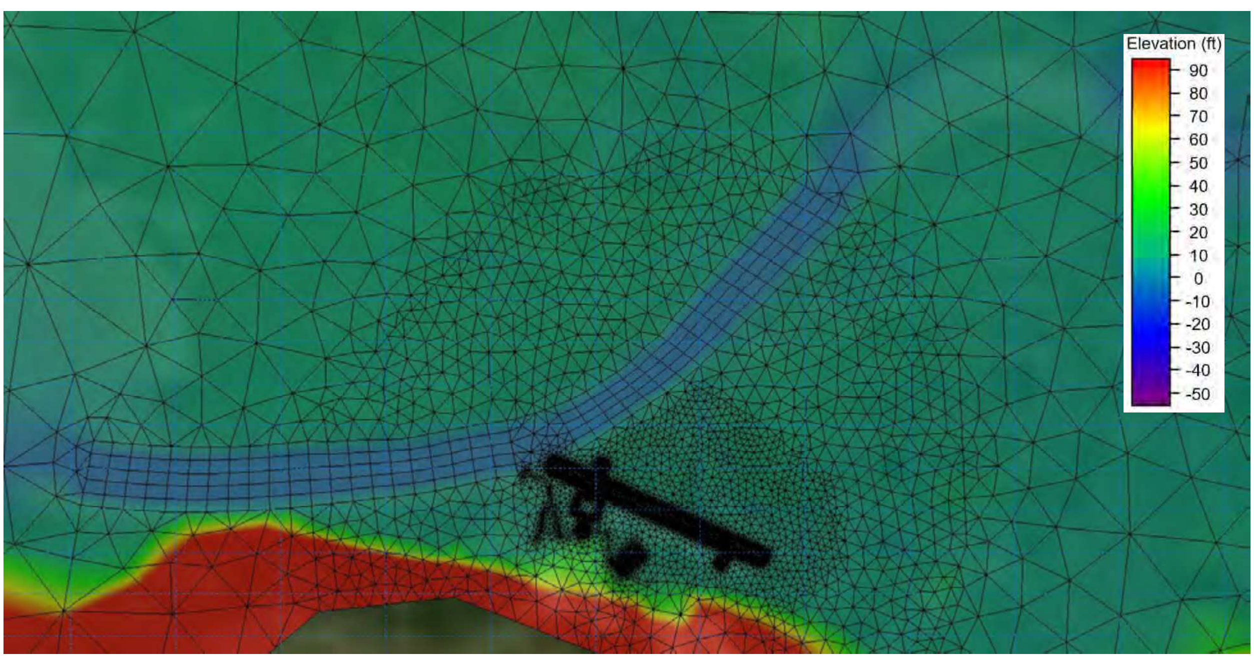


Figure 12: MIKE 21 SW Wave Model Mesh - Enlarged View Showing the Kun River and Scammon Bay

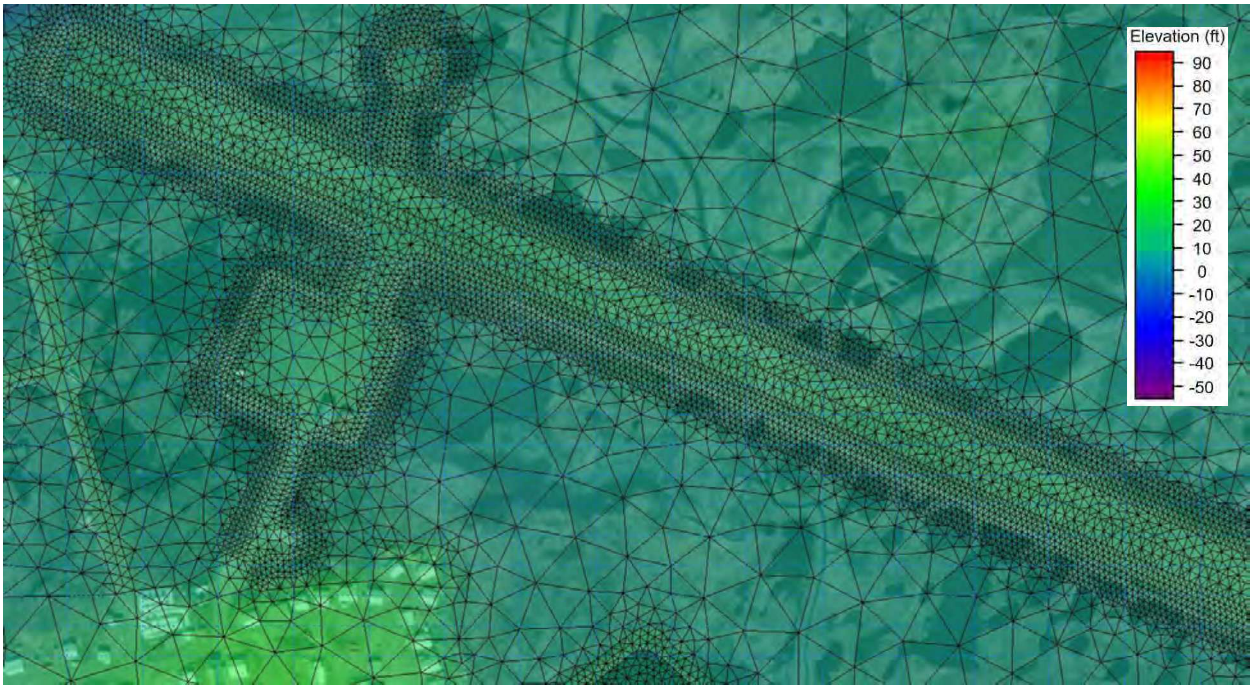


Figure 13: MIKE 21 SW Wave Model Mesh - Enlarged View Showing Refined Mesh Around Runway Embankment

5.2.3 Wave Model Boundary Conditions

Primary model inputs included water level, wind speed, and wind direction. Wave (beyond those generated by wind) and current boundary conditions were not included in the model.

Water Level: The 100-year return period water level was determined by using the maximum water level reached during the Storm Surge Analysis numerical modeling (Section 5.1). This water level was applied constantly throughout the domain for all simulations (i.e., no tidal action), as this provides a more conservative approach for simulating wave conditions.

Wind: Wind events were identified from the Scammon Bay ASOS dataset from 2010 to 2021 (temporal extent of data). These events were sorted into 16 intercardinal directions on a 22.5° interval. An extreme value analysis was performed for “All Directions” (shown on Figure 4) and for each intercardinal direction. The 100-year return period wind speeds for each direction are shown in Table 5.

Table 5: 100-year Wind Events by Direction

Direction	Direction (degrees)	Speed (knots)
North	0	30.7
North by Northeast	22.5	26.4
Northeast	45	23.2
East by Northeast	67.5	28.9
East	90	31.2
East by Southeast	112.5	33.5
Southeast	135	33.3
South by Southeast	157.5	33.3
South	180	43.9
South by Southwest	202.5	33.4
Southwest	225	34.0
West by Southwest	247.5	28.0
West	270	34.7
West by Northwest	292.5	33.4
Northwest	315	29.0
North by Northwest	337.5	24.8

5.2.4 Wave Model Limitations and Assumptions

Limitations and assumptions for the MIKE 21 SW wave model are as follows:

- The model is not calibrated. However, nomographs for wind-generated waves provided in the USACE Shore Protection Manual (USACE 1984) were reviewed for similar water depths and fetches and were found to have good agreement with the wave height and period results.
- Bed resistance was not included in this model. Although this is not a situation that can occur in nature, it provides a conservative approach to wave height estimation.
- Wind events from 2010 to 2021 are assumed to be a representative sample for the statistical analyses.
- Waves in Scammon Bay were assumed to be wind-generated waves only (i.e., swell from the ocean was not included). Swell is assumed to dissipate energy well before reaching the runway during a surge event due to their long wave periods and influence of the shallow water depths.

5.2.5 Wave Model Simulations

Sixteen model simulations (one for each intercardinal direction) varying the wind speed and wind direction were performed. The water level for each simulation was held constant for each simulation, achieving a steady-state wave condition as opposed to continually varying the water level as a tidal cycle. The constant water level was set as the maximum water level during 100-year storm surge model near the runway.

5.2.6 Wave Model Results

Wave model results were extracted at 108 locations around the SCM runway, taxiway, and access road. The largest spectral significant wave heights and associated periods were identified for each extraction location from the 16 model simulations (Figure 14). These results were then used to determine stone stability and overtopping rates at multiple locations along the perimeter of the runway/taxiway/access road.

Figure 14: Spectral Significant Wave Height Results at Scammon Bay Airport

6. Coastal Engineering Design Recommendations

6.1 Airport Surface Elevations

Airport surface elevation recommendations consider storm surge, RSLR, and wave overtopping. Recommendations are provided for both a 50-year (2 percent AEP) and 100-year (1 percent AEP) storm surge event. The RSLR component assumes a 50-year project life duration.

The criteria for determining a recommended runway elevation use critical overtopping discharge rates for revetment seawalls. Table 6 provides the critical discharge guidance from CIRIA (2007). To reduce maintenance and repair due to overtopping, setting the runway elevation to achieve an overtopping discharge at “No Damage” is recommended.

Table 6: Critical Overtopping Discharge for Revetment Seawalls

Description	Q Mean Overtopping Discharge (m^3/s per m)
No Damage	q < 0.05
Damage if promenade not paved	0.05 < q < 0.2
Damage even if promenade paved	q > 0.2

Source: CIRIA 2007
Note: m^3/s per m = cubic meters per second per meter.

Overtopping discharge was calculated at multiple locations (at the same locations shown in Figure 14) around the perimeter of the airport features (runway, taxiway, access road) using the 50- or 100-year return period scenarios assuming side slope of 4H:1V with an armor stone embankment. The elevation was varied until the maximums of all of the locations reviewed were at or below the critical overtopping discharge threshold. Table 7 provides the recommended Airport Surface Elevations and associated overtopping discharges.

Table 7: Recommended Airport Surface Elevations and Associated Overtopping Discharges

Return Period	Recommended Airport Surface Elevation	Overtopping Discharge (m^3/s per m)
50-Year (2% AEP)	**+18.5 feet NAVD88**	0.02 Avg; 0.05 Max
100-Year (1% AEP)	+20.5 feet NAVD88	0.01 Avg; 0.04 Max

Note: m^3/s per m = cubic meters per second per meter; AEP = Annual Exceedance Probability; NAVD88 = North American Vertical Datum.

Airport usability due to storm surge is associated with the probability of occurrence of an event that exceeds the critical overtopping rate of “no damage” over the project life duration. In a storm surge event where the overtopping exceeds this value, it is expected that conditions will exist that do not allow safe use of the runway, such as flooding, damage to the runway or runway safety area, or debris thrown up onto the runway. Unless significant damage is sustained, the duration in which the runway would be unusable would be on the order of a few days to a week. This is based on observations of Western Alaska storm surge hydrographs in which storm surge events will often reach a maximum surge level and sustain that level for 1 to 3 days before receding. It is then assumed that some form of cleanup and minor grading is required to return the runway to a usable condition. Probability of occurrence for the 50- and 100-year storm surge events over varying project life durations is provided in Table 8.

Table 8: Storm Surge Probability of Occurring at Least One Time over the Project Life Duration

Project Life Duration (years)	50-Year Storm Surge (2% AEP)	100-Year Storm Surge (1% AEP)
25	39.7%	22.2%
30	45.4%	26.0%
50	**63.5%**	**39.5%**
75	77.9%	52.9%
100	86.3%	63.4%

Note: AEP = Annual Exceedance Probability.

6.2 Runway Relocation

Historical georeferenced aerial imagery from 1948 and 1977 was gathered for the project area. Riverbank positions were delineated based on the apparent water-land interface. When overlaying these riverbank positions with a recent (2020) aerial image, it can be inferred that the Kun River is migrating towards the runway, albeit slowly. Riverbank retreat near the runway terminal from 1948 to 2020 ranges from 115 to 190 feet, which equates to 1.6 to 2.6 feet per year. Similarly, riverbank retreat from 1977 to 2020 near the terminal ranges from 55 to 100 feet, which equates to 1.3 to 2.3 feet per year.

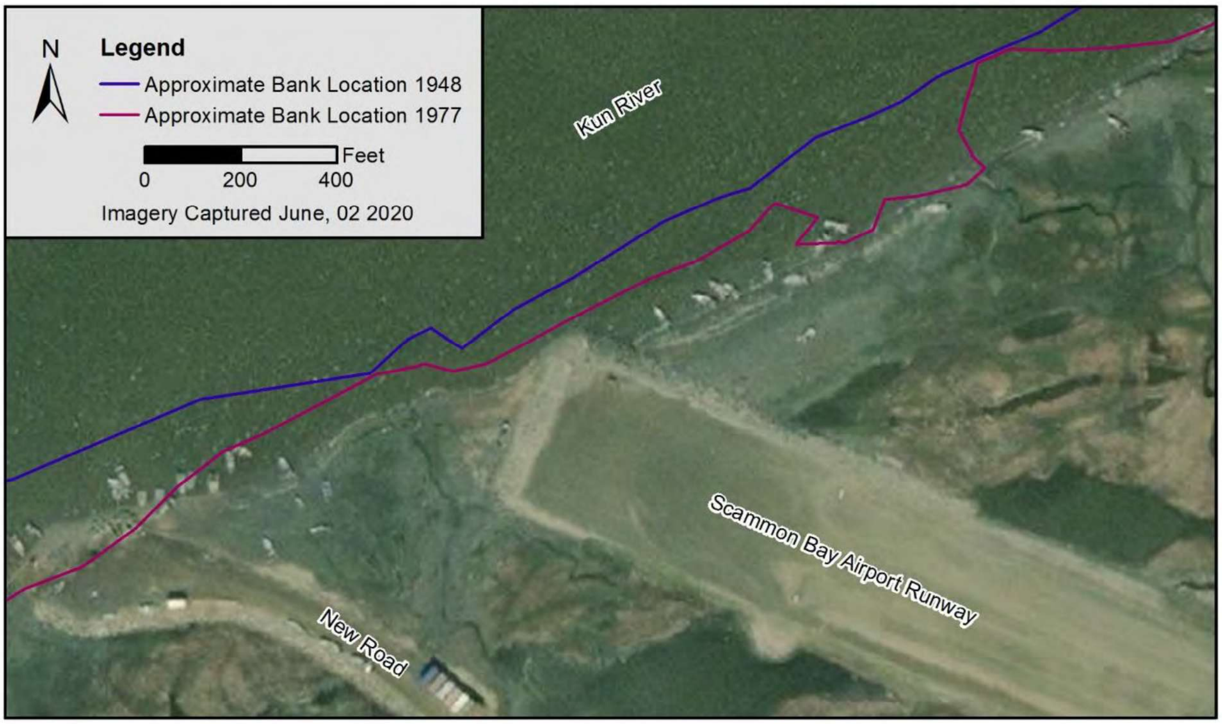


Figure 15: Historical Riverbank Position Superimposed over Recent (2020) Aerial Imagery

Assuming a conservative migration rate of 3 feet per year, the runway would need to be relocated 150 feet from the current riverbank location for a 50-year project life duration. Thus, considering the slightly oblique alignment of the runway and protrusion of the runway terminal beyond the existing riverbank position, the runway would need to shift approximately 340 feet along its current alignment. Figure 16 shows the proposed shifted runway graphically in comparison to the existing runway location. When the runway is shifted, it does not appear that any significant flow paths will be displaced. The distance from the runway terminal to the edge of the wetlands (area where terrain elevation abruptly increases) is shortened from approximately 550 feet to 500 feet with the proposed shift.

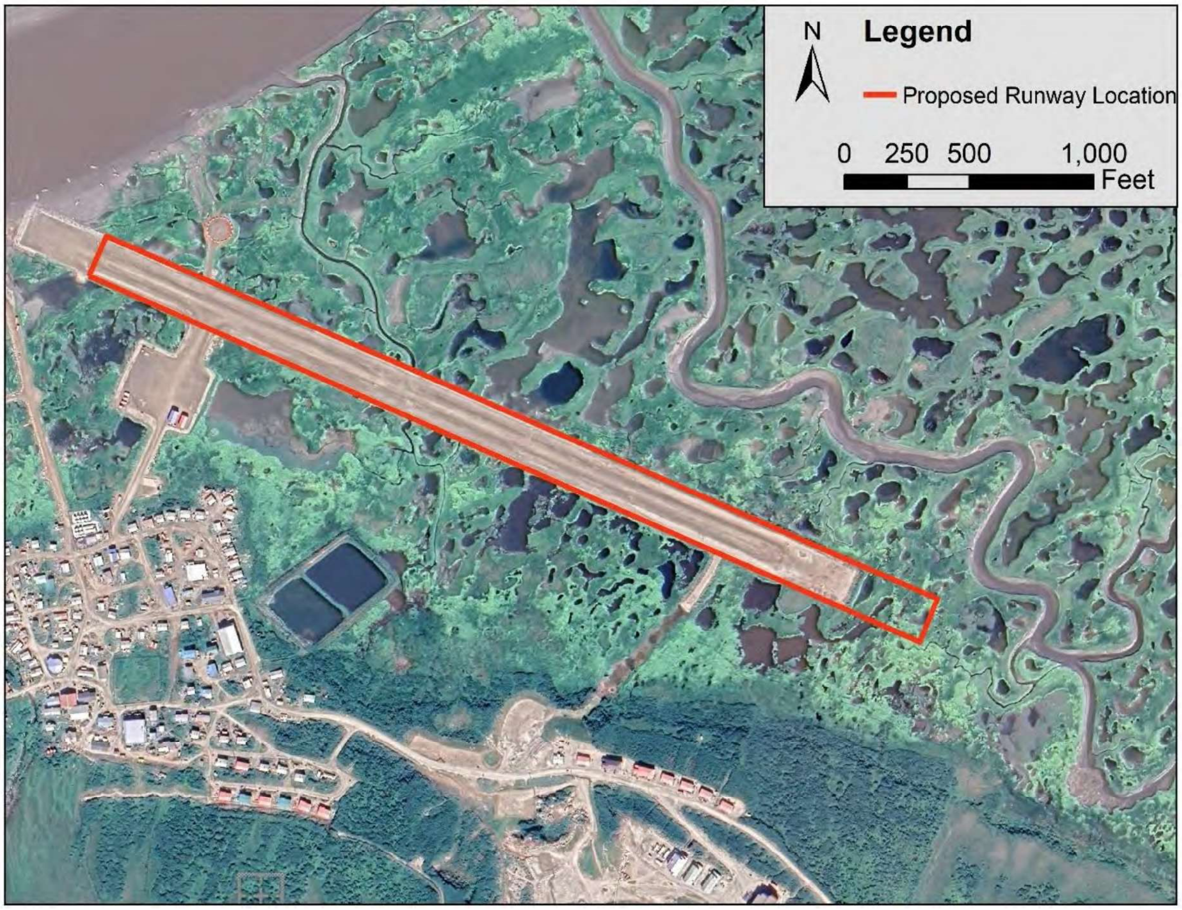


Figure 16: Proposed Runway Relocation

6.3 Erosion Protection

Erosion protection is recommended along the perimeter of the runway, taxiway, and access road to mitigate damage to the embankment due to waves and to reduce wave overtopping, which can damage the surface of the airport features. A traditional buried-toe armor rock revetment, a suitable long-term option for erosion protection that requires minimal maintenance, was the initial method assessed for shoreline protection. This method was assessed using the approximate 4H:1V existing side slopes of the runway. Subsequently, alternative erosion protection methods were assessed to evaluate more cost-effective solutions. These methods included an armor rock revetment with an above-ground toe at various slopes as well as a marine mattress.

6.3.1 Buried-Toe Armor Rock Revetment Method

If a traditional buried-toe armor rock revetment is used, two revetment sections are recommended for different areas of the project area. Each revetment section is a two-layer revetment consisting of a primary amor stone and filter stone material with an underlaying geotextile filter fabric. An embankment slope of 4H:1V was selected based on the proposed repair design in the 2013 Scammon Bay Airport Flood Permanent Repairs DMVA/FEMA project drawings. Armor rock revetments can be constructed at steeper slopes (generally as steep as

2H:1V); however, the size of primary armor stone material and subsequently the layer thickness/volume of stone increases as a result.

6.3.2 Primary Armor Stone (Buried-Toe Armor Rock Revetment Method)

A stone stability analysis was performed to assess primary armor stone size needed for potential waves and currents during a flood event. From this analysis, it was found that wave conditions were the controlling factor. Ice was not considered for armor stone size for the following reasons:

1. The structure will generally be above the tidal level at which ice plucking is not a concern.
2. The runway terminal is a significant distance away from the Kun River, and it is not expected that ice breakup in the river will affect the stability of the revetment.
3. Storm surges generally occur during fall, when sea ice is not present in Scammon Bay.

Stone stability using both the van der Meer and Hudson methodologies was calculated at multiple locations around the runway, taxiway, and access road. From these calculations, it was determined that the maximum required median primary armor stone weight for the van der Meer and Hudson methodologies is 300 lbs. and 400 lbs., respectively. Required median stone size varied along the perimeter runway, taxiway, and access road, with the larger stone calculated at the western runway terminal, primary wind cone, and western embankment of the taxiway and access road. Calculated median stone weight around the perimeter of the runway, taxiway, and access road is shown visually on Figure 17.

Due to the short-period waves anticipated, a riprap-type gradation (wide/uniform gradation) is recommended in lieu of a coastal armor-type gradation (narrow gradation). The riprap-type gradation is generally easier to produce and thus should have a reduced cost compared to a coastal armor-type gradation. The recommended gradation is provided in tabular form in Table 9 and shown graphically in Figure 18. This gradation is the same as ASTM 6092 R-700 with the exception that it is “percent lighter by count” and not “percent lighter by weight.” Also, this gradation is very similar to a DOT&PF Class III gradation.

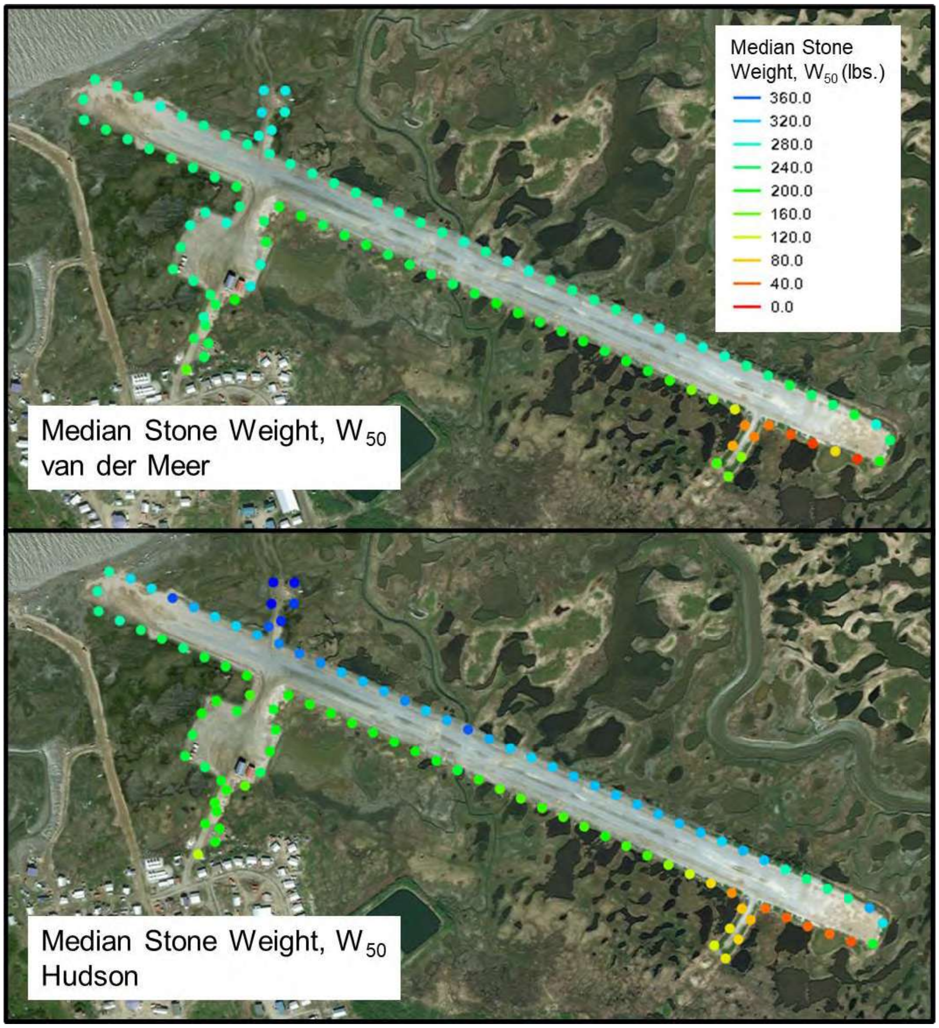


Figure 17: Median Armor Stone Weight using the van der Meer (upper image) and Hudson (lower image) Methodologies

Table 9: Recommended Primary Armor Stone Gradation (PA-700)

Stone Weight, lbs.	Percent Lighter by Count
1,500	100
700	50–100
300	15–50
60	0–15

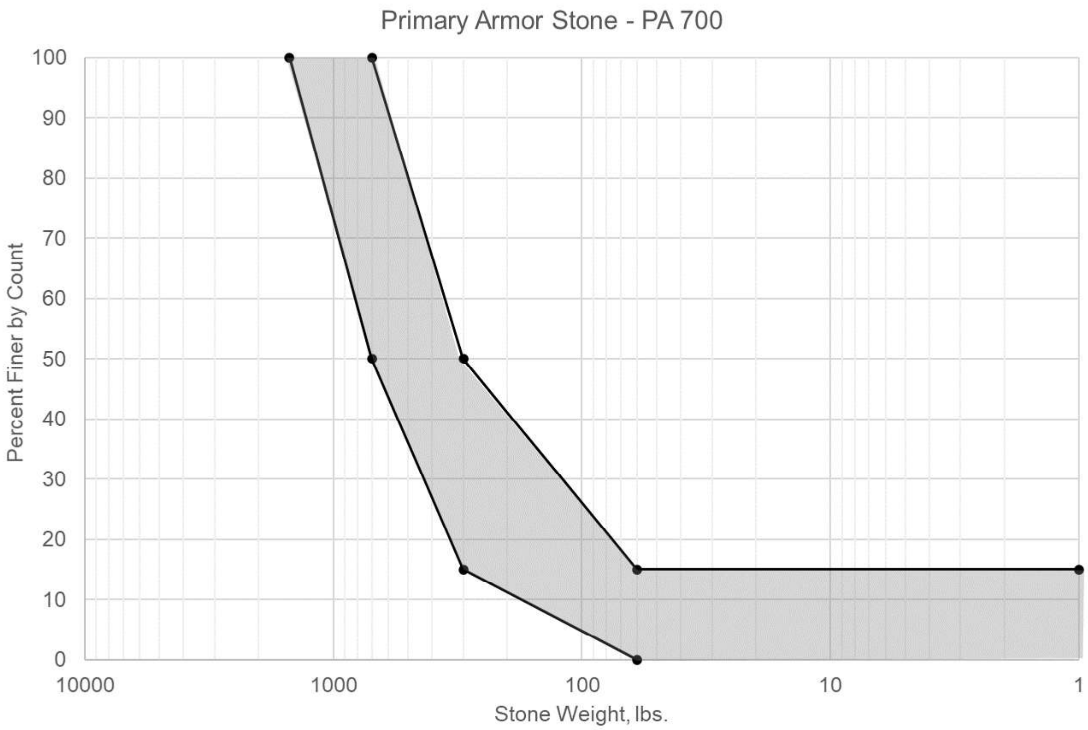


Figure 18: Recommended Primary Armor Stone Gradation (PA-700)

6.3.3 Filter Stone (Buried-Toe Armor Rock Revetment Method)

Filter stone is recommended to be placed under the primary armor stone to provide distribution of the armor stone weight against the underlaying geotextile filter fabric and improved interlocking with the armor stone layer. The filter stone size follows guidance for the USACE *Shore Protection Manual* (USACE 1984) and EM 1110-2-1614 (USACE 1995). The upper bound of the filter stone was selected to match the lower bound of the primary armor stone to increase yield of the processed quarry stone. The recommended gradation for the filter stone is provided in tabular form in Table 10 and shown graphically in Figure 19.

Table 10: Recommended Filter Stone Gradation (F-30)

Stone Weight, lbs.	Percent Lighter by Count
60	100
30	0–50
5	0–15

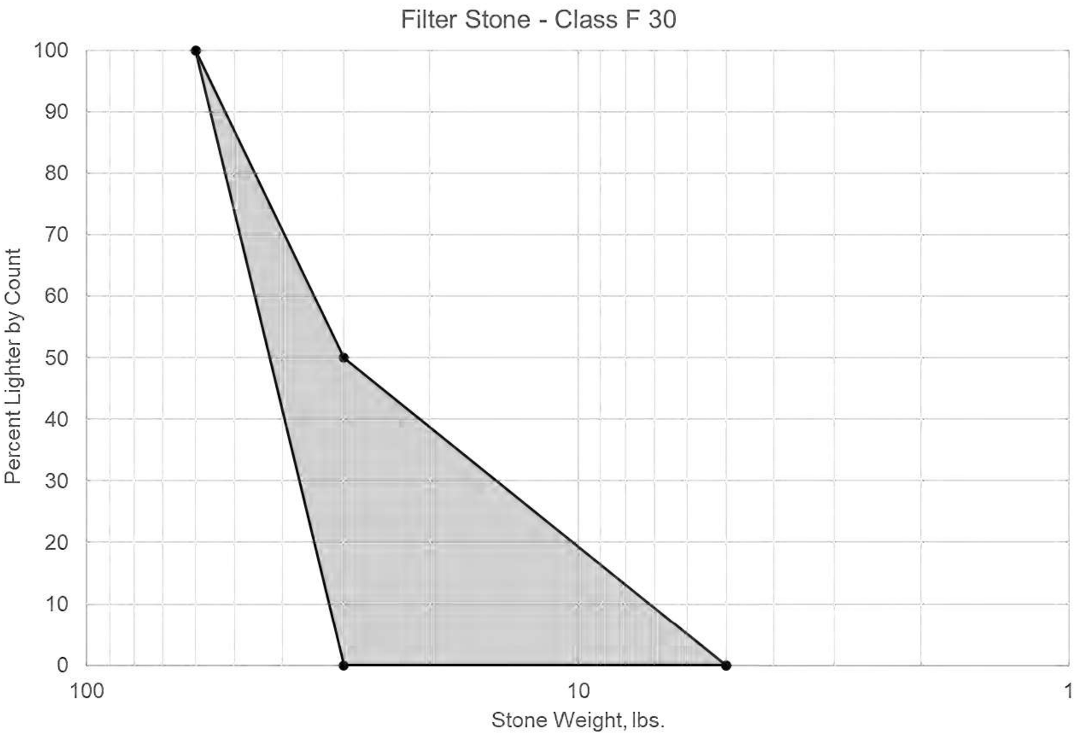


Figure 19: Recommended Filter Stone Gradation (F-30)

6.3.4 Revetment Typical Sections (Buried-Toe Armor Rock Revetment Method)

Two revetment sections are recommended that vary in the design of structure toe. The Erosion Protection – Type I revetment includes a more substantial buried toe that is recommended for areas along the runway, taxiway, and access road with moderate to extreme scour potential. The Erosion Protection – Type II revetment uses a simple entrenched toe with *in-situ* backfill. This section is recommended in areas along the runway, taxiway, and access road with low scour potential. Each toe design follows guidance from EM 1110-2-1614 and should be buried 4 feet below the existing grade to prevent scour. Scour depths were assumed to be equivalent to 1.0-1.5 times the significant wave height.

The revetment typical sections for erosion protection are provided in Figure 20 and Figure 21. Both sections utilize the same primary armor and filter material. The Erosion Protection – Type II areas are expected to have less wave energy and thus could utilize a smaller Primary Armor stone (W_{50} of approximately 200 lbs.). Requiring two primary armor stone and consequentially two filter stone material types is expected to complicate the construction logistics, which may offset any gains from using a smaller material. Given this unknown, a potential procurement strategy to solicit a lower cost is to provide an optional Erosion Protection – Type II with a smaller section utilizing a smaller primary armor stone and filter stone material. Minimum armor and filter stone layer thicknesses (3’) are specified to be two times the median stone diameter (D_{50}).

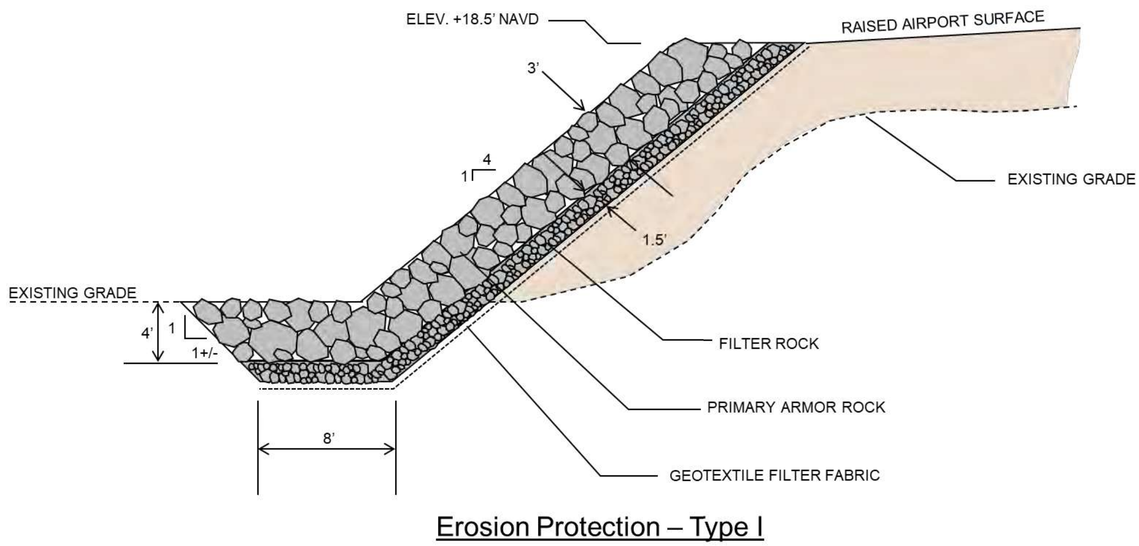


Figure 20: Erosion Protection - Type I Recommended Typical Section

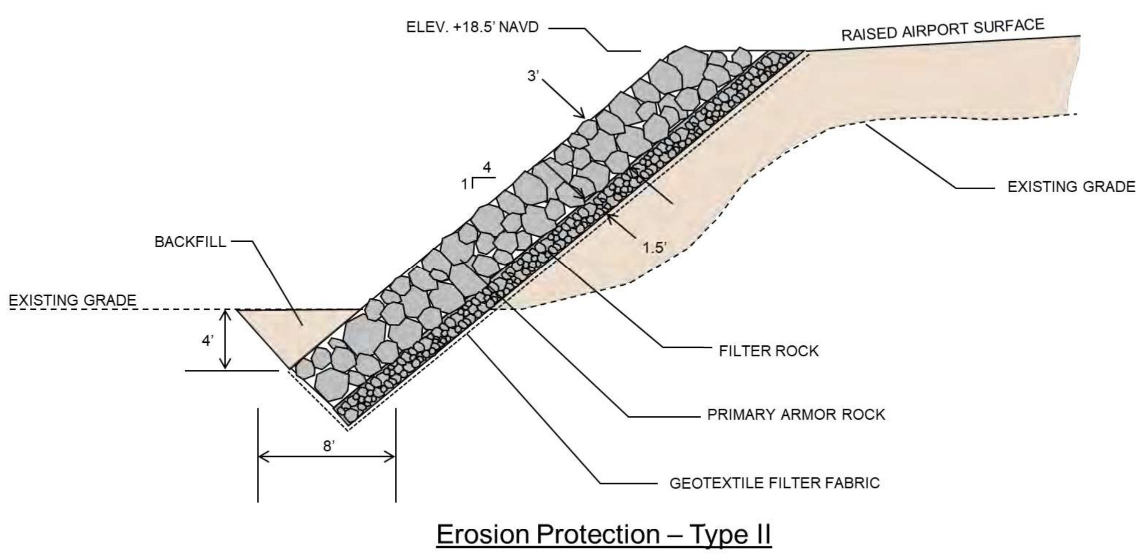


Figure 21: Erosion Protection - Type II Recommended Typical Section

6.3.5 Armor Rock Revetment with an Above-Ground Toe

An armor rock revetment with an above-ground toe reduces the excavation and, when constructed at steeper angle than 4H:1V, requires less material thus reducing the initial construction cost.

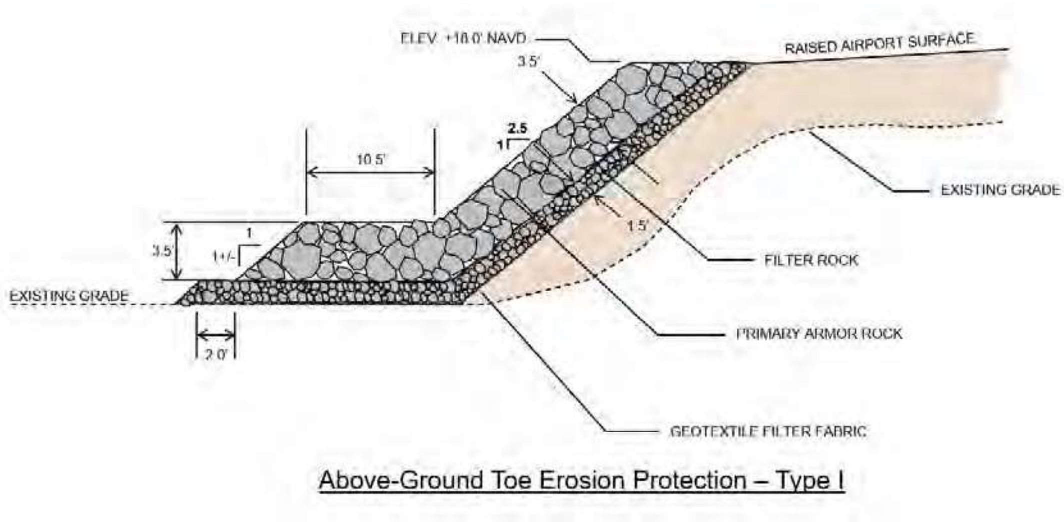


Figure 22: Example of an Above-Ground Toe Erosion Typical Section (Type I 2.5H:1V Concept Shown)

Several configurations of revetments with an above-ground toe were assessed to quantitatively compare construction cost to the initial buried-toe revetment with a 4H:1V slope. These include the following:

- 2.5H:1V & 2H:1V Concept – This concept uses three typical sections covering the entire airport perimeter. In areas with the largest waves, the revetment uses 2.5H:1V slope. In areas with moderate wave action, the revetment uses a 2H:1V slope. In areas with minimal wave action, the revetment uses filter rock material as the primary protection.
- 2.5H:1V Concept – This concept uses three typical sections. In areas with the largest waves as well as moderate waves, a 2.5H:1V slope is used, however, the armor rock size is different creating two different sections. A third section using only filter rock is used in areas with minimal wave action.
- 2H:1V Concept - This concept uses three typical sections. In areas with the largest waves as well as moderate waves, a 2H:1V slope is used, however, the armor rock size is different creating two different sections. A third section using only filter rock is used in areas with minimal wave action.
- 1.5H:1V Concept - This concept uses three typical sections. In areas with the largest waves as well as moderate waves, a 1.5H:1V slope is used, however, the armor rock size is different creating two different sections. A third section using only filter rock is used in areas with minimal wave action.

A summary of these different concepts is provided in Table 11 which also includes a conceptual cost difference from the buried-toe revetment.

Table 11: Summary Comparison of Armor Rock Revetments

Revetment Concept	Type I Armor W_{50}	Type II Armor W_{50}	Revetment Cost Contribution
Buried-Toe 4H:1V Concept	300 lbs.	300 lbs.	$67.7M
Above-Ground Toe 2.5H:1V and 2H:1V Concept	370 lbs.	380 lbs.	$30.1M
Above-Ground Toe 2.5H:1V Concept	520 lbs.	380 lbs.	$30.9M
Above-Ground Toe 2H:1V Concept	520 lbs.	380 lbs.	$31.9M
Above-Ground Toe 1.5H:1V Concept	790 lbs.	590 lbs.	$33.3M

Notes:
1. Revetment cost contribution includes in-place costs of primary armor stone, filter stone, geotextile fabric, and any excavation or fill required.
2. Primary armor stone unit price used is $240 per ton
3. Filter stone unit price used is $200 per ton
4. Geotextile filter fabric unit price used is $10 per square yard
5. Excavation unit price used is $25 per cubic yard
6. Backfill unit price used is $25 per cubic yard
7. A contingency of 30% was used in the cost contribution calculation

6.3.6 Marine Mattress

A potential drawback from using a traditional armor rock revetment, especially in remote locations without suitable local armor material, is the capital cost to construct the project. A marine mattress can be used in environments with low to moderate wave conditions and are advantageous in that they can utilize much smaller, less expensive rock. In other words, the ability to produce high quality large armor stone is not a requirement. A marine mattress is made of geotextile grid in the shape of a 'mattress' that contains small rock. Mattresses are laid in a single layer. Mattress thickness come in a variety of sizes (6", 9", 12", 18", and 24"). Mattresses are generally about 20 to 30 feet long (35 feet max) and 5 feet wide. The mattress can be filled in place or fabricated offsite and placed on a prepared foundation using specialty spreader bars. Figure 23 provides a typical schematic of a marine mattress. An example of marine mattress used as erosion protection is shown in Figure 24.

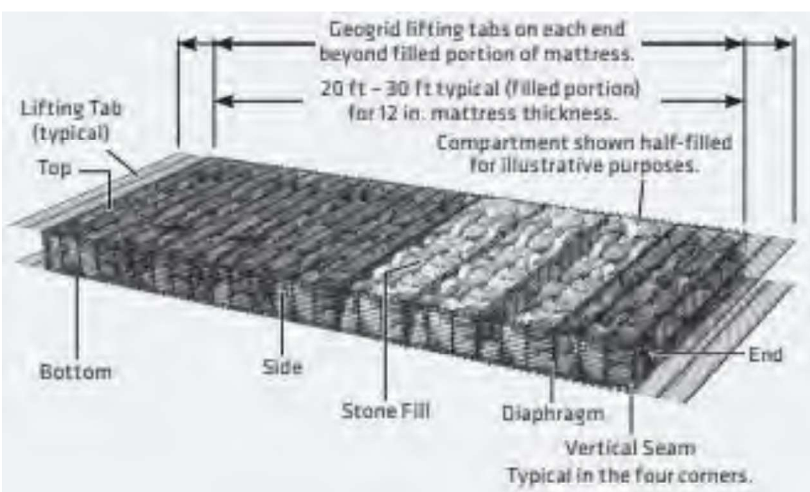


Figure 23. Typical schematic of a marine mattress (Photo source: Tensar.com)

Figure 24. Example of a marine mattress used for erosion protection (Photo source: tensar.com)

It is anticipated that a 12" mattress placed at 1.5H:1V slope can handle the wave conditions at Scammon Bay. The east side of the runway would require excavation to achieve the 1.5H:1V slope or, alternatively, the marine mattress could be placed directly on grade with minor excavation. These concepts are shown schematically in Figure 25 and Figure 26. The west and mid runway, which have a lower existing grade, would require fill to achieve the 1.5H:1V slope. This concept is shown schematically in Figure 27. For comparison, the marine mattress cost component as shown would be $11M (roughly a third less expensive than any of the armor rock options).

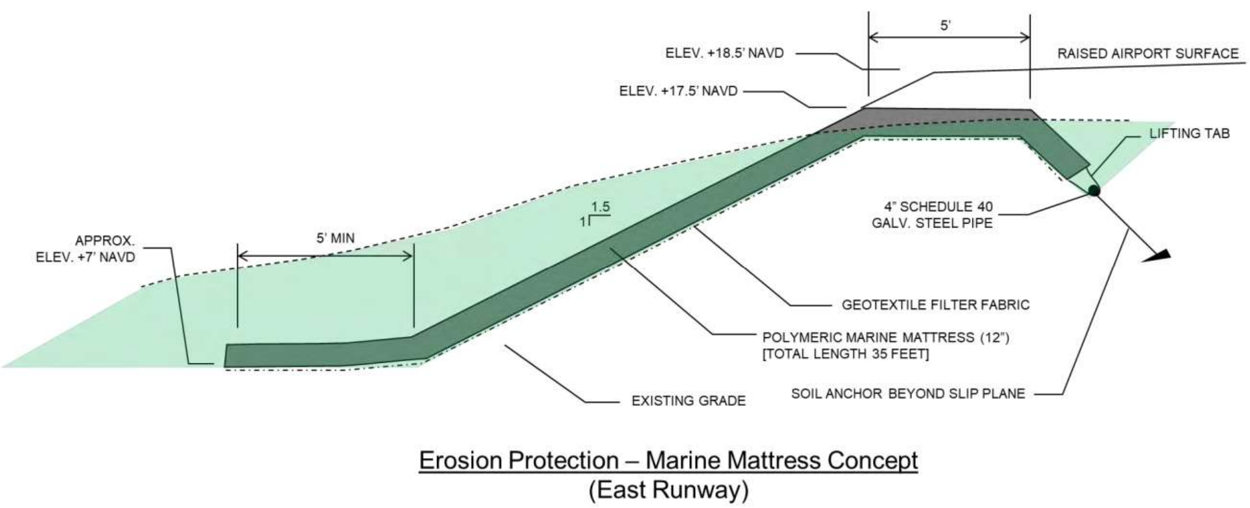


Figure 25. Marine mattress schematic for the east side of the runway (1.5H:1V slope)

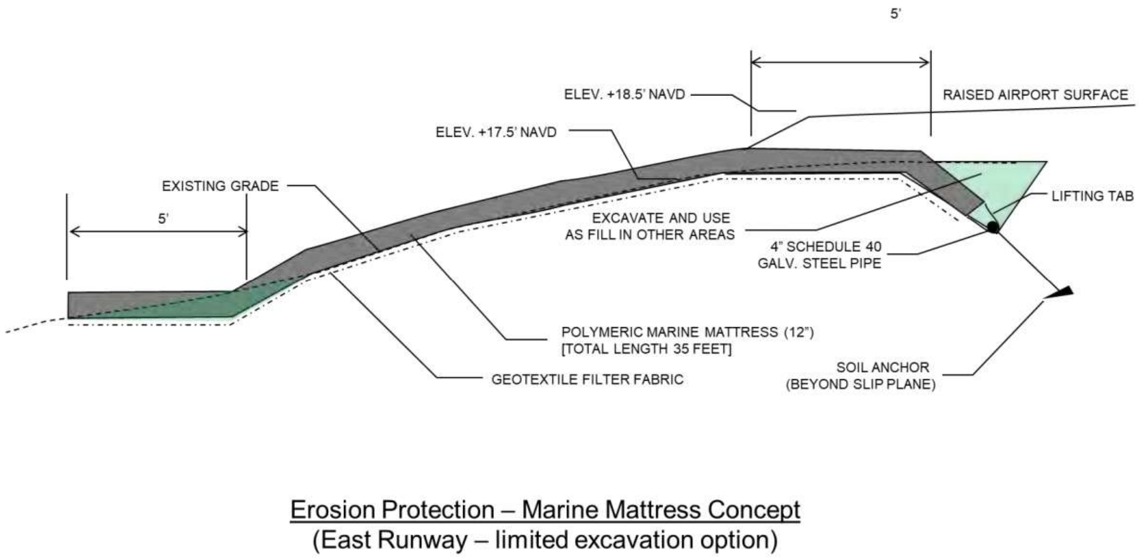


Figure 26. Marine mattress schematic for the east side of the runway (use existing slope)

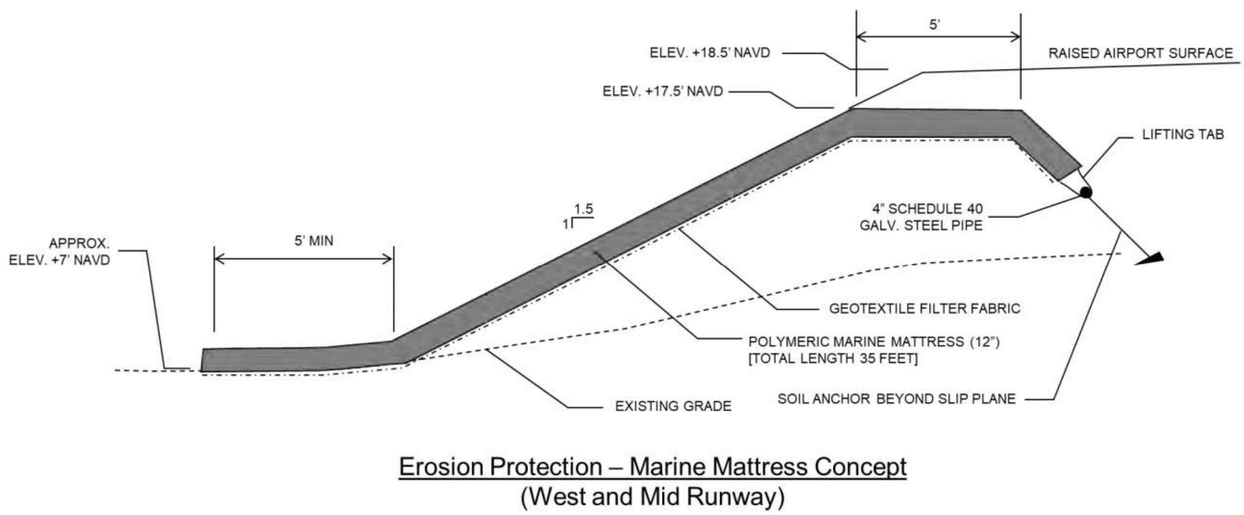


Figure 27. Marine mattress schematic for the west side and mid runway

6.3.7 Other Alternatives Not Assessed

Other alternatives not assessed in detail that may warrant some future consideration include:

- Articulating Concrete Block Mats
- Gabions
- Sacrificial Rock Material/Berm Revetments

Articulating block mats include multiple concrete pieces that interlock via geometry (i.e., puzzle piece), strung together using cable, chain, or rope, or combination of the interlocking geometry and cabling. They can be used in light to moderate wave environments and have a minimal profile compared to armor rock revetments. Similar to a marine mattress, they require a prepared subgrade.

Gabions are like marine mattresses in that they are units that contain small rock, however, are smaller and block-like in geometry. They can be placed more vertically, such as along a riverbank, or at a prescribed slope. There are various gabion materials including zinc and galvanized steel (not suitable for a coastal environment), stainless steel, and HDPE/plastic.

Sacrificial rock material/berm revetments are like the revetments presented in this section, but instead utilize smaller stone and have a larger cross-section, expecting to have movement within the structure during large events. Material is either simply lost (sacrificial) or a berm feature is redistributed by the storm developing a more stable 'S' shape. These structures generally require more material than a traditional armor rock revetment (larger cross section) but may be a benefit economically by using smaller material if the unit price of the rock is significantly cheaper than the equivalent larger material needed for a traditional revetment.

7. Summary

This document presents a preliminary coastal analysis and recommendations pertaining to coastal engineering components as part of a larger feasibility study for improvements to the Scammon Bay Airport. Readily available metocean and elevation data were gathered to develop a coastal storm surge model and spectral wave model to determine potential water levels, current speeds, and wave conditions at the runway, taxiway, and access road. Based on this analysis, airport surface elevation for a 50-year return period storm surge (2 percent AEP) is +18.5 feet NAVD. A 340-foot shift in the runway location along its current alignment away from the Kun River is also recommended based on historical migration rates of the riverbank near the runway terminal. To mitigate against erosion, multiple revetment sections were developed and compared using conceptual costs for protection of the runway, taxiway, and access road perimeters.

The following are key recommendations regarding the feasibility of improving the Scammon Bay Airport:

1. To reduce potential for flood inundation, damage from current flow due to breaching, and damage from flooding and wave overtopping, it is recommended to increase the elevation of the Airport Surfaces. For a 2 percent AEP, an elevation of +18.5 feet NAVD88 is recommended.
2. Relocating the runway along its current alignment at 340 feet is recommended for a project life duration of 50 years.
3. Erosion protection (armor rock revetment or marine mattress) is recommended around the perimeter of the runway, taxiway, and access road is recommended to mitigate potential erosion and scour due to waves and currents during a flood event.

4. In areas expected to sustain larger wave condition, a section with a toe designed for moderate to severe scour is recommended.
5. Different sections that utilize smaller typical sections should be considered in areas of the airport perimeter that experience smaller wave action.
6. Erosion protection utilizing marine mattresses (or other alternatives to armor rock revetment) should be given consideration, given the infrequent and moderate wave conditions expected to reduce overall construction cost.

8. References

Barnhart, K.R., I. Overeem, and R.S. Anderson. 2014. The effect of changing sea ice on the physical vulnerability of Arctic coasts. *The Cryosphere* 8, 1777–1799, 2014.

CIRIA, CUR, CETMEF. 2007. *The Rock Manual*, *The use of rock in hydraulic engineering (2nd Edition)*, C683, CIRIA, London (ISBN: 978-0-86017-683-1).

DHI (Danish Hydraulic Institute). 2017a. MIKE 21 Flow Model FM – Hydrodynamic Module, User Guide.

DHI. 2017b. MIKE 21 Spectral Waves FM – Spectral Wave Module, User Guide.

DOT&PF (State of Alaska Department of Transportation and Public Facilities). 2004. Airport Layout Plan for Scammon Bay Airport. Available at https://dot.alaska.gov/stwdav/airports_public_central.shtml, accessed July 2021.

DOT&PF. 2013. 2013 Scammon Bay Airport Flood Permanent Repairs DMVA/FEMA. Project No Z583570000/FEMA DR-4182-AK. Provided by DOT&PF.

DOT&PF. 2017. Construction Plans – Scammon Bay Airport.

HDR, 2022. *Hydrology and Hydraulics Report*, *Scammon Bay Airport Improvements Feasibility Study*. Project Number: CFPT00691. Prepared for the Alaska Department of Transportation and Public Facilities.

NOAA (National Oceanic and Atmospheric Administration). 2021a. Bathymetry Data Viewer. Available at https://maps.ngdc.noaa.gov/viewers/bathymetry, accessed June 2021.

NOAA. 2021b. Chart Locator. Available at https://www.charts.noaa.gov/InteractiveCatalog/nrnc.shtml#mapTabs-2, accessed June 2021.

NOAA. 2021c. Datums for 9467124, Kun River AK. Available at https://tidesandcurrents.noaa.gov/datums.html?id=9467124, accessed June 2021.

NOAA. 2021d. Relative Sea Level Trend 9468756 Nome, Alaska. Available at https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=9468756, accessed June 2021.

NOAA. 2021e. Tide Predictions at 9467124, Kun River, AK. Available at https://tidesandcurrents.noaa.gov/noaatidepredictions.html?id=9467124, accessed June 2021.

State of Alaska Division of Geological & Geophysical Surveys. 2021. Elevation Portal. IfSAR, Y-K Delta 2016 LiDAR, Scammon 2015 SFM elevation data. Available at https://elevation.alaska.gov/#61.86845:-165.51933:11, accessed June 2021.

UAF (University of Alaska Fairbanks). 2021. Historical Sea Ice Atlas for Alaska & the Arctic, 1850 to present. Alaska Center for Climate Assessment and Policy. Available at https://www.snap.uaf.edu/tools/sea-ice-atlas

U.S. Census Bureau. 2020. Scammon Bay city, Alaska, population. Available at https://data.census.gov/cedsci/profile?g=1600000US0267680, accessed June 2021.

USACE (United States Army Corps of Engineers). 1984. *Shore Protection Manual*, Volume 1.

USACE. 1995. *Design of Coastal Revetments, Seawalls, and Bulkheads*. EM 1110-2-1614. Engineer Manual. June 30, 1995.

USACE. 2009. *Storm-Induced Water Level Prediction Study for the Western Coast of Alaska*.

USGS (United States Geological Survey). 2019. USGS Alaska 5 Meter AK_Ykon_Delta_IfSAR_2018_D18 DTM.

This page was intentionally left blank

APPENDIX D: HYDROLOGY AND HYDRAULICS REPORT – SCAMMON BAY AIRPORT IMPROVEMENTS FEASIBILITY STUDY (HDR 2022B)

Hydrology and Hydraulics Report – Scammon Bay Airport Improvements Feasibility Study

Project Number: CFAPT00691
AIP: 3-02-0255-003-2023

Alaska Department of Transportation and Public Facilities, Central Region

Scammon Bay, Alaska

December 19, 2022

Prepared by:

HDR

STATE OF ALASKA
49 TH
I. Turletes
No. 107276
12/19/2022
REGISTERED PROFESSIONAL ENGINEER

This page intentionally left blank.

Contents

Tables

Figures

Appendices

Acronyms and Abbreviations

ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
AWC	*Anadromous Waters Catalog*
cfs	cubic feet per second
CMP	corrugated metal pipe
DOT&PF	State of Alaska Department of Transportation and Public Facilities
DS	Downstream
°F	degrees Fahrenheit
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FPID	Fish Passage Inventory Database
GFDL-CM3	NOAA Geophysical Fluid Dynamics Laboratory - Coupled Model 3.0
GIS	Geographic Information Systems
GCM	Global Circulation Model
H&H	Hydrology and Hydraulics
HDPE	High Density Polyethylene
HEC	Hydraulic Engineering Circular
HW/D	headwater depth to culvert diameter ratio
IfSAR	Interferometric Synthetic Aperture Radar
LiDAR	Light Detection and Ranging
MHHW	mean higher-high water
MLLW	mean lower-low water
MTL	mean tide level
NAVD88	North American Vertical Datum of 1988
NCAR-CCSM4	National Center for Atmospheric Research - Atmospheric Research Community Earth System Model 4
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRCS	Natural Resources Conservation Service
PCM	*Alaska Highway Preconstruction Manual*
PIH	Plans-in-Hand
PRISM	Parameter-elevation Regression on Independent Slopes Model
Q_{50}	50-year design discharge
SCM	Scammon Bay Airport (International Air Transport Association's airport code)
SNAP	University of Alaska Fairbanks Scenarios Network for Alaska + Arctic Planning
TR-55	Technical Release 55
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

This page intentionally left blank.

1. Introduction

1.1 Project Overview

This Hydrology and Hydraulics (H&H) Report is prepared for the State of Alaska Department of Transportation and Public Facilities (DOT&PF) Central Region as part of a larger feasibility study to assess improvements to the airport at Scammon Bay (project).

The project is at the Scammon Bay State Airport (SCM), which is a state-owned, public use airport. The DOT&PF proposes various airport improvements to enhance safety, improve infrastructure, and bring the airport to Federal Aviation Administration standards. These improvements consist primarily of repairing elements that have been damaged by flooding or have otherwise deteriorated over time, including:

- Increasing the elevation of the runway, taxiway, apron, and access road
- Shifting the runway away from the Kun River
- Replacing the culvert under the runway
- Placing erosion protection adjacent to the Kun River and airport embankments
- Making various building and aviation-specific additions and replacements
- Obtaining additional right-of-way

1.2 Scope of Hydrologic and Hydraulic Analyses

The project involves providing H&H and coastal engineering recommendations to guide a larger feasibility study regarding the various airport improvements to better protect SCM from flooding and scour. The H&H portion consisted of looking at the removal and replacement of one 48-inch-diameter cross culvert near the center of the existing runway. The crossing conveys an unnamed tributary to the Kun River and will require hydraulic design. As of the writing of this report, Alaska Department of Fish and Game (ADF&G) had not determined if this crossing will require hydraulic design to accommodate anadromous fish passage. If anadromous fish passage requirements are established, the supplementary design considerations will need to be considered for the feasibility study.

Details specific to the coastal engineering recommendations to support this project are provided under a separate report (HDR, 2022).

HDR conducted a background review, site visit, and discussions with DOT&PF to gain an overall understanding of the project drainage and site-specific drainage issues. This was followed by basin delineations, development of flood frequencies, culvert hydraulic calculations, and tidal analyses. These are discussed in this report and detailed in its appendices.

1.3 Organization of Report

This report is organized as follows:

- Section 2 discusses existing hydrologic and hydraulic conditions.
- Section 3 discusses the project design criteria.
- Section 4 discusses the hydrologic analysis.
- Section 5 discusses the hydraulic analysis.
- Section 6 discusses floodplain management.
- Section 7 presents the summary and recommendations.
- Section 8 presents the references cited.

All elevations provided are based on the North American Vertical Datum of 1988 (NAVD88) unless otherwise specified.

2. Hydrologic and Hydraulic Conditions

2.1 General Physical Characteristics

The project is located in the community of Scammon Bay in Western Alaska, in the Kusilvak Census Area (Figure 1). Scammon Bay has a population of 594 (U.S. Census Bureau 2020) and covers 299 acres. The runway is located on the south shore of the Kun River along the northeast edge of the community.

DOT&PF and HDR conducted a site visit in May 2021 to assess the existing runway culvert and the surrounding area. Appendix A includes HDR's site visit report with photographs.

Local topography was analyzed using publicly available Interferometric Synthetic Aperture Radar (IfSAR) and Light Detection and Ranging (LiDAR) digital elevation data (State of Alaska Geological & Geophysical Surveys 2021).

Geology of the area was interpreted from the United States Geological Survey (USGS) Geologic Map of Alaska via an online mapper (Wilson et al. 2015).

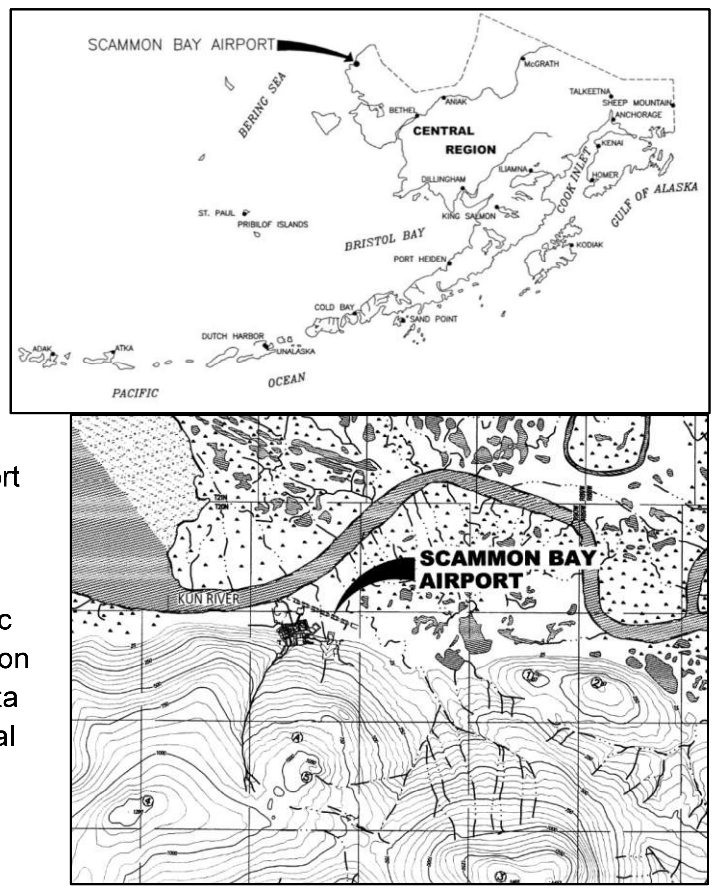


Figure 1: Location and Vicinity Map

Recreated from DOT&PF 2004 and 2013b

Land cover characteristics in the area were analyzed for use in hydrologic estimations and are summarized in Table 1. Land cover type and corresponding hydrologic properties were determined by analysis of vegetation that was observed during site visits, aerial photography, and cover classifications from the National Land Cover Database (NLCD) (Dewitz 2020). Water feature coverage, such as rivers, streams, and ponds, were classified by similar means and the 2021 Alaska Hydrography Database (USGS 2021).

2.1.1 Runway 10/28

The airport consists of one Type A, gravel runway (designated by 10/28). The runway sits between 10 and 17.5 feet in elevation and runs northwest to southeast at a +0.19 percent slope. It is bounded by the Kun River to the northwest, surrounded by intertidal wetlands, and connected to the community with one access road to the southwest.

The runway sits near the border of two geologic regions: uplands and wetlands. The USGS classifies the upland areas of the community as intermediate granitic rocks and the adjacent wetland areas as unconsolidated and poorly consolidated surficial deposits (Wilson et al. 2015).

2.1.2 Runway Culvert

The existing structure beneath the runway is a 48-inch-diameter, 198-foot-long, smooth interior wall, corrugated, high-density polyethylene (HDPE) pipe. The DOT&PF *2013 Scammon Bay Airport Flood Permanent Repairs DMVA/FEMA* plans show the culvert with a 0.2 percent slope, an inlet invert elevation of 4.0 feet, and an outlet invert elevation of 3.6 feet. The crossing allows flow from a perennial stream (unnamed tributary) to pass beneath the runway and discharge to the Kun River.

Upstream of the culvert, the stream meanders through the hillside, the eastern portion of the community, and tundra for approximately 1,400 feet. During the May 2021 site visit, the existing culvert was inspected and appeared to be sagging and partially collapsed in three locations. While the inlet was not visible due to mounded snow, a large pool of water (10–15 feet wide and approximately 20 feet long) was observed immediately upstream of the inlet. A noticeable foul odor was also documented and is suspected to be caused by effluent seeping from the wastewater lagoon, located next to an upstream portion of the meandering stream. This assumption was not confirmed during the site visit.

Downstream of the culvert, the stream travels approximately 1,700 feet through intertidal wetlands to its receiving waters, the Kun River. At the outlet, the stream is approximately 5 feet wide but widens to 10–14 feet immediately downstream of the outlet. Tidal influence on the stream channel is evident from the nearly vertical stream banks that range from 2 to 3 feet in depth.

2.2 Climate

The Scammon Bay area has a maritime climate and receives an average annual precipitation of 24 inches due to its coastal proximity. Climate records for the area indicate that the warmest temperatures occur in July, averaging 51 degrees Fahrenheit (°F), and the coldest temperatures occur in February, averaging 8.4°F. Precipitation varies from the driest month (February), with an average 1.0 inch of rain, to the wettest month (August), with an average 4.4 inches of rain

(SNAP 2021). Historical annual snowfall is around 68 inches and typically accumulates between October and April (Western Regional Climate Center 2021).

2.3 General Basin Hydrology

Scammon Bay is located on the Yukon-Kuskokwim Delta, 60 miles southwest of the mouth of the Yukon River. Most of the streams within the Yukon-Kuskokwim Delta are made up of shallow sloped, meandering channels flowing through tundra and wetlands that contain numerous oxbow lakes and relic channels on their way to the Bering Sea. The Scammon Bay community is located at the intersection of three distinct hydrologic features: the Kun River to the north and east, the Askinuk Mountains to the south, and the Bering Sea to the west. The airport lies along the Kun River, 0.75 mile upstream from its mouth.

2.3.1 Kun River Basin

The Kun River generally flows east to west and acts as a northern boundary for the community of Scammon Bay as it reaches its receiving waters, Scammon Bay, in the eastern Bering Sea. The Kun River's drainage basin at the Scammon Bay airport encompasses an estimated 461 square miles and contains portions of the Askinuk Mountains, perennial alpine streams, tundra, wetlands, and ponds. It is bounded by relatively flat tundra and wetlands to the north, the Black River to the east, and the Askinuk mountain range to the southwest, shown on Figure 2. The wetlands and ponds make up approximately 19 percent of the basin area and likely account for significant flow attenuation during heavy rainfall events.

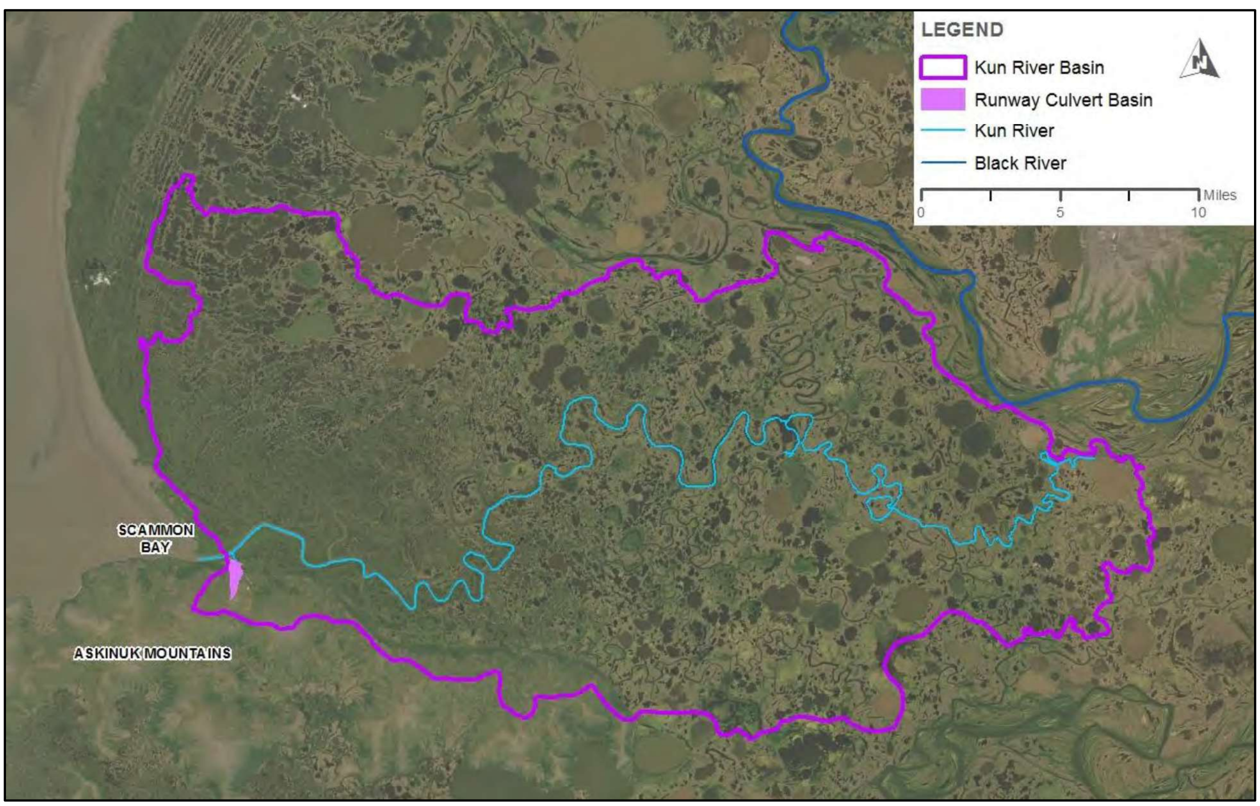


Figure 2: Kun River Basin

The Kun River is listed in the ADF&G *Anadromous Waters Catalog* (AWC) as having Arctic Char and Chum Salmon (ADF&G 2021a).

2.3.2 Runway Culvert Basin

The runway culvert basin for the unnamed tributary to the Kun River is approximately 296 acres. It receives flows from a portion of the hillside above the community, flows from the community, and (likely) small amounts of seepage from the community's sewage lagoon. It is a perennial stream that meanders through the tundra for approximately 1,400 feet before passing through the runway culvert and then traveling approximately 1,700 feet through the intertidal wetlands to the Kun River. The runway culvert basin and surrounding area are shown on Figure 3.

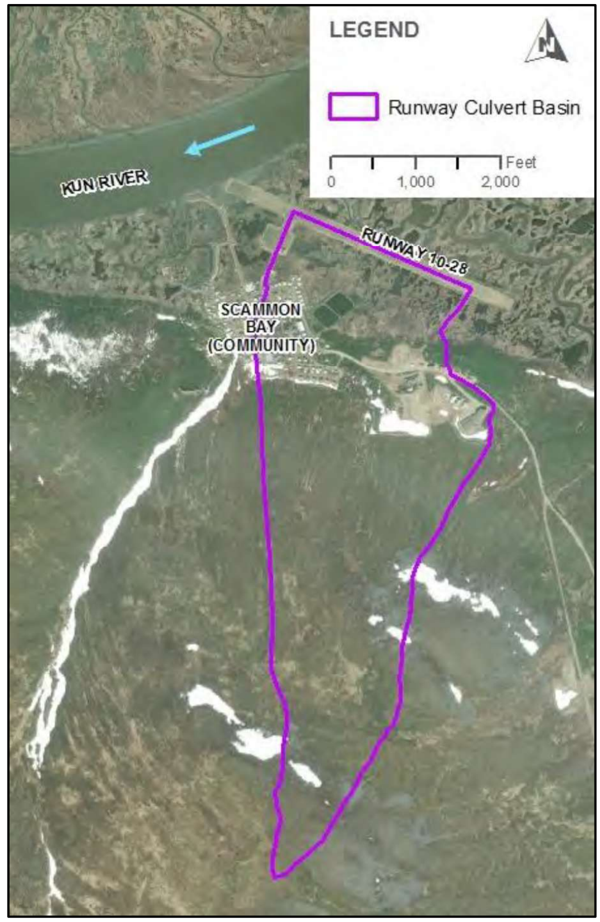


Figure 3: Runway Culvert Basin

During June 2021, discussions with ADF&G indicated that this tributary may have suitable habitat for fish species residing in the Kun River, but it is not currently listed in the AWC.

2.3.3 Basin Characteristic Summary

Table 1 summarizes standard basin characteristics for the Kun River and the runway crossing identified for analysis. These characteristics are frequently used when evaluating hydrology at ungaged sites and are included for reference. Of these characteristics, the values used to calculate design discharges are area and annual precipitation.

Table 1: Project Drainage Basin Characteristics

Feature	Runway Culvert Basin Unnamed Tributary to the Kun River	Kun River at the Scammon Bay Airport
Area (square miles)	0.46	461
Area with Lake and Pond Storage (%)	0.45	18.9
Forested Area[a] (%)	1.6	0.39
Average Stream Slope[a] (feet/feet)	0.13	0.002
Mean Elevation (feet)	363	31
1971–2000 PRISM[b] Annual Precipitation (inches)	24.5	19.0

Notes: PRISM = Parameter-elevation Regression on Independent Slopes Model.
[a] Dewitz 2020.
[b] Gibson 2009.

2.4 Additional Hydrologic Attributes

This section summarizes other hydrologic attributes as required by DOT&PF's *Alaska Highway Preconstruction Manual* for H&H reports (DOT&PF 2013a). Since the runway culvert's basin lies within the greater Kun River basin, both basins are discussed further.

2.4.1 Tidal Influence

The mouth of the unnamed tributary is approximately 2 miles upstream from where the Kun River flows into Scammon Bay in the eastern Bering Sea. The National Oceanic and Atmospheric Administration (NOAA) monitors a tidal benchmark on the Kun River (Station ID: 9467124) that is 948 feet upstream of the runway (NOAA 2021a). The mean lower low water (MLLW) and mean higher high water (MHHW) elevations recorded at this benchmark are 0.30 foot and 6.77 feet, respectively. The existing runway culvert's outlet invert elevation is 3.60 feet, which is 0.01 foot above the mean tide level (MTL) and 3.17 feet below the MHHW. It was suspected that the tributary and culvert were tidally influenced upon inspection during the May 2021 site visit and was later confirmed through coastal modeling.

The runway culvert is estimated to be tidally influenced 45 percent of the time but is never completely inundated during astronomical tides. This percentage is assumed to increase over time due to a predicted 0.64-foot increase in relative sea level over the next 50 years. The culvert can, however, become fully inundated during a coastal storm surge event, which is an abnormal rise in sea level caused by a storm. The extent to which the culvert is inundated is dependent on the severity of the event. See Table 2 for a comparison of the existing culvert outlet's elevation to typical tidal elevations.

Table 2: Kun River (NOAA Station ID: 9467124) Tidal Datums

Datum	Elevation (feet, based on NAVD88)	Elevation (feet from MLLW)
Mean Higher High Water (MHHW)	6.77	6.47
Mean High Water (MHW)	6.00	5.70
Runway Culvert Outlet Invert	3.60	3.30
Mean Tide Level (MTL)	3.59	3.29
Mean Sea Level (MSL)	3.50	3.20
Mean Low Water (MLW)	1.18	0.88
Mean Lower Low Water (MLLW)	0.30	0
NAVD88	0	-0.30

Sources: NOAA 2021b.
Notes: NAVD88 = North American Vertical Datum of 1988.

Based on the 50-year return interval storm surge model, the water surface elevation is greatest (15.7 feet) as the storm recedes the area. The velocities surrounding the inlet of the culvert were nearly identical (1.7 feet per second) during the building and receding of the storm.

2.4.2 Freshwater Streams

The project is located on the banks of the Kun River and includes one perennial freshwater stream, the unnamed tributary to the Kun River, that passes through the runway culvert. Various other perennial freshwater streams (named and unnamed tributaries of the Kun River), seasonal freshwater streams, wetlands, and ponds are located within the greater Kun River basin.

2.4.3 Navigation

The unnamed tributary of the Kun River that passes through the runway culvert is not listed in the Alaska Department of Natural Resources (ADNR) navigable waters catalog as navigable. Sections of the Kun River are listed as either undetermined or potentially navigable, with the mouth and section along the community listed as undetermined (ADNR 2021a). There is an active city-owned, seaplane landing base located at the northwest edge of the community. Additionally, the local community utilizes small boats in the surrounding area.

In a United States Army Corps of Engineers (USACE) – Alaska District 2009 report, barges were indicated to bring bulk supplies in the summer months (the Bering Sea is ice-free from late June through October). The barge landing was noted to be easy to access (USACE 2009).

2.4.4 Confluences

The confluence of the unnamed tributary is approximately 2 miles upstream of the mouth of the Kun River. There are no other confluences upstream of the crossing that would affect the site hydraulics during large flood events.

The Kun River has several named confluences and numerous other unnamed tributaries. From its headwaters to the mouth, the Iaslaktoli, Tungpuk, Kikneak, and Ear rivers converge with the Kun River before it flows into Scammon Bay and then the Bering Sea.

2.4.5 Mining Activity

Based on the ADNR mining claims map, the project extents have no active mining activity (ADNR 2021b). In the past, there may have been some mining activity along the shores of Scammon Bay, but there have been no significant historical mining operations in the project area that might affect the hydrology at the crossing site.

2.4.6 Debris Problems

Problems with debris have not been documented at the crossing, nor were they listed during the May 2021 site visit as a design concern. The flows from the unnamed tributary to the Kun River emanate from upland tundra and wetlands where debris is typically not an issue. The Kun River drains a large, predominantly boggy area that backwaters to the crossing during high-tide events. While the upstream reaches likely do not contain debris that would get stuck inside or damage the culvert, driftwood and other large floating objects brought in during incoming tides might affect the project site.

2.4.7 Icing Problems

Icing problems were not listed as a design concern or observed during the May 2021 site visit. A thaw pipe or other icing counter measures were not observed in the existing runway culvert. If there is seepage from the sewage lagoon, it would provide slightly warmer flows to the culvert, lowering icing potential.

Substantial snow accumulation was present at the runway culvert inlet and outlet. This accumulation is thought to be due to winter runway maintenance, and caution should be taken in the future to avoid plowing/stacking snow near the culvert inlet and outlet to prevent reduction of the hydraulic capacity of the culvert. In terms of icing, snow cover may act as insulation for the culvert.

2.4.8 Fish Passage

The unnamed tributary of the Kun River has not been identified or nominated for fish passage based on the ADF&G Fish Passage Inventory Database (FPID) (ADF&G 2021b). The Kun River is mapped as anadromous in the AWC and is listed with having Arctic Char and Chum Salmon (ADF&G 2021a). While no fish sampling has been conducted in the tributary, its direct connection to the Kun River with no apparent barriers to fish passage increases the likelihood that it contains fish.

Discussions with ADF&G to date indicate that while the stream is relatively small and has a small connected habitat, ADF&G desires to maintain connectivity with the Kun River. Discussion with ADF&G should be concluded, and determination should be made on design requirements.

3. Design Criteria

Specific design criteria for airport culverts are not provided in the Alaska Aviation Preconstruction Manual or the FAA Advisory Circular for Airport Drainage Design (dated 8/15/2013). Therefore, the new runway is to be designed to the standards set forth in the *Alaska Highway Preconstruction Manual* (PCM) *(*DOT&PF 2013a) and the *Alaska Highway Drainage Manual* (Drainage Manual) (DOT&PF 2006). Both documents require culverts 48 inches in diameter or greater to be hydraulically designed (PCM section 450.9.7, Drainage Manual section 9.2.2). Table 1120-1 of the PCM establishes a design flood frequency of 50 years (Q_{50}) for this type of crossing. The Drainage Manual, section 9.3.3, requires a headwater depth to culvert diameter ratio (HW/D) no greater than 1.5. The proposed culvert should have a design life of 30 to 75 years.

If required at future design stages, fish passage shall be accommodated and the structure design will follow the guidelines set forth by the *Memorandum of Agreement between ADF&G and DOT&PF for the Design, Permitting, and Construction of Culverts for Fish Passage* (DOT&PF 2001).

4. Hydrologic Analysis

4.1 Flood Frequency Analyses

The method of flood frequency analysis is typically selected by the contributing basin area. The 2016 USGS Regression Equations (USGS 2016) are typically used when the (site) basin meets the minimum area and mean annual precipitation criteria. In areas that do not meet the limitations of USGS Regression Equations, the Rational method and/or the National Resources Conservation Service (NRCS) Urban Hydrology for Small Watershed Technical Release 55 (TR-55; NRCS 1986) methods can be utilized. Between the two latter methods, the TR-55 method is typically selected for basins outside of the 2016 USGS regression equations criteria, as it tends to be the more conservative method for design discharges, producing higher estimated flows at Q_{50}. In a case in which the 2016 USGS regression equations can be used, the other methods can also be calculated, and their results compared for corroboration and consistency.

The methods considered and the basin area requirements for each method are:

- 2016 USGS regression equations (basin area greater than 0.4 square mile; between 8 and 280 inches of mean annual precipitation)
- Rational method (basin area less than 200 acres [0.31 square mile])
- NRCS TR-55 (no basin area limitation)

4.1.1 USGS Regression Equations

The USGS first introduced Regression Equations specific to Alaska (and the Yukon River) in 2003 and divided the state geographically into seven regions (Curran et al. 2003). These regions were drawn to group areas with similar hydrologic characteristics (e.g., climate, terrain) and had regression equations specific to each region. These equations were developed by analyzing the hydrologic characteristics of between 25 and 97 basins throughout each region. Basin characteristics that were used in the regression equations varied by region but typically (except for the North Slope) included basin area and mean annual precipitation, in addition to other regional characteristics such as percent storage area, elevation, percent forested area, and mean January temperature. The Regression Equations were updated and simplified in 2016, combining all seven regions into one and changing the hydrologic characteristics used in the equations to just two: basin area and mean annual precipitation (Curran et al. 2016). The basin for the runway culvert meets the 2016 Regression Equations' recommended criteria and was used for flood frequency analysis at the site.

To calculate discharges of various return intervals, basins are delineated in ArcMap using high-resolution imagery and topographic mapping. Precipitation values are developed in ArcMap by area-weighting the Mean Precipitation for Alaska 1971–2000 Parameter-elevation Regression on Independent Slopes Model (PRISM) dataset sponsored by the National Park Service (NPS) (Gibson, 2009).

4.1.2 NRCS TR-55 Method

TR-55 is a simplified version of the NRCS TR-20, which is used to estimate storm runoff and peak discharge for small basins. TR-55 uses basin geometry, 24-hour local rainfall depth, ground cover type, and peak discharge curves to estimate time of concentration and flood frequencies.

As part of the TR-55 method, the maximum flow length for each basin was determined using Geographic Information Systems (GIS) and surface LiDAR survey data obtained through the Alaska Division of Geological and Geophysical Surveys. The TR-55 method divides overland flow into three categories when estimating peak runoff: shallow sheet flow, shallow concentrated flow, and open channel flow. TR-55 states that open channel flow calculations should be used only in areas "where cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets (NRCS, 1986)."

Because limited cross sections or formal stream surveys exist for the project area, the flow lengths used to calculate times of concentration were broken down as follows. The first 300 feet of overland flow was designated as sheet flow. In basins where none of the information previously stated was available, the remaining flow length was split evenly between shallow concentrated flow and open channel flow. In basins where blue lines are present on USGS quadrangle sheets, the length of each blue line was assigned to open channel flow and the remaining flow length was assigned to shallow concentrated flow.

Local rainfall depth for the 24-hour event was obtained from the NOAA Atlas 14, Volume 7, Version 2 point precipitation frequency estimates.

4.1.3 FHWA HEC-17 Analyses

The Federal Highway Administration (FHWA) provides technical guidance for analyzing highways during extreme events in the Hydraulic Engineering Circular (HEC)-17, *Highways in the River Environment – Floodplains, Extreme Events, Risk, and Resilience* (FHWA 2016). HEC-17 lays out five varying levels of analysis to account for risk and vulnerability assessments. The appropriate level is chosen based on information available, project needs, and service life (see Chapter 7 of HEC-17 [FHWA 2016]).

A Level 2 analysis, which includes the analysis of confidence limits in addition to the Level 1 – Historical Discharge Analysis, was determined to be appropriate. The Level 1 analysis is completed and summarized in Section 4.1.4. Based on a hydrologic service life of between 30 and 75 years, the Level 2 analysis reviews the 68 percent confidence interval of the design discharge and other methods of estimating nonstationary impacts, specifically anticipated increases in precipitation due to climate change. These values allow for consideration of a larger exposure period, when the probability of extreme events and nonstationary impacts increase, and current estimates of climate change impacts.

To estimate increases to flows over the service life of the culvert (30-75 years), the University of Alaska Fairbanks Scenarios Network for Alaska + Arctic Planning (SNAP) data were used to adjust the annual PRISM precipitation data and the NOAA Atlas 14, Volume 7, Version 2 point precipitation frequency estimates.

SNAP has predicted an overall increase in annual precipitation of 9.1 percent for the years 2060–2069 and 17 percent for the years 2090–2099. The 2090–2099 precipitation values were used as they provide a more conservative estimate for the anticipated service life of the project. These increased factors were applied to the PRISM annual precipitation data used in the 2016 Regression Equations. It should be noted that the (limitations of) 2016 Regression Equations cautions users when exploring the potential for future precipitation increases from climate models within the Regression Equations because of the unknown error associated with the combination of methods. Because of this uncertainty, the SNAP adjusted results provided below are not intended for use as design flows.

Effects of climate change for the 24-hour rainfall event were also estimated based on SNAP data for the project area. SNAP currently has two Global Circulation Models (GCMs) that predict future short-duration rainfall events for the service life of the proposed structure (the years 2080–2099 were selected for this analysis): the NOAA Geophysical Fluid Dynamics Laboratory - Coupled Model 3.0 (GFDL-CM3) and the National Center for Atmospheric Research - Atmospheric Research Community Earth System Model 4 (NCAR-CCSM4). GFDL-CM3 uses an aggressive climate change model and estimates an increase in the 50-year, 24-hour rainfall depth of 299 percent. NCAR-CCSM4 uses a less aggressive but still conservative climate change model and predicts an increase in the 50-year, 24-hour rainfall depth of 59 percent, deeming it the chosen GCM for this analysis.

Table 3 shows the comparison of the design discharge for the basin (Level 1) with the upper limit of the 68 percent confidence interval and the SNAP adjusted 2016 Regression Equations. The purpose of this comparison is for design consideration, looking at the potential consequences, and mitigating where feasible and reasonable. These values are not meant to be used as design criteria.

Table 3: Level 2 HEC-17 Analyses

Stream Name	**Runway Culvert Basin Unnamed Tributary of the Kun River**		
Estimation Method	2016 USGS Regression Equations		
Adjustment	**None**	**Upper 68% Confidence Interval**	**SNAP Adjusted**
Return Period	Estimated Discharge (cfs)		
2-year	13	25	15
10-year	35	66	40
25-year	50	94	56
50-year	62	118	70
100-year	75	145	84

Notes: USGS = United States Geological Survey; cfs = cubic feet per second; SNAP = Scenarios Network for Alaska + Arctic Planning.

4.1.4 Flood Frequency Analyses Results

Table 4 and Table 5 summarize the results of the flood frequency analysis for the runway culvert and the Kun River respectively. Flood frequency analysis results for the Kun River were calculated for use in coastal analysis (see Coastal Analysis Report) and were not used to size the runway culvert. The 2016 USGS Regression Equations, and the SNAP adjusted TR-55 (only used for the runway culvert) results are included. The SNAP adjusted TR-55 results include estimates for future changes in precipitation for the service life of the culvert (30-75 years). Flood frequency analysis calculations are included in Appendix B.

Table 4: Flood Frequency Analysis Summary for the Runway Culvert

Return Period	Estimated Discharge (cfs)	
	2016 USGS Regression Equations	TR-55 with SNAP Adjustment
2-year	**13**	3.3
10-year	**35**	16
25-year	**50**	27
50-year[a]	**62**	37
100-year	**75**	49

Table 5: Flood Frequency Analysis Summary for the Kun River

Return Period	Estimated Discharge (cfs)
	2016 USGS Regression Equations
2-year	**3,235**
10-year	**5,937**
25-year	**7,403**
50-year[a]	**8,500**
100-year	**9,630**

The flood frequency results from the 2016 USGS Regression Equations will be used for design. Flood frequency analysis calculations are included in Appendix B.

4.1.5 Fish Passage Flows

Fish passage design is currently not within the project scope, as the crossing was not nominated for fish passage within the AWC prior to project initiation. Discussion with ADF&G indicates that maintaining connectivity with the anadromous Kun River is a desired project outcome. While no sampling or other methods for verifying fish residency have occurred, the unnamed tributary to the Kun River is assumed to have resident fish due to its unobstructed connection to the Kun River.

The DOT&PF and ADF&G Fish Passage Memorandum of Agreement outlines three tiers of design for fish passage: Tier 1 is stream simulation, Tier 2 is FISHPASS Program design, and Tier 3 is hydraulic engineering design. **As of the release of this report, a decision has not been made for the fish passage tier requirement.**

Once guidance from DOT&PF and ADF&G is obtained on the level of fish passage design requested, further analysis will need to be conducted to meet the chosen tier requirements. It should also be noted that the design fish species, size, and time of year will need to be supplied by ADF&G before further analysis can be conducted.

5. Hydraulic Analysis

Hydraulic calculations utilize FHWA's HY-8, version 7.60 (FHWA 2019), for hydraulic analysis at the runway culvert. HY-8 uses several essential design features for the crossing structure, tailwater, and roadway to automate culvert hydraulic calculations.

Additional hydraulic design considerations were made for this crossing, including tidal influence and fish passage. To accommodate tidal changes and floating debris, the crown of the culvert outlet should be designed 2 feet above the MHHW elevation to provide headspace in the culvert during high tide events. It should be noted that this crossing will be designed to the MHHW elevation, and not to coastal storm surge event elevations.

Fish passage requirements may change the maximum HW/D ratio and would need to be addressed. Section 5.1 presents the hydraulic characteristics and analyses for the existing and proposed structures.

5.1 Crossing Structure Sizing

The recommended structure has design criteria (tidal influence and fish passage) outside of the required hydraulic minimums that drove the structure selection. Hydraulic analysis served as a verification of the structure size selected. To accommodate tidal influence, the structure's outlet crown elevation was set at least 2 feet above the MHHW elevation with consideration for relative sea level rise of 0.63 feet (crown minimum of 9.40 feet) and the structure diameter was sized to maintain a HW/D ratio of less than 1.5 during the 50-year coastal storm surge event. To accommodate fish passage design, the inlet and outlet invert elevations were selected to maintain a constant hydraulic connection with the Kun River. Various other parameters may need to be met in the future based on a design fish and design flow required for fish passage design criteria.

A 72-inch-diameter culvert was needed to meet the minimum crown elevation requirement at MHHW. When modeling the 100-year upper 68 percent confidence interval of 145 cubic feet per second (cfs), a 72-inch-diameter culvert produces a HW/D ratio of 1.43.

The HW/D ratio for a 72-inch-diameter culvert during the 50-year return interval coastal storm surge event is 1.93. An increased structure size of a 96-inch-diameter culvert produces a HW/D of 1.44. In this case, the increase in cost and constructability of a 96-inch-diameter pipe in comparison with a 72-inch-diameter pipe is likely minimal in the overall project cost, and therefore justifies upsizing the pipe to 96-inches based on this design criteria.

See Figure 4 for a profile of the proposed culvert at the design discharge, Q_{50}, of 62 cfs. Table 6 summarizes the existing and proposed crossing structures and characteristics. Refer to Table 7 and Table 8 for summaries of the existing and proposed crossing structure hydraulics. See Appendix C for the HY-8 report and riprap apron calculations.

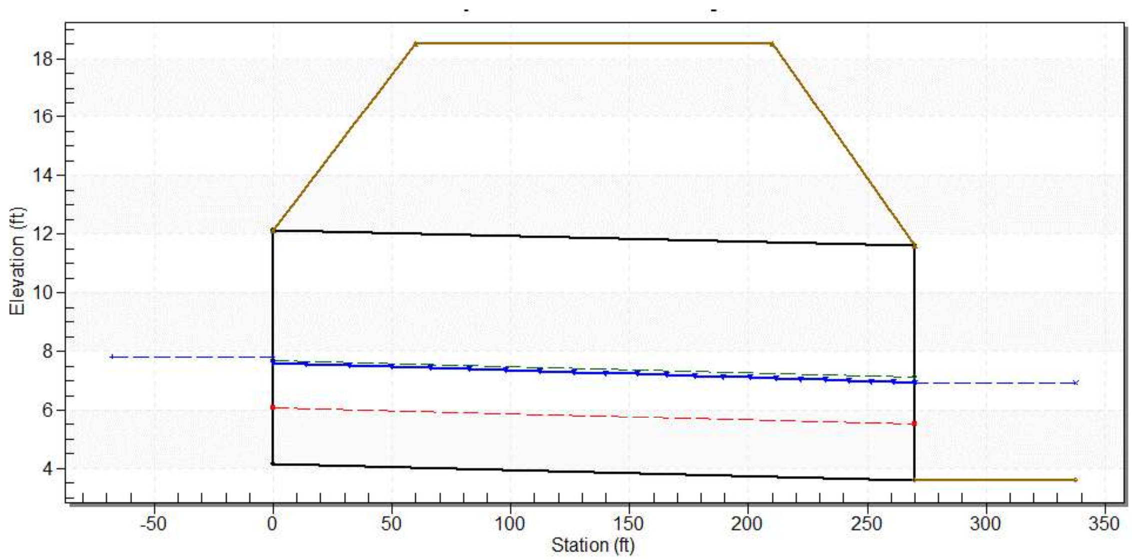


Figure 4: Proposed Culvert Profile at Q_{50} (62cfs)

Table 6: Existing and Proposed Culvert and Channel Characteristics

Culvert Name	Runway Culvert	
Structure	Existing Structure	Proposed Structure
Length (feet)	199	270
Shape and Dimension	48-inch, round, smooth-wall HDPE	96-inch, round, 8-gage[a] aluminum structural plate
Culvert Slope (%)	0.2	0.2
US Channel Slope (%)	1.3	
DS Channel Slope (%)	0.1	

Notes: HDPE = high-density polyethylene; US = upstream; DS = downstream.
[a] If 8 gage is unavailable, 10 gage is also acceptable.

Table 7: Existing Structures Hydraulic Analysis

Basin Name	Event (Q-Year)	Discharge (cfs)	Existing Structure				
			Headwater Elevation (feet)	Culvert Discharge (cfs)	Roadway Discharge (cfs)	HW/D[a]	Tailwater Elevation (feet)
Runway Culvert	2	13	5.65	13	0		4.75
	50 (Design)	62	8.08	62	0		6.93
	100	75	8.79	75	0	1.2	7.42
	Upper 68% (50)	118	12.40	118	0	2.1	7.60
	Overtopping	126	13.2	126	0	2.3	7.60

Notes: cfs = cubic feet per second; HW/D = headwater depth to culvert diameter ratio.
[a] Blank unless HW/D is greater than 1.0.

Table 8: Proposed Structures Hydraulic Analysis

Basin Name	Event (Q-Year)	Discharge (cfs)	Proposed Structure Non-tidally influenced				Proposed Structure Tidally (MHHW) influenced			
			Headwater Elevation (feet)	Culvert Discharge (cfs)	HW/D[a]	Tailwater Elevation (feet)	Headwater Elevation (feet)	Culvert Discharge (cfs)	HW/D[a]	Tailwater Elevation (feet)
Runway Culvert	2	13	5.77	13		4.75	7.43	13		7.40
	50 (Design)	62	7.80	62		6.93	8.05	62		7.40
	100	75	8.25	75		7.42	8.24	75		7.40
	Upper 68% (50)	118	9.73	118		8.94	9.03	118		7.40
	Overtopping	315 / 500	18.50	315	1.8	12.00	18.50	500	1.8	7.40

Notes: cfs = cubic feet per second; HW/D = headwater depth to culvert diameter ratio.
[a] Blank unless HW/D is greater than 1.0.

5.1.1 Runway Culvert

The existing culvert is a 48-inch, round, smooth-wall HDPE pipe, is 198.15 feet in length with a 0.2 percent slope, and has an estimated HW/D ratio of 1.02 at the 50-year discharge. Its inlet and outlet inverts are at 4.0 feet and 3.6 feet, respectively. The outlet invert is 0.01 foot above the MTL and 3.17 feet below the MHHW.

The proposed culvert is a 270-foot-long, 96-inch, 8-gage aluminum structural plate culvert, at a 0.2 percent slope. When selecting culvert material, aluminum was preferred over steel due to its increased corrosion resistance to seawater. Structural plate pipe was selected over corrugated pipe because it comes in a thicker gage (8-gage vs 10-gage) and can be shipped in stacks of 4.5-foot sheets to cut cost getting to the site. 10-gage corrugated aluminum pipe is a viable alternative to structural plate, however, it can only be shipped in 20-foot long segments and may be more expensive to barge to the site.

The proposed culvert will pass the 50-year design discharge and the 100-year discharge with a HW/D ratio of less than 1. Its proposed inlet and outlet inverts are at 4.15 feet and 3.6 feet, respectively, keeping the same outlet invert elevation as existing conditions. To accommodate tidal influence, the structure's outlet crown reaches 11.6 feet in elevation, more than accounting for the desired 2 feet above the MHHW elevation (crown minimum of 8.77 feet). This additional elevation will allow for headspace in the culvert during high tide events and allow for up to 0.63 feet of relative sea level rise (see accompanying *Coastal Report*). When considering crossing resilience through HEC-17, a 72-inch culvert was determined to provide a more conservative design and allow for greater resiliency with a minimal increase in material and construction costs.

5.2 Riprap Protection

The flows from the unnamed tributary of the Kun River are significantly smaller and slower in velocity when compared to tidal influxes. Therefore, the inlet and outlet scour protection will be based on tidal flows and velocities. The riprap protections required for the tidal flows are analyzed and calculated in the accompanying *Coastal Report* and were determined to have an average diameter of 1.4 feet and average weight of 238 pounds. The riprap protection that will be used for the coastal applications will also be used to surround the inlet and outlet and serve as riprap aprons at their entrances. A mixture of sands, gravels, and fines should be placed within the upstream and downstream channel to fill voids between riprap to allow for migration of any local fish species into and out of the runway culvert. Mixture specifications will be specified at a future stage of design.

The Drainage Manual does not include guidance on the design of energy dissipators and riprap aprons. Chapter 10 of FHWA's HEC-14: *Hydraulic Design of Energy Dissipators for Culverts and Channels* (FHWA 2006) was used for the riprap apron design. The median riprap diameter size, or D50, is calculated using input variables of the design discharge, culvert diameter, and tailwater depth. Supercritical flow requires an additional adjustment using the normal depth within the culvert. Once the size of the riprap is determined, it can be compared to standard riprap classes. The dimensions of the riprap apron are determined based on the riprap class and diameter of the culvert.

Apron calculations can be found in Appendix C, and its layout and details can be found in the plan set.

5.3 End Section Treatment

The proposed culvert is designed to pass the 50-year return interval coastal storm-surge event with a HW/D ration of less than 1.5. During these events, the culvert may contain an air pocket that would create a buoyant force, possibly displacing the culvert upward. Anchors at each end of the culvert (inlet and outlet) are proposed to restrain against these buoyant forces. Concrete headwalls are recommended due to the lack of geotechnical information at the project site.

Based on buoyant force calculations, 20,032 pounds of restraining force, located 1 foot from each culvert end, is required to overcome buoyant forces under inundated, storm-surge conditions. Based on DOT&PF's standard plans for drainage, a precast, type 1, concrete headwall for a 96-inch culvert with 2 to 1 side slopes will provide the necessary restraining force (DOT&PF 2019).

6. Floodplain Management

This project is outside the limits of any Federal Emergency Management Agency (FEMA) mapped floodplain areas. As a federally funded project, this project is subject to the requirements of Executive Order 11988, which stipulates avoidance and mitigation of potential impacts to the 100-year floodplain (FEMA 1977). In addition, the enlarged culvert at the crossing will not increase the elevation of the 100-year floodplain. The proposed design calls for additional conveyance in the form of an enlarged structure where drainage improvements are included.

7. Summary and Recommendation

Table 9 outlines the existing and proposed culverts, with notes and details specific to the crossing.

Table 9: Culvert Summary Table

Purpose	Drainage Feature	Design Flow (cfs)	Anadromous Stream	Existing Structure					Proposed Work				
				Shape/ Type	Size (inches)	Length (feet)	Inverts (feet)	Discharge at HW/D = 1 (cfs)	Shape/ Type	Size (inches)	Length (feet)	Inverts (feet)	Discharge at HW/D = 1 (cfs)
Runway Culvert	Unnamed tributary of the Kun River	62 (50-year)	No	Round / HDPE	48	199	Inlet = 4.0 Outlet = 3.6	61	Round / SP Aluminum	96	270	Inlet = 4.15 Outlet = 3.6	184

Notes: cfs = cubic feet per second, HDPE = high density polyethylene, HW/D = headwater / diameter, SP = structural plate

8. References

ADF&G (Alaska Department of Fish and Game). 2021a. *Anadromous Waters Catalog*. Available at https://www.adfg.alaska.gov/sf/SARR/AWC/index.cfm?ADFG=data.GIS.

ADF&G. 2021b. Fish Passage Inventory Database (FPID). Available at http://www.adfg.alaska.gov/index.cfm?adfg=fishpassage.database.

ADNR (Alaska Department of Natural Resources). 2021a. Navigable Waters Map. Division of Mining, Land and Water. Available at http://dnr.alaska.gov/mlw/nav/map/.

ADNR. 2021b. Alaska Mining Claims Mapper. Available at http://akmining.info/.

Curran, J.H., D.F. Meyer, and G.D. Tasker. 2003. *Estimating the Magnitude and Frequency of Peak Streamflows for Ungaged Sites on Streams in Alaska and Conterminous Basins in Canada. Water-Resources*. Water-Resources Investigations Report 03-4188. U.S. Geological Survey. Available at https://pubs.usgs.gov/wri/wri034188/.

Curran, J.H., N.A. Barth, A.G. Veilleux, and R.T. Ourso. 2016. *Estimating Flood Magnitude and Frequency at Gaged and Ungaged Sites on Streams in Alaska and Conterminous Basins in Canada, Based on Data through Water Year 2012*. Scientific Investigations Report 2016-5024. U.S. Geological Survey. Available at http://dx.doi.org/10.3133/sir20165024.

Daly, C., J. Smith, and M. Halbleib. 2018. 1981-2010 High-Resolution Temperature and Precipitation Maps for Alaska. Available at https://prism.oregonstate.edu/projects/alaska.php.

Dewitz, J. 2020. National Land Cover Database (NLCD) 2016 Products. Version 2.0. U.S. Geological Survey data release, Available at https://doi.org/10.5066/P96HHBIE.

DOT&PF (State of Alaska Department of Transportation and Public Facilities). 2001. Memorandum of Agreement Between Alaska Department of Fish and Game and Alaska Department of Transportation and Public Facilities for the Design, Permitting, and Construction of Culverts for Fish Passage. Available at https://dot.alaska.gov/stwddes/desenviron/assets/pdf/procedures/dot_adfg_fishpass080301.pdf.

DOT&PF. 2004. Airport Layout Plan for Scammon Bay Airport. Available at https://dot.alaska.gov/stwdav/airports_public_central.shtml, accessed July 2021.

DOT&PF. 2006. *Alaska Highway Drainage Manual.* Available at http://www.dot.alaska.gov/stwddes/desbridge/pop_hwydrnman.shtml.

DOT&PF. 2013a. *Alaska Highway Preconstruction Manual*, Section 1120.5.6, Elements of Design: Hydrologic and Hydraulic Reports. Available at http://www.dot.state.ak.us/stwddes/dcsprecon/assets/pdf/preconhwy/chapters/chapter11.pdf.

DOT&PF. 2013b. 2013 Scammon Bay Airport Flood Permanent Repairs DMVA/FEMA. Project No. Z583570000/FEMA DR-4182-AK. Provided by DOT&PF.

DOT&PF. 2019. Standard Plans – English, (D) Drainage – Culverts & Sewers, D-31.01 Headwalls -- Precast -- Type I. Available at https://dot.alaska.gov/stwddes/dcsprecon/stddwgspages/drainage_eng.shtml, accessed July 2021.

FEMA (Federal Emergency Management Agency). 1977. Executive Order 11988--Floodplain management. Available at https://www.archives.gov/federal-register/codification/executive-order/11988.html, accessed July 2021.

FHWA (Federal Highway Administration). 2006. Hydraulic Engineering Circular No. 14, 3rd Edition: Hydraulic Design of Energy Dissipators for Culverts and Channels.

FHWA. 2016. Hydraulic Engineering Circular No. 17, 2nd Edition: Highways in the River Environment – Floodplains, Extreme Events, Risk, and Resilience.

FHWA. 2019. HY-8 Culvert Hydraulic Analysis Program, Version 7.60. Available at https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/.

NOAA (National Oceanic and Atmospheric Administration). 2021a. Tidal Bench Mark for Kun River at Scammon Bay, Alaska. Station ID 9467124. Available at https://tidesandcurrents.noaa.gov/benchmarks/9467124.html, accessed June 2021.

NOAA. 2021b. Datums by Station. Station 9467124, Kun River AK. Available at https://tidesandcurrents.noaa.gov/datums.html?id=9467124, accessed June 2021.

NRCS (Natural Resources Conservation Service). 1986. Urban Hydrology for Small Watersheds, TR-55. Available at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf.

SNAP (Scenarios Network for Alaska + Arctic Planning) 2021. Precipitation Projections for Alaska Infrastructure. Available at https://uaf-snap.org/web-tool/precipitation-projections-for-alaska-infrastructure/, accessed June 2021.

State of Alaska Division of Geological & Geophysical Surveys. 2021. Elevation Portal. IfSAR, Y-K Delta 2016 LiDAR, Scammon 2015 SFM elevation data. Available at https://elevation.alaska.gov/#61.86845:-165.51933:11, accessed June 2021.

U.S. Census Bureau. 2020. Scammon Bay city, Alaska, population. Available at https://data.census.gov/cedsci/profile?g=1600000US0267680, accessed June 2021.

USACE (United States Army Corps of Engineers). 2009. Alaska District. Alaska Barge Landing System Design Statewide Phase 1. Available at https://www.poa.usace.army.mil/Portals/34/docs/civilworks/archive/alaskabargelandingsystemdesignstatewidephase1.pdf, accessed July 2021.

USGS (United States Geological Survey). 2016. *Estimating Flood Magnitude and Frequency at Gaged and Ungaged Sites on Streams in Alaska and Conterminous Basins in Canada, Based on Data through Water Year 2012*. Scientific Investigations Report 2016-5024.

USGS. 2021. National Geospatial Program, 20210614, USGS National Hydrography Dataset Best Resolution (NHD) for Hydrologic Unit (HU) 4 - 1909 (published 20210614): U.S. Geological Survey. Available at https://www.sciencebase.gov/catalog/item/5a58a580e4b00b291cd690ae, accessed June 2021.

Western Regional Climate Center. 2021. CAPE ROMANZOF, ALASKA (501318). Monthly Climate Summary for 05/01/1953 to 02/24/1985. Available at https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?ak1318, accessed June 2021.

Wilson, F.H., C.P. Hults, C.G. Mull, and S.M. Karl (compilers). 2015. Geologic map of Alaska: U.S. Geological Survey Scientific Investigations Map 3340, pamphlet 196 p., 2 sheets, scale 1:1,584,000, http://dx.doi.org/10.3133/sim3340. Online mapper available at: https://alaska.usgs.gov/science/geology/state_map/interactive_map/AKgeologic_map.html, accessed June 2021.

This page intentionally left blank.

Appendix A – Field Notes and Trip Report

Appendix B – Flood Frequency Estimates and Supporting Data

Appendix C – HY-8 Report and Riprap Apron Calculations

Appendix A – Field Notes and Trip Report

Site Visit Report

Date:	Tuesday, May 25, 2021
Project:	Scammon Bay Airport Improvements CFAPT00691
To:	Jenelle Brinkman, PE (DOT&PF)
From:	Ronny McPherson, PE (HDR) Irene Turletes, PE (HDR)
Subject:	Scammon Bay Coastal and H&H Site Visit

A site visit was performed to Scammon Bay, AK to support the hydraulics & hydrology (H&H) and coastal processes in the vicinity of the Scammon Bay runway. The site visit occurred on May 18th, 2021 from approximately 2:30pm to 5:30pm. Conditions at the site were considered wintery/spring breakup, however, enough of the runway, runway edge, access road, surrounding uplands, and existing culvert were exposed to allow for an adequate understanding of the site. Weather was in the upper 30s and overcast for the duration of the site visit.

Site visit attendees included the following:

- Philip Cheasebro, DOT&PF
- Rory Bryant, DOT&PF
- Bill Starn, CRW
- Irene Turletes, HDR
- Ronny McPherson, HDR

The following provides observations from the site visit.

Existing Runway Culvert

1. The existing culvert spanning the width of the runway appears to be sagging and partially collapsed in three locations. The culvert was confirmed to be 3.5 feet diameter non-metallic (HDPE). Class I riprap was placed at both inlet and outlet for approximately 10 feet.
2. The stream at the culvert outlet appears to be approximately 5 feet wide with a depth of 1 foot at the time of the site visit. Immediately downstream, the channel became 10 to 14 feet wide and 0.5 to 0.75 feet deep at the thalweg. The stream appears to be tidal as evident by the 2 to 3 feet nearly vertical stream banks.
3. The upstream side at the culvert inlet had a large pool approximately ten to fifteen feet wide and approximately twenty feet long with a depth of approximately 2 feet at the time of the site visit. There was a noticeable foul odor at the culvert inlet and is suspected to be caused by some amount of effluent from the nearby wastewater lagoon. The inlet was not visible due to snow.

East Runway Terminal

1. There were no signs of obvious erosion due to wave action that would have occurred during upland flooding nor were the obvious signs of scour due to swift currents from

filling or draining the area between the runway and the adjacent higher land elevation during a storm surge.
2. There were signs of typical upland runoff erosion (e.g., rilling) and signs of heavy equipment and ATV wheel trenches along the perimeter.
3. The remnants of a burnt snowmachine was observed just landward of the east runway terminal
4. The east runway RSA elevation undulated significantly with noticeable ATV traffic
5. The lower elevations of the terminal bank had well established thick vegetation (i.e., alders, willows, or similar).
6. The windsock spur represents the shortest distance from the runway to the adjacent higher land elevation. There were no obvious signs of erosion or scour from waves/storm surge at this location. The bank material at this location primarily consisted of 2- to 4-inch gravel with very little fines.

West Runway Terminal

1. Armor rock material is placed along the western runway terminal which appeared to be in the DOT&PF Class II Riprap size range.
2. Several armor rocks were observed to be displaced and are no longer interlocked with the structure on north side of the runway. The armor rock at the very west terminal (immediately adjacent to the Kun River) was entirely displaced leaving only small stone material and fines.
3. The Kun River was observed to have a very slow flow rate (<1 fps) at the time of the site visit.

Anecdotal Data

Scammon Bay residents provided some anecdotal data when inquired about storm surge in the area. The following summarizes their comments

1. Storm surge only happens in the Fall (September through November). The latest storm surge recalled was once in December.
2. The highest storm surge recalled was shin to knee high above the runway apron. This equates to approximately +14 feet NAVD.
3. All houses in the community are higher than historical storm surge elevations.
4. When storm surges recede, it creates very fast currents around the East Runway Terminal. Noting that the river east of the runway and the Kun River also flows very quickly during these times.

Figure 1. Runway access road. Side slopes appeared to be in good condition – no obvious signs of scour/erosion.

Figure 2. Runway apron. Anecdotal data provided noted highest surges flood entire apron up to knee high.

Figure 3. Runway, wastewater lagoon, and creek. Photo taken from hillside vantage point south of runway and within the community.

Figure 4. Creek downstream of runway culvert outlet. Nearly vertical banks indicate tidal influence.

Figure 5. Runway culvert outlet.

Figure 6. Inside runway culvert looking from outlet to inlet. The culvert was observed to have some sagging and partially collapse in three locations

Figure 7. Pool at runway culvert inlet.

Figure 8. Side slope at windsock (closest point to adjacent elevation). No obvious scour or erosion caused by storm surge/waves.

Figure 9. Side slopes at east terminal. Vegetation observed along bank with no obvious signs of scour or erosion from storms surge waves.

Figure 10. North slope of runway edge. No obvious signs of recent scour or erosion due to storm surge/waves (side slopes were noted to have been reworked/graded).

Figure 11. Armor rock protection at western terminal along north edge (looking west). Some rocks observed to be displaced.

Figure 12. Armor rock protection at western terminal along north edge (looking east). Some rocks observed to be displaced but less than at the western end.

Figure 13. Western runway terminal. No armor rock observed.

Appendix B – Flood Frequency Estimates and Supporting Data

Project Name: Scammon Bay *Updated: 7/14/21 K. Grundhauser*

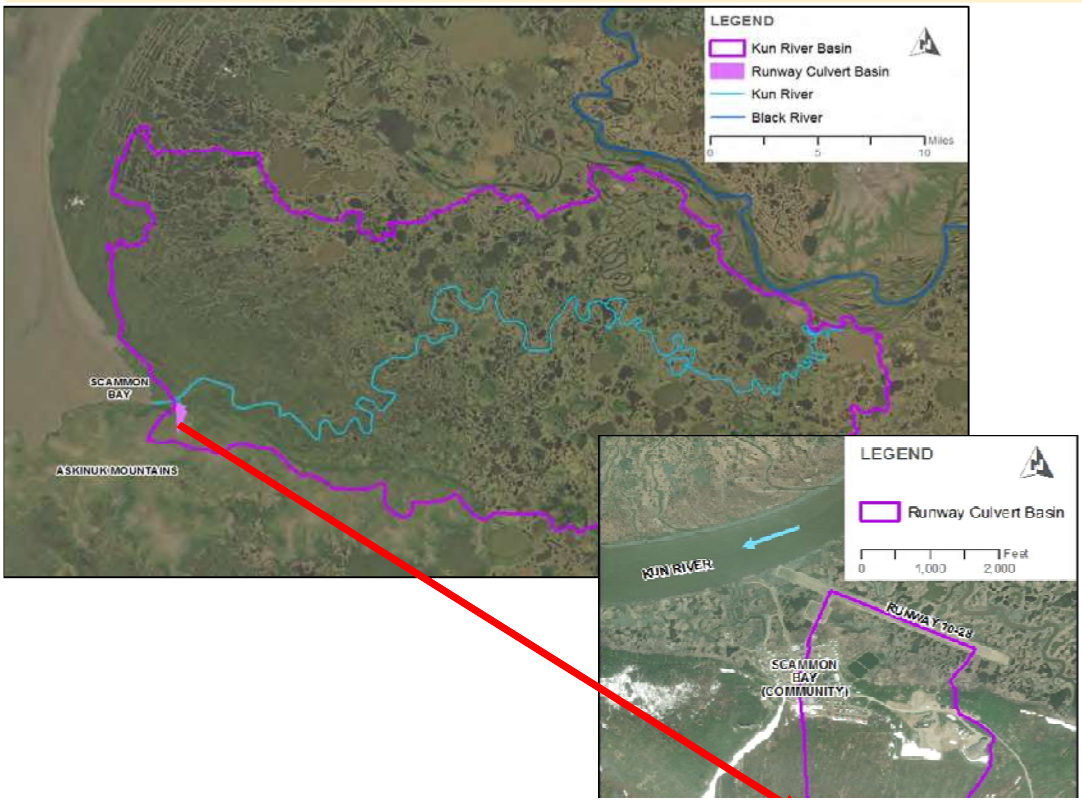
Step 1: Use basin size (ft^2) to determine which peak flow calculation methods apply by basin size.

Basin #	Basin Size	Basin Size	Basin Size	Applicable Method
	ft^2	acres	mi^2	
RW Culvert	**12,915,452**	**296**	**0.463**	**2016 USGS Regression Equations**
Kun River	**12,857,297,057**	**295163**	**461**	**2016 USGS Regression Equations**

Basin falls within 2016 USGS Regression Equation parameters

Basin falls only within NRCS TR-55 Parameters

Basin falls within Rational Method parameters and NRCS TR-55 parameters



Project Name Scammon Bay
Step 2: Calculate flows using 2016 USGS Regression Equations, flows incorporating SNAP Climate Data, and flows adjusting for local gage factors.

2016 USGS Regression Equations					% Exceedance							
					50%	20%	10%	4%	2%	1%	0.5%	0.2%
ADF&G Culvert ID #	**Basin Size**	**Basin Size**	**PRISM Precip ***	**PRISM Precip**	**2-year**	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**	**200-year**	**500-year**
	ft^2	mi^2	mm*100	in	2016 Regression Flow (cfs)							
RW Culvert	**12,915,452**	**0.46**	**58,047**	**22.9**	**12**	**24**	**33**	**47**	**58**	**71**	**84**	**103**
Kun River	**12,857,297,057**	**461.19**	**48,231**	**19.0**	**3235**	**4804**	**5937**	**7403**	**8500**	**9630**	**10778**	**12312**

*Values calculated in GIS using Zonal Statistics tool with basin polygons and 1 m by 1 m resampled rainfall raster.
Source: Mean Precipitation for Alaska 1981-2010, https://prism.oregonstate.edu/projects/alaska.php
**See SNAP Data

Basin falls within 2016 Regression Equation parameters
Basin falls outside of 2016 USGS Regression Equations

ADF&G Culvert ID #	**Basin Size**	**SNAP** Adjusted PRISM Precip**	% Exceedance							
			50%	20%	10%	4%	2%	1%	0.5%	0.2%
			2-year	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**	**200-year**	**500-year**
	mi^2	in	SNAP Adjusted Flow (cfs)							
RW Culvert	**0.46**	**26.7**	**14**	**27**	**38**	**53**	**66**	**80**	**95**	**116**
Kun River	**461.19**	**22.2**	**3800**	**5548**	**6802**	**8416**	**9620**	**10860**	**12115**	**13790**

Local Stream Gage Factors

Map Identification No.	**USGS Station No.**	**USGS station Name**	**Annual exceedance probability discharge, in cubic feet per second**												**Skew coefficient used for Sta AEP**	**Skew coefficient used in appendix B**	**MSE of skew coefficient used in appendix B**
			50-percent			**20-percent**			**10-percent**			**4-percent**					
			Sta	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**			
219	15304000	Kuskokwim River at Crooked Creek, Alaska	162,000	121,000	161,000	212,000	150,000	212,000	243,000	169,000	243,000	281,000	193,000	280,000	-0.141	0.260	0.154
361	15621000	Snake River near Nome, Alaska	2,710	925	2,680	3,430	1,450	3,400	3,820	1,830	3,790	4,240	2,340	4,200	-0.555	-0.555	0.235
209	15302000	Nuyakuk River near Dillingham, Alaska	19,400	17,300	19,400	23,200	22,800	23,200	25,400	26,500	25,500	27,900	31,200	28,000	-0.203	-0.202	0.115

Map Identification No.	**USGS Station No.**	**USGS station Name**	**Annual exceedance probability discharge, in cubic feet per second**												**Skew coefficient used for Sta AEP**	**Skew coefficient used in appendix B**	**MSE of skew coefficient used in appendix B**
			2-percent			**1-percent**			**0.5-percent**			**0.2-percent**					
			Sta	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**	**Sta**	**Reg**	**Wtd**			
219	15304000	Kuskokwim River at Crooked Creek, Alaska	308,000	210,000	306,000	334,000	226,000	331,000	359,000	243,000	355,000	392,000	264,000	385,000	-0.141	0.260	0.154
361	15621000	Snake River near Nome, Alaska	4,510	2,740	4,460	4,750	3,140	4,690	4,960	3,560	4,890	5,220	4,120	5,140	-0.555	-0.555	0.235
209	15302000	Nuyakuk River near Dillingham, Alaska	29,600	34,700	29,700	31,200	38,100	31,300	32,700	41,600	32,800	34,500	46,100	34,800	-0.203	-0.202	0.115

[Location of map identification Nos. are shown in figure 1. **Usage in this report**: Regr, used to develop regression equations; RegISkew, used to develop regional skew; redundant, omitted from any regional analysis on the basis of hydrologic redundancy with another site; Sta, used for station analysis only. INF, infinity; No., number; PILF, potentially influential low flood; USGS, U.S. Geological Survey. ft^3/s, cubic feet per second; in., inches; mi^2, square miles]

Map identification No.	**USGS station No.**	**Station name**	**Drainage area (mi^2)**	**Mean annual precipitation (in.)**	**Kendall *tau* correlation coefficient, for sites having statistically significant trends**	**Kendall *tau* *p*-value**	**Usage in this report**	**Skew Region, for sites within applicable range of drainage area**	**Period of record used**	**Historic period length (years)[1]**	**Water year(s) for data omitted from analysis[2]**	**Number of peaks in record[3]**	**Perception threshold for water years noted (ft^3/s)[4,5]**	**Interval discharge range for noted water year (ft^3/s)[5]**	**PILF threshold (ft^3/s)[6]**	**Number of PILFs**
219	15304000	Kuskokwim River at Crooked Creek, Alaska	31100	21	--	--	Regr	--	1952-2012	61		60	1995: INF-INF (j, p)	--	--	--
361	15621000	Snake River near Nome, Alaska	86	22	--	--	Regr	--	1965-1991	27	1994 (d)	27		--	--	--
209	15302000	Nuyakuk River near Dillingham, Alaska	1510	37	--	--	Regr	--	1954-2012	59		50	1997-2002, 2005-2007: INF-INF (j, p)	--	--	--

Project Name Scammon Bay
Step 3: Calculate flows using TR-55 Method

*TR-55 Applied to all basins for comparison purposes. See TR-55 Publication for more detailed information about TR-55 Method and limitations.

Compute Watershed Runoff (Chapter 2)

Part 1: Determine Basin** area and CN
**If the basin is one homogenous basin, use only subbasin 1 and leave others blank. Otherwise break up basin into major subbasins

Basin ID*	Gravel/Dirt Road/Residential			Brush / Forest			Herbaceous / Water / Wetlands			Product of CN x Area
	Description	Area (sq. ft)	CN	Description	Area (sq. ft)	CN	Description	Area (sq. ft)	CN	
RW Culvert	Residential	2264152.82	82	Schrub / Forest	8762962	70	Brush	1888337	85	**74**

Part 2: Solve for Runoff Q (inches) using eq. 2-4 and eq. 2-3:
Use SNAP future estimates

Basin ID*	CN	S	P - Rainfall (inches) for 24-hour storm					Q - Runoff (inches)				
			2-Year	10-Year	25-Year	50-Year	100-Year	2-Year	10-Year	25-Year	50-Year	100-Year
RW Culvert	74	3.5	1.77	3.12	3.89	4.5	5.15	0.26	1.00	1.54	2.00	2.51

Time of Concentration and Travel Time (Chapter 3)

Part 3: Find Time of Concentration by adding all times Travel times
Part 3A: Calculate sheet flow time using eq. 3-3

*First 300 feet of all flows are assumed to be sheet flow

	Basin Slope		
	Max El (ft)	Min El (ft)	Flow Length (ft)
	Slope Calc		
Sheet	1060	1055	300
Shallow	1055	29.5	6189.8
Open	29.5	6.1	1814.3

Time of Concentration - Sheet Flow					
Basin ID*	Manning's n	L* (ft)	P_2 (in)	S (ft/ft)	T_t (hr)
		Flow Length	*2-yr, 24-hour*	*Slope*	
RW Culvert	0.20	300	0.059	0.0162	3.97

Part 3B: Calculate shallow concentrated flow* time using eq. 3-1

Basin ID*	Surface description	L (ft)	S (ft/ft)	V (ft/s)	T_t (hr)	
		Flow Length	*Slope*	*Average Vel.*		
RW Culvert	Hillside Brush	6190	0.1656	6.7	0.26	(Est. velocity)

Part 3C: Calculate open-channel flow time using eq. 3-3, or using open channel flow calculator***.
Open channel flows lengths assumed to be in a surveyed channel, channels visable from aerial photos, or where streams appear on USGS quadrangle sheets. Assumed a 10 ft wide rectangular channel, Manning's 0.04, at bankfull, ~14 cfs.
***Useful Online open channel flow calculator Auburn Engineering Department
*** For this project open channel flows lengths were measured from USGS topo maps.

Basin ID*	A (ft^2)	P_w (ft)	r (ft)	S (ft/ft)	Manning's n	V (ft/s)	L	T_t (hr)
	XS Area	*Wetted Perimeter*	*Hydraulic Radius*	*Channel Slope*			*Flow Length*	
RW Culvert	5.39	11.08	0.486462094	0.0129	0.04	2.6	1814	0.19

Part 3D: Calculate Time of Concetration by adding Parts 3A-3C.

Time of Concentration				
Basin ID*	Part 3A	Part 3B	Part 3A	T_c (hr)
	Sheet Flow	Shallow Concentrated Flow	Open Channel Flow	
RW Culvert	3.97	0.26	0.19	4.42

Graphical Peak Discharge Method (Chapter 4)

Part 4: Compute the peak discharge using Table 4-1, eq. 4-1, and exhibit 4-I, IA, II, III, or IV

Basin ID*	A_m (sq. mi)	CN	I_a	T_c (hr)	Rainfall Distribution (I, IA, II, III)	F_p	Q (in)	I_{a-2}/P	I_{a-10}/P	I_{a-25}/P	I_{a-50}/P	I_{a-100}/P
	Drainage Area	Runoff CN		Time of Conc.		Pond Factor No = 1.0	Runoff	2-Year Event	10-Year Event	25-Year Event	50-Year Event	100-Year Event
RW Culvert	0.46	74	0.703	4.42	Type I Storm Event	0.7	See Part 2	0.40	0.23	0.18	0.16	0.14

Basin ID*	q_{u-2} (csm/in)	q_{u-10} (csm/in)	q_{u-25} (csm/in)	q_{u-50} (csm/in)	q_{u-100} (csm/in)
	Use T_c & I_a/P with 4-1A	*Use T_c & I_a/P with 4-1A*	*Use T_c & I_a/P with 4-1A*	*Use T_c & I_a/P with 4-1A*	*Use T_c & I_a/P with 4-1A*
RW Culvert	39	48	53	55	58

TR-55 Peak Flows					
Basin ID*	q_{p-2} (cfs)	q_{p-10} (cfs)	q_{p-25} (cfs)	q_{p-50} (cfs)	q_{p-100} (cfs)
	2-Year Discharge	*10-Year Discharge*	*25-Year Discharge*	*50-Year Discharge*	*100-Year Discharge*
RW Culvert	3.3	16	27	37	49

Project Nai Scammon Bay
Step: HEC-17 Upper 68% Confidence Interval Analysis

Enter a site-description name:

Scammon Bay Airport - Runway Culvert

Enter the explanatory variables:

Drainage area, in square miles	DRNAREA	0.46	Equations are valid for DRNAREA between 0.4 and 1,000 mi^2 with PRECPRIS00 between 8 and 280 inches, and for DRNAREA greater than 1,000 and less than 31,100 mi^2 with PRECPRIS00 between 10 and 111 inches.
Mean annual precipitation from 1971-2000 PRISM data, in inches	PRECPRIS00	22.9	

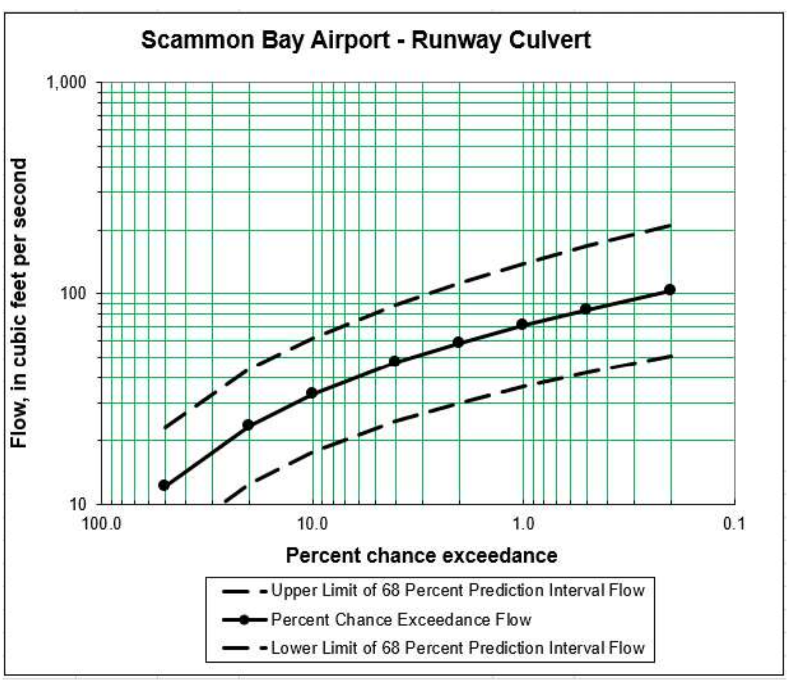
Warnings regarding range of variables:

Results:

Percent chance exceedance	Percent chance exceedance flow, in ft^3/s	Lower limit of 68 percent prediction interval flow, in ft^3/s	Upper limit of 68 percent prediction interval flow, in ft^3/s	-$SEP_{P,i}$ (percent)	+$SEP_{P,i}$ (percent)	Average $SEP_{P,i}$ (percent)
50	12.1	6.4	23.0	-47.4	90.0	71.4
20	23.5	12.5	43.9	-46.7	87.7	69.8
10	33.0	17.6	61.7	-46.8	87.8	69.8
4	46.8	24.6	88.8	-47.5	90.3	71.6
2	58.0	30.2	112	-48.1	92.8	73.4
1	70.6	36.3	138	-48.8	95.2	75.1
0.5	83.8	42.2	167	-49.8	99.3	78.0
0.2	103	50.2	211	-51.4	105.6	82.5

Notes

Differences in rounding of equation parameters can produce minor differences between the results obtained using the regression equations in table 7 and using WREG software. The estimates in this spreadsheet use the regression equations as published in table 7. The regression estimates for streamgages shown in table 4 were computed using WREG during the regression analysis.

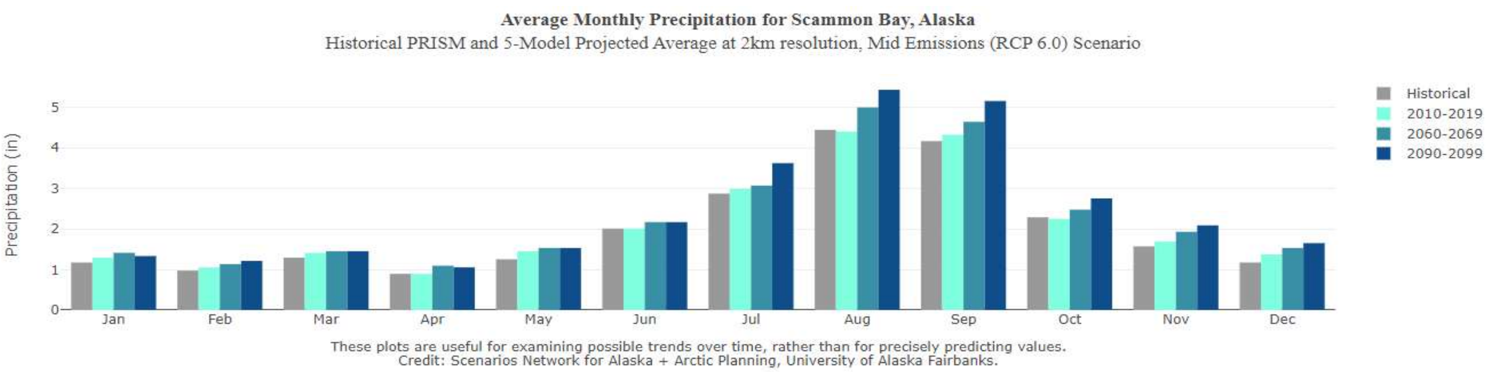


Appendix B: Flood Frequency Estimates and Supporting Data

Scammon Bay, AK SNAP Data**

Month	Precipitation (in)				2010-2099
	Historical	2010-2019	2060-2069	2090-2099	% Increase
January	1.18	1.30	1.42	1.34	3.0
February	0.98	1.06	1.14	1.22	14.8
March	1.30	1.42	1.46	1.46	2.8
April	0.91	0.91	1.10	1.06	17.4
May	1.26	1.46	1.54	1.54	5.4
June	2.01	2.01	2.17	2.17	7.8
July	2.87	2.99	3.07	3.62	21.1
August	4.45	4.41	5.00	5.43	23.2
September	4.17	4.33	4.65	5.16	19.1
October	2.28	2.24	2.48	2.76	22.8
November	1.57	1.69	1.93	2.09	23.3
December	1.18	1.38	1.54	1.65	20.0
Annual	24.17	25.20	27.48	29.49	17.0
			9.1	17.0	

Decimal Increase: 1.170



SNAP data collected from UAF Scenarios Network for Alaska + Arctic Planning website:

Data: https://www.snap.uaf.edu/tools/community-charts

About: https://uaf-snap.org/snap-story/community-charts-help-northerners-see-changes/

GFDL-CM3 Method and NCAR-CCSM4 Method Results

GFDL-CM3 Method (in)								
	2-Year	5-year	10-Year	25-Year	50-Year	100-Year	200-Year	500-Year
60-Minute	0.65	0.88	1.08	1.38	1.64	1.93	2.29	2.83
2-Hour	0.74	1.01	1.24	1.62	1.97	2.39	2.92	3.82
3-Hour	0.81	1.11	1.37	1.76	2.1	2.49	2.97	3.86
6-Hour	1.15	1.55	1.9	2.43	2.9	3.44	4.09	5.08
12-Hour	1.74	2.47	3.13	4.22	5.23	6.44	7.96	10.42
24-Hour	2.29	3.42	4.52	6.47	8.46	11.02	14.39	20.28

NCAR-CCSM4 Method (in)								
	2-Year	5-year	10-Year	25-Year	50-Year	100-Year	200-Year	500-Year
60-Minute	0.47	0.63	0.74	0.87	0.96	1.05	1.14	1.27
2-Hour	0.57	0.75	0.87	1.01	1.11	1.2	1.3	1.41
3-Hour	0.62	0.84	1	1.23	1.41	1.59	1.81	2.11
6-Hour	0.85	1.14	1.34	1.6	1.79	1.97	2.18	2.45
12-Hour	1.23	1.73	2.04	2.38	2.58	2.74	2.87	2.97
24-Hour	1.77	2.55	3.12	3.89	4.5	5.15	5.85	6.82

Predicted Change (%) using NCAR-CCSM4 Method								
	2-Year	**5-year**	**10-Year**	**25-Year**	**50-Year**	**100-Year**	**200-Year**	**500-Year**
60-Minute	32	42	42	40	37	34	31	28
2-Hour	34	41	40	35	32	28	25	19
3-Hour	25	36	38	42	45	46	49	53
6-Hour	25	34	35	34	33	32	31	29
12-Hour	25	40	42	38	33	26	18	8
24-Hour	25	42	49	54	59	63	66	69

SNAP: Precipitation frequency estimates with future climate models
Data: https://snap.uaf.edu/tools/future-alaska-precip

Data Type: **Precipitation Intensity**

Units: English

Time Series: Partial Duration

Mountain Village **Precipitation intensity**

Precipitation Estimates (inches/hour)

Duration	Average Recurrence Interval (years)						
	2	10	25	50	100	200	500
5-min	1.49	2.18	2.62	2.95	3.29	3.67	4.16
10-min	1.00	1.46	1.76	1.98	2.21	2.46	2.80
15-min	0.780	1.14	1.37	1.55	1.72	1.92	2.18
30-min	0.518	0.760	0.910	1.03	1.14	1.27	1.45
60-min	0.355	0.520	0.623	0.703	0.782	0.873	0.992
2-hr	0.212	0.311	0.373	0.420	0.468	0.522	0.594
3-hr	0.165	0.241	0.288	0.325	0.362	0.404	0.459
6-hr	0.113	0.166	0.199	0.224	0.249	0.278	0.317
12-hr	0.082	0.120	0.144	0.162	0.181	0.202	0.230
24-hr	0.059	0.087	0.105	0.118	0.132	0.147	0.168

NOAA Atlas 14 Point Precipitation Frequency Estimates:
https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_ak.html

Appendix C – HY-8 Report and Riprap Apron Calculations

HY-8 Culvert Analysis Report

48-inch Aluminum Round Culvert

Existing Culvert

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Scammon Bay Runway Culvert

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
5.06	40% Q2	5.60	5.60	0.00	1
5.71	Q2	14.00	14.00	0.00	1
8.28	Q50	66.00	66.00	0.00	1
9.19	Q100	80.00	80.00	0.00	1
11.85	Q50 U68%	112.00	112.00	0.00	1
13.28	Q100 U68%	138.00	121.42	16.33	12
13.20	Overtopping	126.46	126.46	0.00	Overtopping

Rating Curve Plot for Crossing: Scammon Bay Runway Culvert

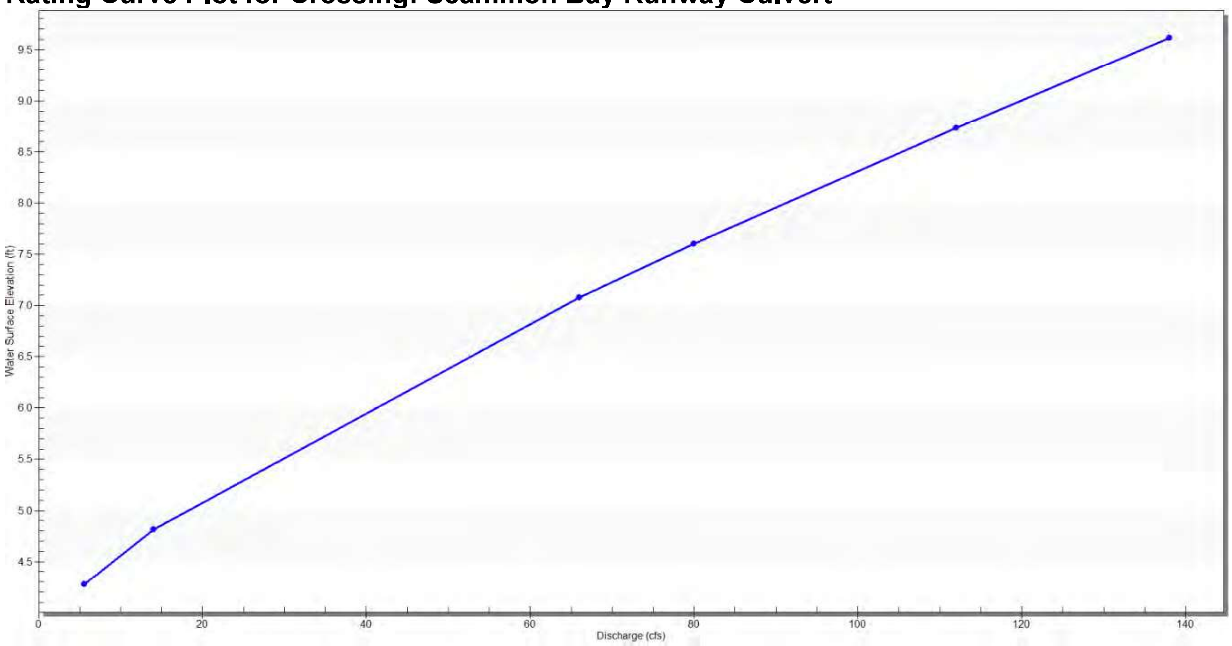


Table 2 - Culvert Summary Table: 48-inch Culvert

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
40% Q2	5.60	5.60	5.06	0.97	1.06	2-M2c	0.76	0.69	0.69	0.67	3.91	0.83
Q2	14.00	14.00	5.71	1.56	1.71	3-M2t	1.21	1.09	1.21	1.21	4.36	1.16
Q50	66.00	66.00	8.28	3.82	4.28	7-M1t	3.09	2.45	3.48	3.48	5.69	1.90
Q100	80.00	80.00	9.19	4.48	5.19	7-M2t	4.00	2.71	4.00	4.00	6.37	2.00
Q50 U68%	112.00	112.00	11.85	6.46	7.85	4-FFf	4.00	3.20	4.00	5.13	8.91	2.18
Q100 U68%	138.00	121.42	13.28	7.18	9.28	4-FFf	4.00	3.31	4.00	6.01	9.66	2.29

****

Straight Culvert

Inlet Elevation (invert): 4.00 ft, Outlet Elevation (invert): 3.60 ft

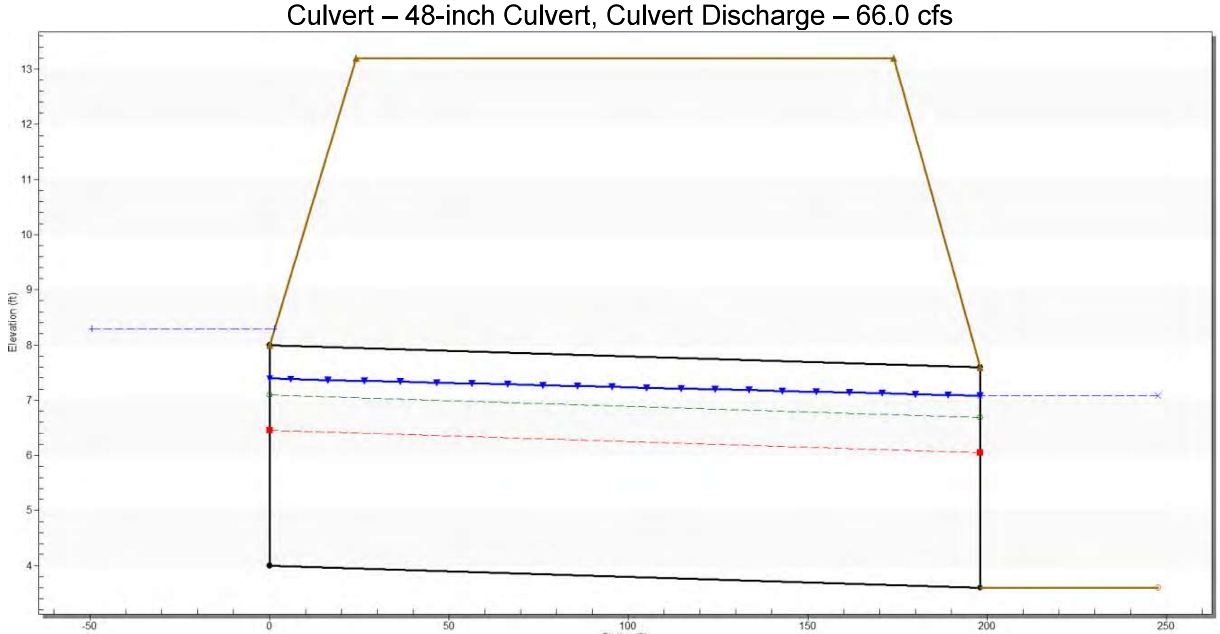
Culvert Length: 198.15 ft, Culvert Slope: 0.0020 ft/ft

****

Water Surface Profile Plot for Culvert: 48-inch Culvert

Crossing – Scammon Bay Runway Culvert, Design Discharge – 66.0 cfs

Culvert – 48-inch Culvert, Culvert Discharge – 66.0 cfs



Site Data - 48-inch Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4.00 ft

Outlet Station: 198.15 ft

Outlet Elevation: 3.60 ft

Number of Barrels: 1

Culvert Data Summary - 48-inch Culvert

Shape: Circular

Diameter: 4.00 ft

Barrel Material: Smooth HDPE

Embedment: 0.00 in

Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Runway Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)
5.600	4.274	0.674	0.830
14.000	4.812	1.212	1.155
66.000	7.079	3.479	1.897
80.000	7.599	3.999	2.000
112.000	8.731	5.131	2.183
138.000	9.614	6.014	2.295

Tailwater Channel Data: Scammon Bay Runway Culvert

Channel Type: Rectangular Channel

Bottom Width: 10.00 ft

Channel Slope: 0.0010 ft/ft

Manning's n (channel): 0.040

Channel Invert Elevation: 3.60 ft

Roadway Data for Crossing: Scammon Bay Runway Culvert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 ft

Crest Elevation: 13.20 ft

Roadway Surface: Gravel

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report

66-inch Aluminum Round Structural Plate Culvert

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Scammon Bay Runway Culvert

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
5.35	40% Q2	5.60	5.60	0.00	1
6.03	Q2	14.00	14.00	0.00	1
8.54	Q50	66.00	66.00	0.00	1
9.18	Q100	80.00	80.00	0.00	1
11.39	Q50 U68%	112.00	112.00	0.00	1
13.69	Q100 U68%	138.00	138.00	0.00	1
18.50	Overtopping	185.23	185.23	0.00	Overtopping

Rating Curve Plot for Crossing: Scammon Bay Runway Culvert

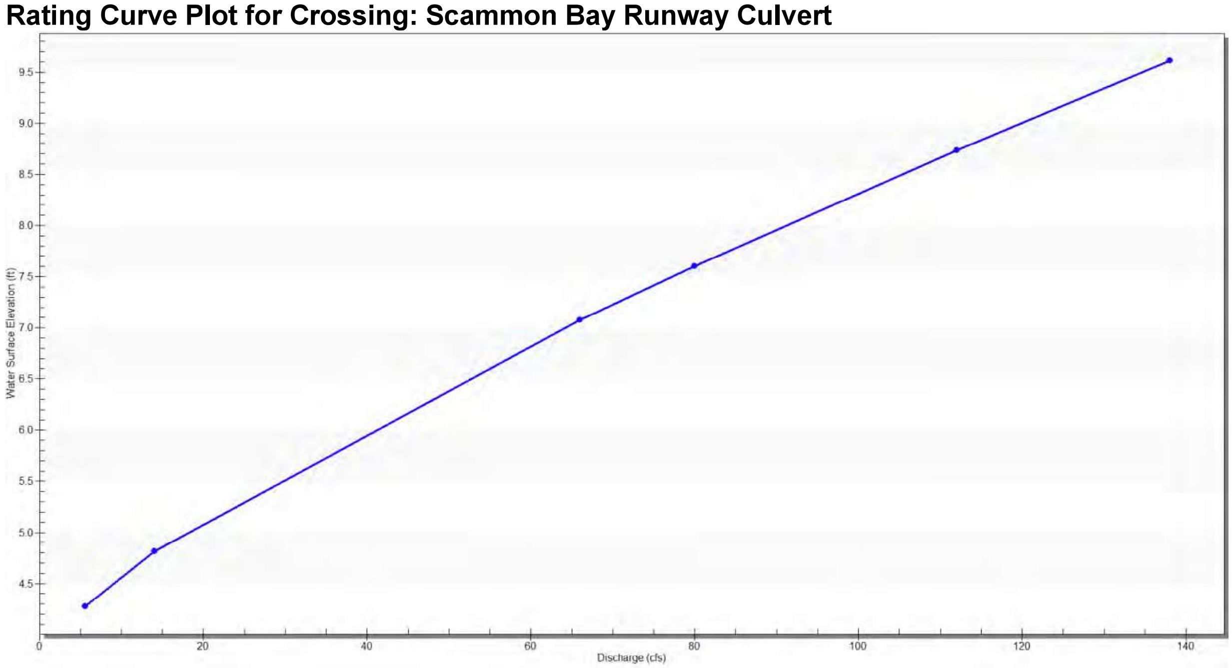


Table 2 - Culvert Summary Table: 66-inch Culvert

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
40% Q2	5.60	5.60	5.35	0.85	1.20	3-M2t	1.17	0.63	0.67	0.67	3.36	0.83
Q2	14.00	14.00	6.03	1.37	1.88	3-M2t	1.87	1.00	1.21	1.21	3.61	1.16
Q50	66.00	66.00	8.54	3.12	4.39	3-M2t	5.50	2.22	3.48	3.48	4.17	1.90
Q100	80.00	80.00	9.18	3.49	5.03	3-M2t	5.50	2.46	4.00	4.00	4.32	2.00
Q50 U68%	112.00	112.00	11.39	4.28	7.24	7-M2t	5.50	2.93	5.13	5.13	4.85	2.18
Q100 U68%	138.00	138.00	13.69	4.90	9.54	4-FFf	5.50	3.27	5.50	6.01	5.81	2.29

****

Straight Culvert

Inlet Elevation (invert): 4.15 ft, Outlet Elevation (invert): 3.60 ft

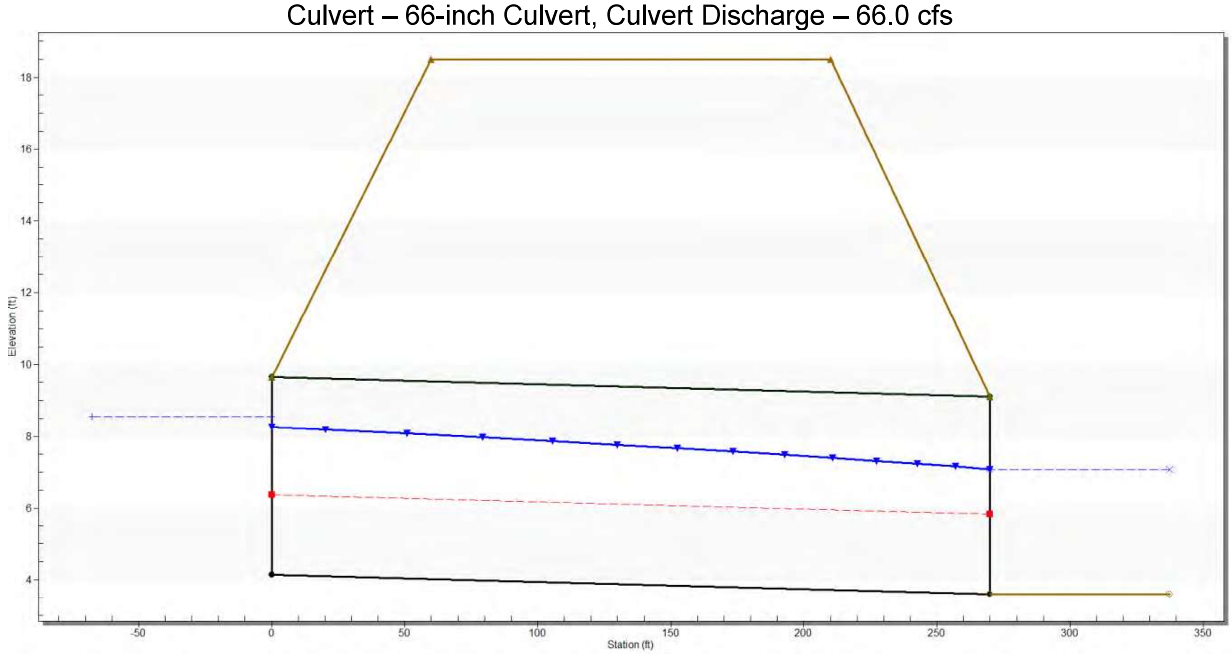
Culvert Length: 270.0 ft, Culvert Slope: 0.0020 ft/ft

****

Water Surface Profile Plot for Culvert: 66-inch Culvert

Crossing – Scammon Bay Runway Culvert, Design Discharge – 66.0 cfs

Culvert – 66-inch Culvert, Culvert Discharge – 66.0 cfs



Site Data - 66-inch Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4.15 ft

Outlet Station: 270.00 ft

Outlet Elevation: 3.60 ft

Number of Barrels: 1

Culvert Data Summary - 66-inch Culvert

Shape: Circular

Diameter: 5.50 ft

Barrel Material: Corrugated Aluminum

Embedment: 0.00 in

Manning's n: 0.0350

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Runway Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)
5.600	4.274	0.674	0.830
14.000	4.812	1.212	1.155
66.000	7.079	3.479	1.897
80.000	7.599	3.999	2.000
112.000	8.731	5.131	2.183

Tailwater Channel Data: Scammon Bay Runway Culvert

Channel Type: Rectangular Channel

Bottom Width: 10.00 ft

Channel Slope: 0.0010 ft/ft

Manning’s n (channel): 0.040

Channel Invert Elevation: 3.60 ft

Roadway Data for Crossing: Scammon Bay Runway Culvert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 ft

Crest Elevation: 18.50 ft

Roadway Surface: Gravel

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report

72-inch Aluminum Round Structural Plate Culvert

(Preferred Alternative)

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Scammon Bay Runway Culvert

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
5.34	40% Q2	5.60	5.60	0.00	1
5.98	Q2	14.00	14.00	0.00	1
8.35	Q50	66.00	66.00	0.00	1
8.91	Q100	80.00	80.00	0.00	1
10.36	Q50 U68%	112.00	112.00	0.00	1
12.23	Q100 U68%	138.00	138.00	0.00	1
18.50	Overtopping	215.25	215.25	0.00	Overtopping

Rating Curve Plot for Crossing: Scammon Bay Runway Culvert

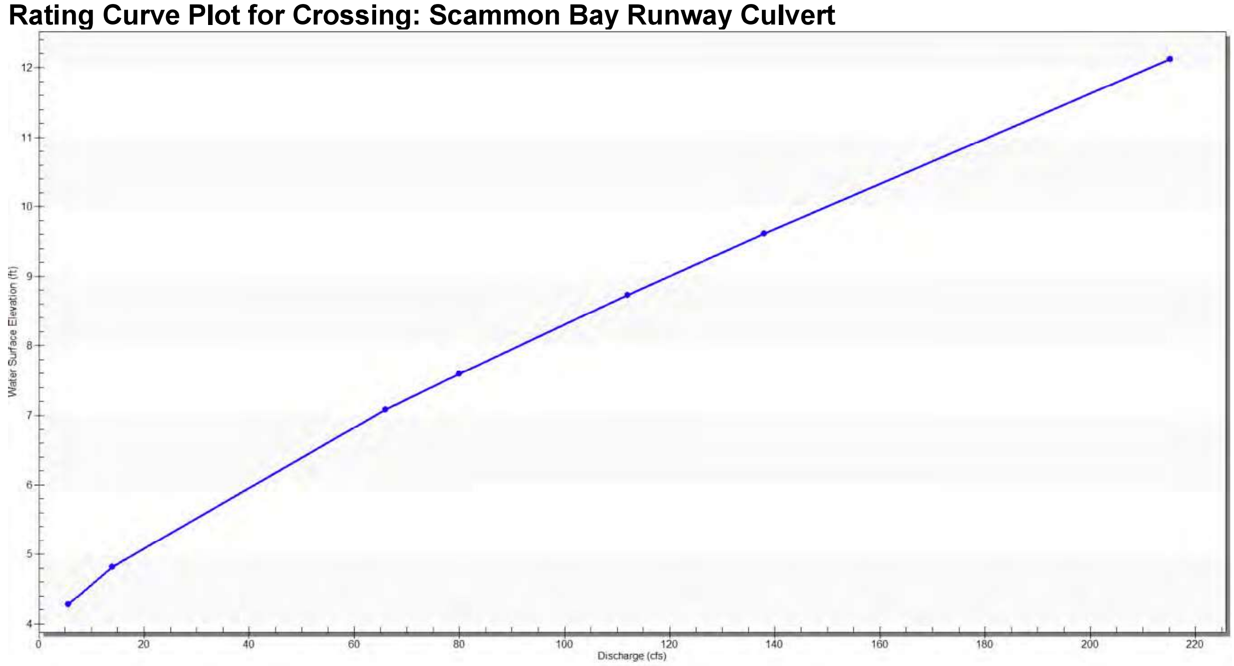


Table 2 - Culvert Summary Table: 72-inch Culvert

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
40% Q2	5.60	5.60	5.34	0.83	1.19	3-M2t	1.14	0.61	0.67	0.67	3.21	0.83
Q2	14.00	14.00	5.98	1.33	1.83	3-M2t	1.80	0.98	1.21	1.21	3.43	1.16
Q50	66.00	66.00	8.35	3.01	4.20	3-M2t	4.57	2.17	3.48	3.48	3.88	1.90
Q100	80.00	80.00	8.91	3.35	4.76	3-M2t	6.00	2.39	4.00	4.00	4.00	2.00
Q50 U68%	112.00	112.00	10.36	4.09	6.21	3-M2t	6.00	2.85	5.13	5.13	4.35	2.18
Q100 U68%	138.00	138.00	12.23	4.64	8.08	4-FFf	6.00	3.18	6.00	6.01	4.88	2.29

****

Straight Culvert

Inlet Elevation (invert): 4.15 ft, Outlet Elevation (invert): 3.60 ft

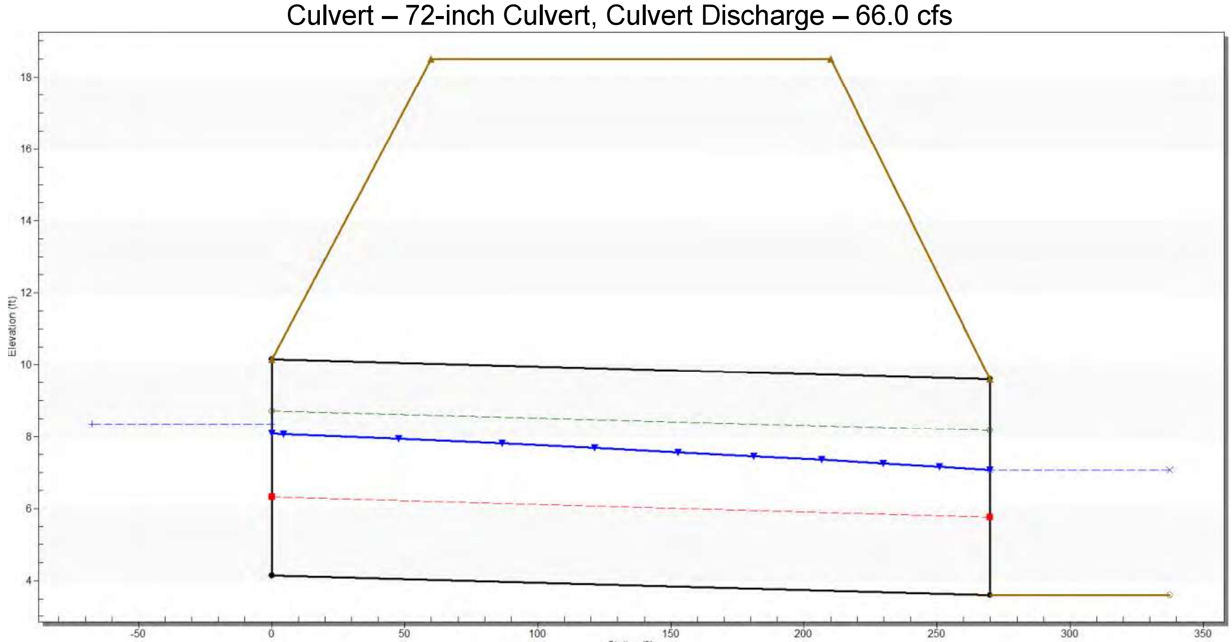
Culvert Length: 270.0 ft, Culvert Slope: 0.0020 ft/ft

****

Water Surface Profile Plot for Culvert: 72-inch Culvert

Crossing – Scammon Bay Runway Culvert, Design Discharge – 66.0 cfs

Culvert – 72-inch Culvert, Culvert Discharge – 66.0 cfs



Site Data - 72-inch Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4.15 ft

Outlet Station: 270.00 ft

Outlet Elevation: 3.60 ft

Number of Barrels: 1

Culvert Data Summary - 72-inch Culvert

Shape: Circular

Diameter: 6.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 0.00 in

Manning's n: 0.0350

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Runway Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)
5.600	4.274	0.674	0.830
14.000	4.812	1.212	1.155
66.000	7.079	3.479	1.897
80.000	7.599	3.999	2.000
112.000	8.731	5.131	2.183
138.000	9.614	6.014	2.295

Tailwater Channel Data: Scammon Bay Runway Culvert

Channel Type: Rectangular Channel

Bottom Width: 10.00 ft

Channel Slope: 0.0010 ft/ft

Manning's n (channel): 0.040

Channel Invert Elevation: 3.60 ft

Roadway Data for Crossing: Scammon Bay Runway Culvert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 ft

Crest Elevation: 18.50 ft

Roadway Surface: Gravel

Roadway Top Width: 150.00 ft

HY-8 Culvert Analysis Report

72-inch Aluminum Round Structural Plate Culvert under Tidally Influence Conditions

(Preferred Alternative)

Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: Scammon Bay Runway Culvert

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Roadway Discharge (cfs)	Iterations
6.79	40% Q2	5.60	5.60	0.00	1
6.89	Q2	14.00	14.00	0.00	1
8.26	Q50	66.00	66.00	0.00	1
8.67	Q100	80.00	80.00	0.00	1
9.64	Q50 U68%	112.00	112.00	0.00	1
10.51	Q100 U68%	138.00	138.00	0.00	1
18.50	Overtopping	265.81	265.81	0.00	Overtopping

Rating Curve Plot for Crossing: Scammon Bay Runway Culvert

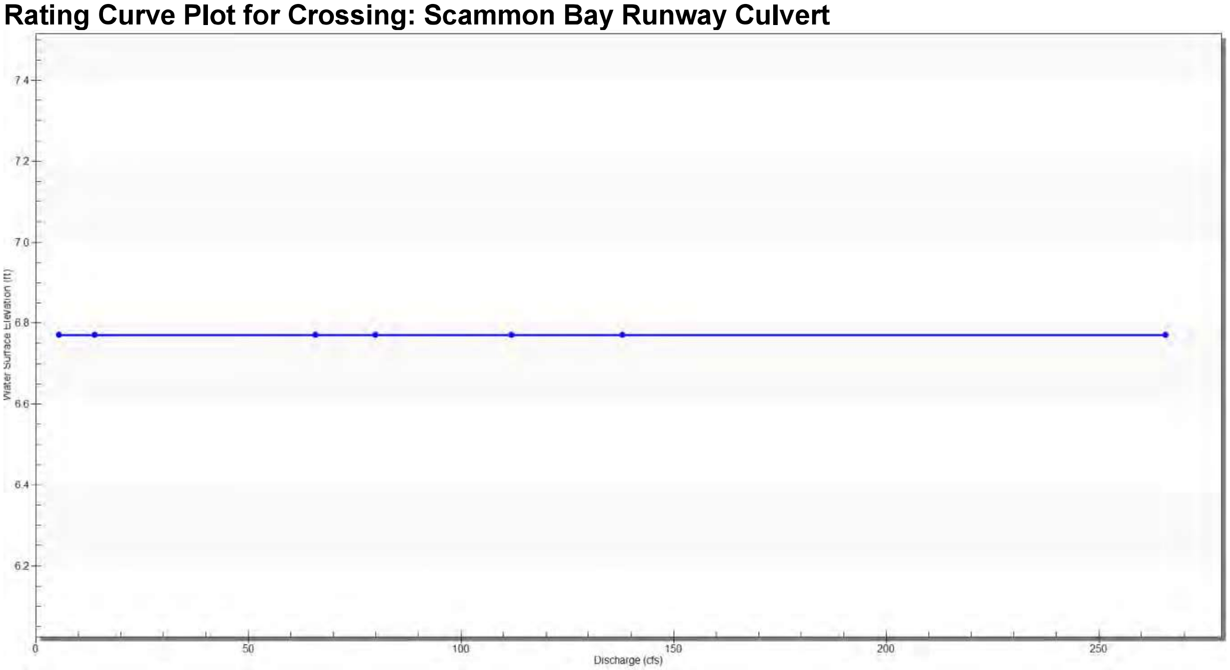


Table 2 - Culvert Summary Table: 72-inch Culvert

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
40% Q2	5.60	5.60	6.79	0.83	2.64	3-M1t	1.14	0.61	3.17	3.17	0.37	0.00
Q2	14.00	14.00	6.89	1.33	2.74	3-M1t	1.80	0.98	3.17	3.17	0.92	0.00
Q50	66.00	66.00	8.26	3.01	4.11	3-M2t	4.57	2.17	3.17	3.17	4.35	0.00
Q100	80.00	80.00	8.67	3.35	4.52	3-M2t	6.00	2.39	3.17	3.17	5.28	0.00
Q50 U68%	112.00	112.00	9.64	4.09	5.49	3-M2t	6.00	2.85	3.17	3.17	7.39	0.00
Q100 U68%	138.00	138.00	10.51	4.64	6.36	7-M2c	6.00	3.18	3.18	3.17	9.05	0.00

****

Straight Culvert

Inlet Elevation (invert): 4.15 ft, Outlet Elevation (invert): 3.60 ft

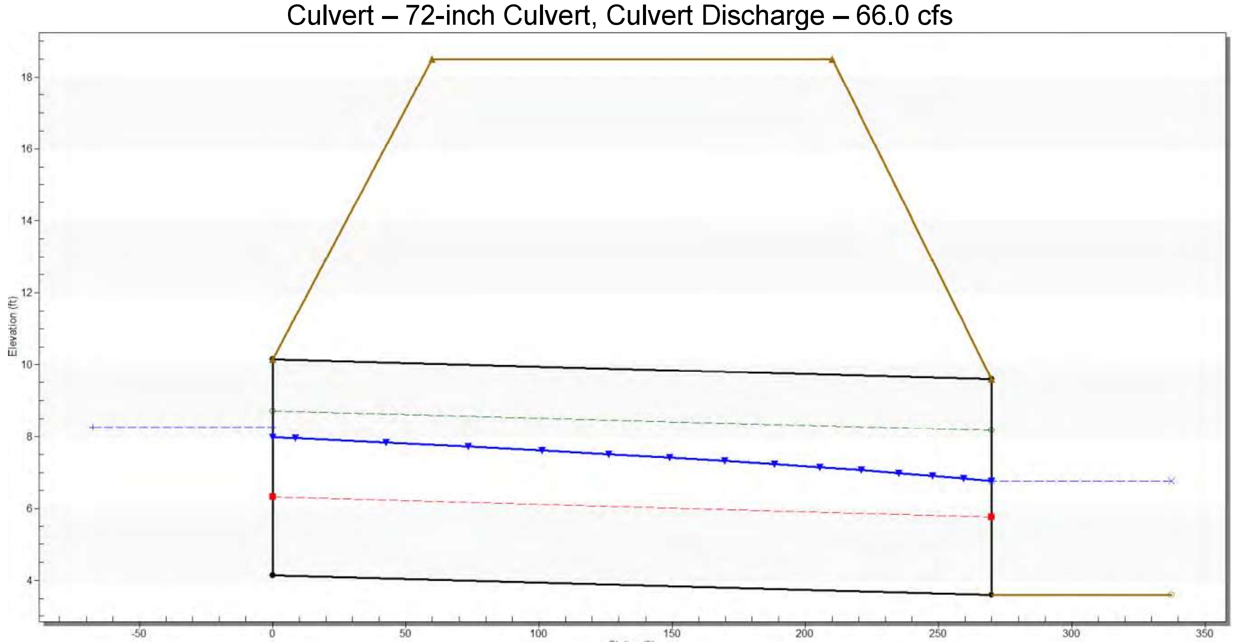
Culvert Length: 270.0 ft, Culvert Slope: 0.0020 ft/ft

****

Water Surface Profile Plot for Culvert: 72-inch Culvert

Crossing – Scammon Bay Runway Culvert, Design Discharge – 66.0 cfs

Culvert – 72-inch Culvert, Culvert Discharge – 66.0 cfs



Site Data - 72-inch Culvert

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4.15 ft

Outlet Station: 270.00 ft

Outlet Elevation: 3.60 ft

Number of Barrels: 1

Culvert Data Summary - 72-inch Culvert

Shape: Circular

Diameter: 6.00 ft

Barrel Material: Corrugated Aluminum

Embedment: 0.00 in

Manning's n: 0.0350

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Runway Culvert)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)
5.600	6.770	3.170	0.000
14.000	6.770	3.170	0.000
66.000	6.770	3.170	0.000
80.000	6.770	3.170	0.000
112.000	6.770	3.170	0.000
138.000	6.770	3.170	0.000

Tailwater Channel Data: Scammon Bay Runway Culvert

Channel Type: Constant Tailwater Elevation

Channel Invert Elevation: 3.60 ft

Constraint Tailwater Elevation: 6.77 ft (Mean Higher-High Water Elevation [MHHW])

Roadway Data for Crossing: Scammon Bay Runway Culvert

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 ft

Crest Elevation: 18.50 ft

Roadway Surface: Gravel

Roadway Top Width: 150.00 ft

Riprap Bed Sizing for Proposed Runway Culvert

Updated 7/21/2021 K. Grundhauser

Inputs
Set by Specs
Calculated

Step 1

From HEC-RAS or HY-8 enter values for depth and velocity of Q100 flows and select D85/15 and stability coefficients

This will produce the course fraction gradations for rip rap sizing at the bottom of the table

Using Corps of Engineers Equations - FHWA Circular on Development in the River System - Page 6.25.
FHWA NHI 01-004; River Engineering for Highway Encroachments, 2001
http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=8&id=2C

Safety Factor	**1.5**			
Stability Coefficient for Incipient Failure	0.3	Round or Angular Rock?	Angular	(0.36 round rock, 0.3 angular rock)
Vertical Velocity Distribution Coeff	1.00	(1.0 for straight channels)		
Blanket Thickness Coeff	1	(1xD100 or 1.5 or D50 max, whichever is greater)		
Local depth of flow	4	ft for 100-year event		
Unit Weight of water	62.4	lb/ft^3	(assumed)	
Unit weight of rock	165	lb/ft^3	(assumed)	
Local depth-average velocity	4	ft/s from 100-year event avg. velocity in pipe		
Side Slope correction factor	1			
Gravitational Acceleration	32.2	ft/s^2		
D85/D15	3.4	(1.7-5.2)	IN RANGE	
D50/D30	2			

Note: This method is based on the minimum D30 size

Riprap Design Method - Selecting Proper Gradation, Page 131.
Design Hydrology and Sedimentology for Small Catchments, Haan, Barfield and Hayes, 1981.

D15	0.0	ft	1.0	inches
D30	0.1	ft	1.0	inches
D50	0.1	ft	2.0	inches
D85	0.2	ft	3.0	inches
D100	0.2	ft	3.0	inches

Using D50 size, used FHWA circular for Rip Rap design to spec out D100, D85 and D15.
D100 = 2.0D50

Buoyancy Force Calculations for Scammon Bay Runway Culvert *Updated: K. Grundhauser 7/9/2021*

Resistance = Weight of pipe + Weight of water (in pipe) + Weight of fill (over pipe), lbs/ft.

Hydrostatic Uplift (Buoyant) Force = Weight of water displaced by the pipe, lb/ft.

Assumed (from Virginia DOT):

Weight of dry fill =	F_d =	100	lb/ft^3	
Weight of coastal protection =	F_s =	160	lb/ft^3	<- D50 - 1.4' diameter, 238 lb. We calculated a 300-400 lb d50 with an average density of 160 lbs/ft3. The density can range from 155 into the 170s.
Unit weight of water =	γ =	62.43	lb/ft^3	

Provide:

Weight of pipe =	W_p =	47.6	lb/ft	(72-inch, 10-gage thickness, aluminum, CMP)
Flow =	Q =	138	cfs	@ Q100 68%
Headwater =	H =	12.1	ft	@ avg Q50 storm surge, 15.7 NAVD88
Diameter of the pipe =	D =	6	ft	
Radius of the pipe =	R =	3	ft	
Critical depth =	y_c =	**3.13**	**ft**	@ Q100 68%
Normal depth =	y_n =	6	ft	@ Q100 68%
Length of pipe =	L =	274.5	ft	
Length of pipe per unit =	$L_{(unit)}$ =	1		
Cross section area =	A_{xc} =	28.27	ft^2	

Calculate: **At Critical Depth**

Buoyant force = $L_{(unit)}$*A*	Buoy =	1,765.2	lb/ft

Section 1 (Inlet)

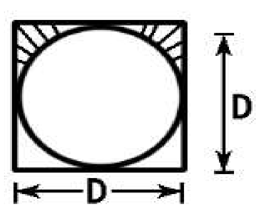
Surcharge (lbs./ft.) = Wt. of Fill + Wt. of Water + Wt. of Pipe

Area of Fill =	A_F =	0.00	ft^2					
Weight of Fill =	W_F =	0.0	lb/ft					
Area of Water =	A_W =	14.9	ft^2					
Weight of Water =	W_W =	931.3	lb/ft					
Weight of pipe =	W_p =	47.6	lb/ft					
Surcharge (lbs./ft.) =		978.9	lb/ft					
At Section 1 -	Weight	979	lb/ft	<	Buoy =	1,765	lb/ft	**Unstable**

Section 2 (Inlet to 12 ft)

Surcharge (lbs./ft.) = Wt. of Fill + Wt. of Water + Wt. of Pipe

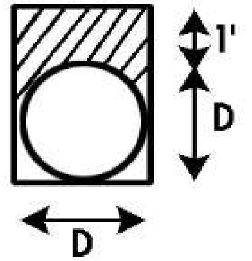
Area of Fill =	A_F =	3.86	ft^2
Weight of Fill =	W_F =	618.1	lb/ft
Area of Water =	A_W =	14.9	ft^2
Weight of Water =	W_W =	931.3	lb/ft
Weight of pipe =	W_p =	47.6	lb/ft



Surcharge (lbs./ft.) =		1596.9 lb/ft					
At Section 2 -	Weight	1,597	lb/ft	<	Buoy =	1,765 lb/ft	**Unstable**

Section 3 (12 ft to 16 ft)

Surcharge (lbs./ft.) = Wt. of Fill + Wt. of Water + Wt. of Pipe

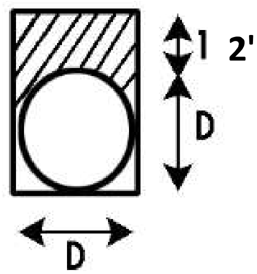


Area of Fill =	A_F =	9.86 ft^2
Weight of Fill =	W_F =	1578.1 lb/ft
Area of Water =	A_W =	14.9 ft^2
Weight of Water =	W_W =	931.3 lb/ft
Weight of pipe =	W_p =	47.6 lb/ft
Surcharge (lbs./ft.) =		2556.9 lb/ft

At Section 3 -	Weight	2,557	lb/ft	>	Buoy =	1,765 lb/ft	**Stable**

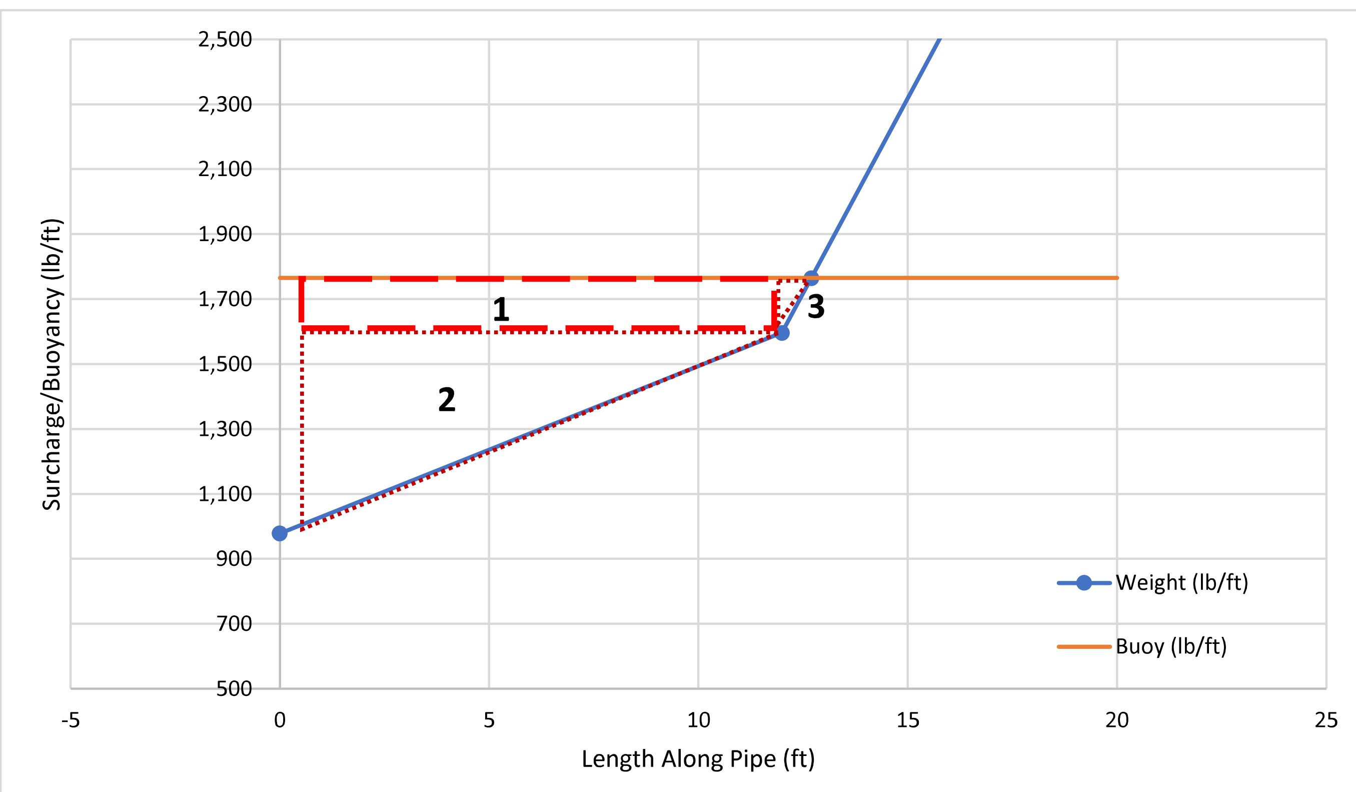
Section 4 (16 ft to 20 ft)

Surcharge (lbs./ft.) = Wt. of Fill + Wt. of Water + Wt. of Pipe



Area of Fill =	A_F =	15.86 ft^2
Weight of Fill =	W_F =	2538.1 lb/ft
Area of Water =	A_W =	14.9 ft^2
Weight of Water =	W_W =	931.3 lb/ft
Weight of pipe =	W_p =	47.6 lb/ft
Surcharge (lbs./ft.) =		3516.9 lb/ft

At Section 4 -	Weight	3,517	lb/ft	>	Buoy =	1,765 lb/ft	**Stable**



y= 240 x + -1283

Distance from Inlet (ft)	Weight (lb/ft)	Buoy (lb/ft)
0	979	1,765
0	979	1,765
12	1,597	1,765
12.700	1,765	1,765
16	2,557	1,765
20	3,517	1,765

Area			X Centroid	
1	2,017	lbs.	6	ft
2	3,708	lbs.	4.00	ft
3	59	lbs.	12.23	ft
Sum	5,784	lbs.	2.40	ft

Hinge Point =	12.700	ft			
Buoyancy Force =	59,561	lb*ft	Restrain =	59,561	lb*ft
Location of restraint =	1.00	ft (from Inlet)			
Required Restraining Forc	5,091	lb			

Minimum Restraining Force*	**5,091**	lbs. at	**1**	ft from Inlet.
	5,566		**2**	
	6,846		**4**	

Assume Concrete Toe Wall		**Wall**		**Toe**	
Width =	B_C =	11.0	ft	11.00	ft
Depth =	D_C =	1	ft	4.00	ft
Height =	H_C =	4	ft	1.00	ft
Unit Weight of Concrete	W_C =	165	lb/ft^3		
Unit weight of water =	γ =	62.43	lb/ft^3		
Concrete weight =	13,612.50	lb	>	Buoy =	6,846.09 **lb**

Passes

*Analysis is for non-rigid pipe. Additional restraining force may not be needed for a rigid pipe.

Recommend

At the inlet and outlet, install a DOT standard toe wall, see detail for dimensions.

Sources:

Virginia DOT Procedure:	http://www.virginiadot.org/business/resources/LocDes/DrainageManual/chapter8.pdf
Pipe Weight:	https://www.conteches.com/Portals/0/Documents/Design%20Guides/CMP-Design-Guide.pdf?ver=2018-05-16-083622-383
General Soil Weights:	http://www.geotechnicalinfo.com/soil_unit_weight.html
Saturated Soil Weight:	https://www.concretepipe.org/wp-content/uploads/2014/09/DD_22M.pdf
Equation of a line:	https://planetcalc.com/8110/
DOT Standard Toe wall:	https://dot.alaska.gov/stwddes/dcsprecon/assets/pdf/stddwgs/eng/d3101p1.pdf