PREVENTION OF EROSION IN HOOPER BAY, ALASKA

By

Ethan E. Hunsiger, B.S.

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APPROVED:

Tom Ravens, Ph.D., Committee Chair
Matthew Calhoun, Ph.D., Committee Member
Joey Yang, Ph.D., Committee Member
Scott Hamel, Ph.D., Chair
Department of Civil Engineering
Kendrick Mock, Ph.D., Dean
College of Engineering

Abstract

Many rural communities in Alaska are at risk of losing infrastructure to erosion. One of these communities is Hooper Bay, on the west coast of Alaska. According to predictions generated by the Alaska Department of Natural Resources, several hundred feet of airport runway and road will be exposed to erosion between the years of 2015 and 2075. While the runway's current erosion mitigation measures are effective, overtopping and the depositing of debris remain an issue. There are currently community measures underway to elevate the endangered section of road, and there are plans to implement more rigorous protect in place measures within the next 10 years. A salient is present on the coast south of the runway that is slowly moving north. The exact mechanics behind its formation and movement are not known, but it may provide natural beach nourishment to the beach near the runway within the next 15 years. Continued observation, data collection and research is required to identify effective, long term solutions to the erosion problem, but the measures currently in place, being implemented, and planned should provide short term protection.

Introduction

Over recent decades the warming of the environment has led to a number of issues. These include salt water intrusion into groundwater, worsening storms, coastal flooding, increasing rates of erosion, reduced sea ice, and permafrost thaw which leads to land subsidence. The increasing rates of erosion in particular can pose a significant risk to coastal communities. The residential areas and vital infrastructure of those communities could be disrupted or even destroyed without intervention.

Alaska as a state is particularly vulnerable to erosion for two primary reasons. The first is the extensive amount of land water interface the state contains. This includes nearly 44 thousand miles of tidal shoreline, about 10 thousand named and unnamed rivers, creeks, and streams, and more than 3 million lakes (U.S. Army Corps of Engineers 2009).

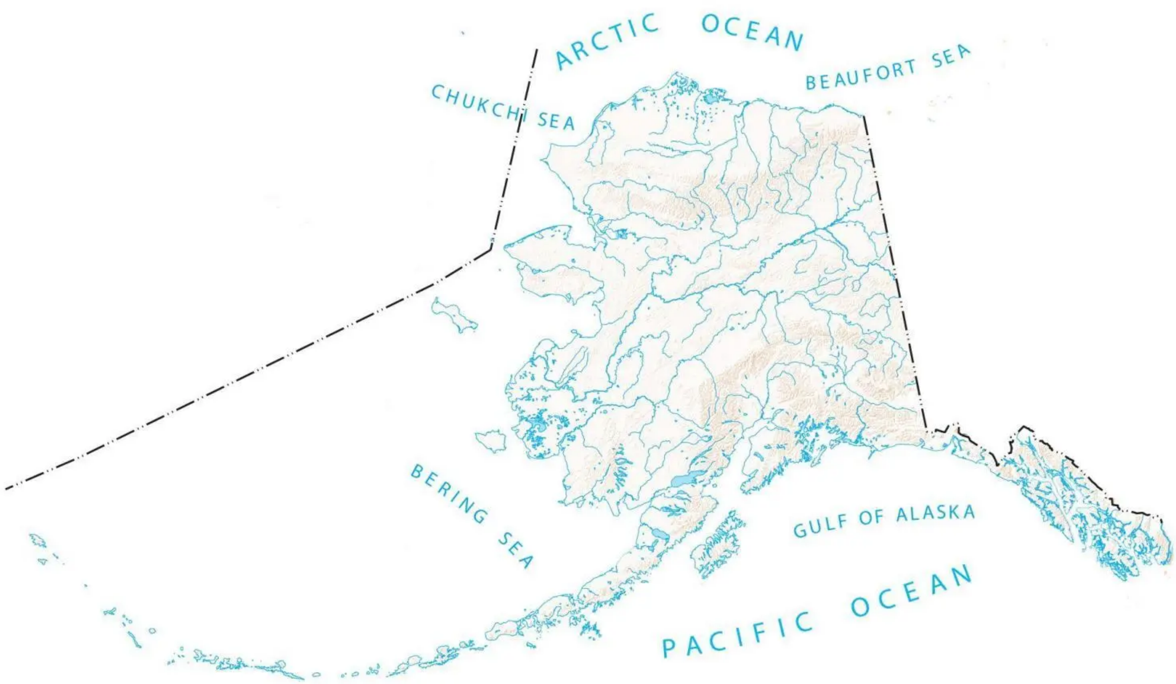

Figure 1: Alaska Lakes and Rivers Map, GISGeography.com, (accessed 4/18/2022)

The second is the large number of rural communities along the Alaska coast, some of which can only be reached by plane or boat. It is these communities that are the most vulnerable due to their proximity to the coast, their relative isolation from sources of support, and intensifying coastal hazards like erosion and flooding

One of these at-risk communities is the town of Hooper Bay, on the western coast. Hooper Bay has a population of roughly 1375 according to the 2020 Census. Seasonal flooding has caused disruptions of the community's roads and the Hooper Bay Airport, worsening erosion and covering the vital infrastructure with debris. There have been several attempts to mitigate the erosion suffered by the Hooper Bay community, some of them unsuccessful.

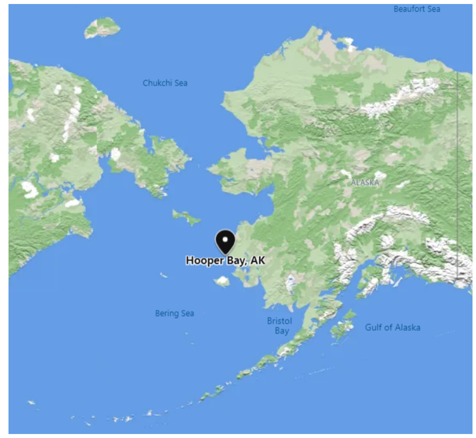

Figure 2: Hooper Bay, Ak, bing.com/maps, (accessed 4/18/2022)

Literature Review

Between April 2005 and March 2007, the US Army Corp of Engineers conducted a study called the Alaska Baseline Erosion Assessment (ABEA) (U.S. Army Corps of Engineers 2009). A total of 178 communities were investigated, and each was sorted into one of three categories, "Priority Action Communities", "Monitor Conditions Communities", and "Minimal Erosion Communities" with 26, 69, and 83 communities in those categories respectively. The study notes how many of the at-risk communities struggle to meet the cost-sharing requirements for larger projects. This combined with the low cost to benefit ratio of projects in rural Alaska makes funding such projects difficult without dedicated State or Federal funding. The authority of the US Army Corp of Engineers to assist these communities was temporarity expanded in 2005 by

Section 117 of the 2005 Energy and Water Development Appropriations Act, but that Section was repealed in 2009. According to the surveys conducted in the investigated communities, the primary source of river erosion is flooding, followed by ice jams. The primary cause of coastal erosion according to those same surveys is storm surges followed by wind, waves, and high tides.

As part of the ABEA, the US Army Corp of Engineers also produced a community specific report for the Hooper Bay community (U.S. Army Corps of Engineers 2009). According to the report, Hooper Bay is classified as a “Monitor Conditions Community”, meaning that while erosion was taking place, it did not require immediate action at the time (~2007). The primary sources of erosion in Hooper Bay were identified as storm surges and wave action, which were worsened by regular ATV and pedestrian traffic. The erosion area at the time of the report was 6000 feet long and 15 feet wide with the erosion rate being estimated at ~10 feet per year. In addition to the constant erosion rate, 4 major erosion events in the past 20 years resulted in the loss of ~100 feet of shoreline. Two previous attempts to mitigate the coastal erosion near the Hooper Bay Airport runway are mentioned. The first is a mat made of a series of interlocking concrete blocks that failed to mitigate erosion. The second was a sheet pile wall installed along the western edge and northern end of the runway that is still functioning today.

In 2011 a report was prepared for the Alaska Department of Transportation and Public Facilities (ADOT&PF) by Coastline Engineering titled Hooper Bay Coastline Modeling (Jones 2011). That report had two goals, with the primary goal being predicting the next 100 years of erosion. The secondary goal was to offer potential shoreline protection methods. Three previous efforts to mitigate erosion are noted: a curtain wall made of 55 gallon drums in 1972, the previously mentioned concrete matting in 1981, and the 1000 foot sheet pile wall placed in 1996.

Only the sheet pile wall was successful in the long term. A basic sediment budget, based on a single point was developed, giving an erosion rate of ~2 feet per year. The most significant observation in the report, in relation to this paper, is the presence of a salient south of the airport runway. The salient has a mass of ~1,500,000 cubic yards and moves north along the coast ~150 feet a year. It is estimated that by the year ~2036 the salient would begin providing natural erosion protection to the north end of the runway, and would provide varying degrees of protection for ~25 years. Three images showing the salient's position in the years 1951, 2005, and 2020, Figures A.1, A.2, and A.3, can be found in the Appendix. Some other notes concerning the coast near Hooper Bay are a tidal range of ~2 feet, relatively stable sea level change at ~+-2mm, 50% of the beach sediment is smaller than 0.18 mm , and along shore sediment transport based on 19 years of wind records is ~18.590 cubic feet per year to the south.

There were a series of infrastructure improvements to the Hooper Bay airport between the years of 2014 and 2016 (Beck 2015). These include new lighting, a new snow removal equipment storage building, and various improvements to the airport access road. Included in the project was the installation of 413.5 feet of armor stones at the north end of the runway. The ADOT&PT provided an engineer's estimate as part of the compilation of bids for the project, however it is difficult to say with certainty which of the costs listed in the compilation were associated with the installation of the armor stones.

In 2021, the state of Alaska published a report titled Erosion Exposure Assessment of Infrastructure in Alaskan Coastal Communities (Buzzard et al. 2021). In this report the state predicted the amount of infrastructure that will be exposed due to erosion in the next 60 years for 38 rural Alaskan communities. This was done by using aerial photographs to estimate shoreline change for the next 60 years in 20 year segments, and using those erosion forecasts along with community maps to identify at risk infrastructure. Then, using a table of infrastructure replacement costs generated by Alaska Native Tribal Health Consortium, a cost of replacement was generated for the at risk infrastructure. This cost to replace table, Table A.1, can be found in the Appendix. It is important to note that the replacement costs generated by this report are not meant to be construction estimates, rather they are meant to aid planners in identifying areas or facilities that may be a priority. The Hooper Bay sub-report contained both tables detailing the amount and replacement cost of endangered infrastructure and a map indicating the endangered areas. These tables, Table A.2 and A.3, and the map, Figure A.4, are found in the Appendix.

Goals

My goals for this project are to predict the need and cost of future erosion mitigation projects in Hooper Bay Alaska.

Methodology

The recent work done in 2021 by the DGGS is the most recent erosion projection currently publicly available. In the report (Buzzard et al. 2021), the DGGS builds on work done in a 2020 report that uses aerial imagery to predict shoreline changes in rural Alaska communities (Overbeck et al 2020). Information from the 2021 DGGS report will be used to predict future erosion impacts in this study. The previous projects in the community, most notably the airport improvements done in 2014-2016, will be used to create a rough estimate of the costs of future projects of a similar nature.

Results

Figures 3,4: Hooper Bay Erosion Forecast Map, Drawn from (Buzzard et al. 2021)

According to the 2021 DGGS erosion exposure assessment, the total amount of infrastructure that will be exposed to erosion between the years 2015 and 2075 are 968 linear feet of runway, 334 linear feet of road, and 7 linear feet of fuel line. In this case, the primary concerns are the exposed road and runway. The total estimated replacement costs for this infrastructure was $200,000 for the exposed road and $9,680,000 for the exposed runway

As part of the 2014-2016 Hooper Bay Airport improvements, a total of 2,731.43 tons of primary armor stones, class PA-1200 lb, were used to armor 413.5 feet of the northern end of the runway (Beck 2015). This was in addition to the 1996 sheet pile wall. However, it is difficult to say how much of the costs of the improvements can be attributed to the armoring of the runway. Table A.5, found in the Appendix, represents the costs pulled from the engineer's estimate in the compilation of bids for the improvement project that may have contributed to the specific cost of the armoring (Smith 2015). Most of these costs reflect a much larger and longer term project than only armoring the runway, and as such would be much lower for a project that has that as its only goal. Some of the costs, such as the cost of the armor stones themselves and the mobilization and demobilization, would still remain significant even with a smaller project. Other costs could be removed entirely based on certain context. For example, the heating fuel may not be needed depending on the time of year and length of the project. Another cost that could potentially be removed is the geotextile drainage, as it is unclear in the as built drawings if that material was used in conjunction with the armor stones or not.

With these factors in mind, the first step in creating a cost estimate was assigning a multiplier to three cost groups generated from the costs found in Table A.5. These cost groups and their multipliers are found in the table below. The multipliers are based on an estimation of how much of that cost was applied to the armoring of the runway. All of the armor stone material cost was included as those stones were not used in any other part of the project. A multiplier of 0.35 was used for the Mobilization and Demobilization due to such costs having a fairly significant baseline that increases with the scope of the project. The multiplier for the other costs, 0.20, was chosen based on what the approximate percentage of the Airport Improvement project was the runway armoring based on the project As Builts. After applying these multipliers, the total estimated cost for the runway armoring is $2,165,020. When this cost is divided by the amount of runway armored, 413.5 linear feet, the resulting cost per linear foot for armor stone estimation is $5,236.

Item	Cost $	Multipier
Armor Stones	530,000	1.00
Mobilization and Demobilization	3,353,000	0.35
Other Costs	2,307,350	0.20

Table 1: Cost Groups and Multipliers used in Estimating Cost of Runway Armoring

Using this cost per linear foot and the erosion exposure assessments generated by the DGGS, an estimate for installing armor stones along the exposed sections of runway can be developed. For the time intervals 2035-2055 and 2055-2075, the estimated cost for an armor stone installation would be $2,424,268 and $2,644,180 respectively. These estimations are significantly lower than the replacement cost estimates generated by the DGGS, at $4,630,000 and $5,070,000 for the 2035-2055 and 2055-2075 time intervals. (Buzzard et al. 2021). Should these estimates be accurate, this would indicate that the cost of armoring the airport runway would be notably less expensive than replacing it. However, it must be noted that the estimated replacement costs generated by the DGGS were not intended to be used as true construction estimates for an infrastructure replacement project. As such this comparison may not be accurately representing the relative costs of a runway armoring project and a runway replacement project.

There are two complicating factors when discussing the erosion mitigation of the runway, those being the presence of a salient and the flooding of the runway. The salient is mentioned almost exclusively in the report prepared for the Alaska Department of Transportation and Public Facilities (ADOT&PF) by Coastline Engineering (Jones 2011). The salient is a mass of sediment with a volume of ~1,500,000 cubic yards that is slowly moving north at a rate of ~150 feet a year. In the 2030s it is predicted to begin to provide natural beach nourishment to the section of beach on which the north end of the runway rests. However, there are some important caveats where the salient is concerned. First is that it is currently unknown what exactly is causing it, both its formation and its movement. As such it cannot be guaranteed that its northward movement will continue. Second, it is unclear how the salient will react to the presence of the river mouth to the north of the runway if its northern movement continues.

The second complicating factor is the flooding of the runway. The sheet pile wall, despite being installed in 1996, remains effective. That combined with the additional armor stones to prevent scouring means that the erosion itself at the northern is not as much of an immediate concern. The current erosion mitigation does not prevent the flooding caused by storm surges. While storm surges are often associated with erosion, another effect is the spreading of debris on the runway. While this debris is present the usability of the runway may be impacted. Because Hooper Bay, and the other, smaller surrounding communities, use the runway as the primary means of importing goods, even a temporary suspension of air traffic could have significant economic impact on the community specifically and the surrounding region generally.

There are few easy answers to the problem presented by the flooding debris. Increasing the height on the sheet pile wall could protect against some of the flooding. However, the sheet pile wall could not be heightened on the northern end for safety reasons, and due to the angle of the runway relative to the shore, this would mean that some of the flooding would still enter from that point. Nourishment of the beach adjacent to the north end of the runway, either by natural or artificial means, could increase the distance storm surges would need to travel before reaching the runway. Unfortunately, without enough of an increase in elevation it would be difficult to create enough distance, horizontal and vertical, between the runway and the shoreline to prevent the storm surges from reaching the runway.

Despite these complications, there are some options for mitigating the flooding issue for the runway. One is giving the Hooper Bay access to equipment dedicated to clearing the runway of debris. A structure could be constructed for the storage of the equipment similar to the one constructed for snow clearing equipment built during the 2014-2016 improvements. Another option is extending the runway to the south. Doing this would maintain the same usable length of runway even if the exposed northern end is unavailable. Beyond the debris issue, erosion could still seriously damage the runway if left unchecked. Fortunately the sheet pile wall and its armor stone addition is effective in preventing that damage. Both of these measures could be extended as needed, using the DGGS exposure predictions to plan out which sections of the runway will require protection during which time period.

Other than the runway, the other major piece of infrastructure projected to be exposed to erosion is 334 feet of road. Unlike the runway, this section of road is exposed to riverine erosion rather than coastal erosion. Due to the method used by the DGGS, projecting shoreline changes using aerial photographs being less effective at predicting river erosion, the prediction of the amount of exposed road is not as reliable as the runway prediction. This is because the course of a river is prone to change over long periods of time, such as the 60 year span of the DGGS predictions. Despite this limitation the predicted exposure between the years of 2035-2055 is close enough to be taken seriously. A more effective method at predicting river shoreline change can be found in the NCHRP Report 533, Handbook for Predicting Stream Meander Migration (Lagasse et al, 2004).

There are several potential solutions to the road erosion risk, including armoring the road or elevating it. However, there are some considerations that need to be examined when discussing the exposed road. The greatest is that, unlike the airport runway, this section of road is not vital to the community.

Figure 5: Image of a portion of Hooper Bay from Google Earth, accessed 4/18/22

Because that section of road is part of a loop, all of the structures near that section of the road could be reached by an alternative route. There also exists space in the surrounding area for another alternate route if greater ease of access to those structures is required. A second consideration is that, even looking at the worst of the projections, the structures near that section of the road will not be exposed to erosion until after the year 2075. The third consideration is community efforts. The ability of these rural communities to enact their own erosion mitigation measures, even if sometimes short term, is often overlooked.

According to William Naneng, a resident of Hooper Bay and the General Manager for the local Native Corporation, Sealion Corp, the Hooper Bay community is currently undertaking a near term project to elevate that section of road above the flood line. In addition all of the roads will be fortified with protect in place measures, similar to those used for the airport access road in 2014-2016, within the next 10 years. These measures include elevating the road, the installation of a Class II rip-rap revetment, the inclusion of a geotextile drainage under layer, and the installation of a new culvert. These measures can be seen in Figure A.5 in the Appendix. With these community efforts either underway or planned, combined with the relatively unpredictable nature of river erosion, continued observation of the area will be required to see if further mitigation measures are needed.

Discussion

The most interesting question encountered during this project was the salient. The salient was only mentioned in one of the reports used as sources for this paper, the Coastline Engineering report (Jones 2011). The writers of that report did not have the resources or time to ascertain the cause of the salient's formation nor the mechanisms behind its northward movement. The Hooper Bay salient could prove to be an interesting topic of study not only due to its importance to the ongoing runway erosion mitigation efforts but also because the salient is, in and of itself, an intriguing coastal phenomenon.

Of the two sections of infrastructure that face erosion exposure, the runway is the more important. Fortunately the risk of the runway being damaged by erosion itself has been mitigated by past efforts, while flooding caused by storm surges and the debris they carry remains an issue. Future studies should focus on how to mitigate runway closures due to debris while also maintaining the protections needed to prevent the erosion of the runway.

Conclusion

According to predictions made by the DGGS, 334 feet of road and 968 feet of runway will be exposed to erosion between the years 2015 and 2075. The 334 feet of exposed road are benefiting from current and future community efforts to mitigate erosion and flooding. This section of road should be under continued observation to ensure that the community efforts continue to be effective. The length of road currently exposed to erosion is protected by a combination of armor stones and sheet pile wall, and these protections can be extended as needed. The current issue is the debris deposited on the runway by storm surges. Further research is required in order to identify viable solutions. As part of that research the contributing factors and their magnitude to the erosion experienced by Hooper Bay need to be identified, such as wave action or permafrost degradation. For the runway, some of those solutions may include heightning the sheet pile wall or extending the runway to the south. For the time intervals 2035-2055 and 2055-2075, an estimated cost for an armor stone installation would be $2,424,268 and $2,644,180 respectively. Another possible research subject is the Hooper Bay salient as the cause of its formation and the mechanisms behind its movement are not yet understood.

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Appendix

Figure A.1: Salient position in 1951, Drawn from (Jones 2011)

Figure A.2: Salient position in 2005, Drawn from (Jones 2011)

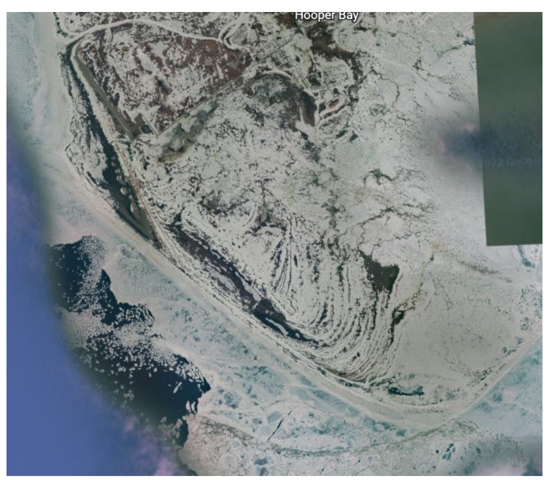

Figure A.3: Salient position in 2020, Drawn from Google Earth, accessed 4/20/22

Table 1. Generic cost of infrastructure in rural Alaska communities determined by the Alaska Native Tribal Health Consortium (ANTHC). Infrastructure listed include only those identified using community planning documents and aerial imagery. Units are linear foot (LF), square foot (SF), and lump sum (LS).

Infrastructure	Unit	Unit Cost	Minimum Cost	Note
Boardwalk	LF	$75	$75,000	
Fuel Lines	LF	$60	$50,000	2-inch schedule 40 steel pipeline
Gravel Road	LF	$400	$200,000	Based on average of $2.1 million per mile of road
Overhead Distribution Lines	LF	$200	$50,000	Average distance between poles of 100 LF
Water/Sewer Line	LF	$400	$50,000	
Community Hall	SF	$1,000	$4,000,000	Based on construction similar to the Mertarvik Evacuation Center (multi-purpose building)
Residential Housing	SF	$350	$400,000	New construction of 3- or 4-bedroom residence, indoor plumbing, post and pad gravel foundation
Unspecified Building	SF	$350	$400,000	Only if greater than 500 SF; maximum cost of $500,000
Airport	LS	$40,000,000*	N/A	Based on $10,000,000 per 1,000 feet; will vary based on gravel price
Barge Landing	LS	$2,500,000*	N/A	Shallow draft landing with mooring points and small laydown area
Bulk Fuel Farm	LS	$4,500,000	N/A	140,000 gallon capacity
Church	LS	$500,000	N/A	Large but simpler construction compared to residential home
City Office	LS	$500,000	N/A	Approximately equivalent to residential housing
Clinic (medium size)	LS	$2,500,000	N/A	
K–12 School	LS	$35,000,000	N/A	
Landfill	LS	$1,000,000	N/A	
Lift Station	LS	$1,000,000	N/A	
Police and Jail	LS	$750,000	N/A	
Power Plant	LS	$3,250,000	N/A	3-generator module, 250 kW capacity
Store	LS	$500,000	N/A	
Teacher Housing	LS	$500,000	N/A	Duplex construction
Tribal Office	LS	$500,000	N/A	Approximately equivalent to residential housing
Wastewater Lagoon	LS	$6,000,000	N/A	3 acres
Water Storage Tank	LS	$1,500,000	N/A	200,000 gallon tank on gravel pad

*Cost may be estimated using cost per SF or LF if appropriate.

Table A.1: Cost to Replace, Generated by the ANTHC. Drawn from (Overbeck et al. 2020)

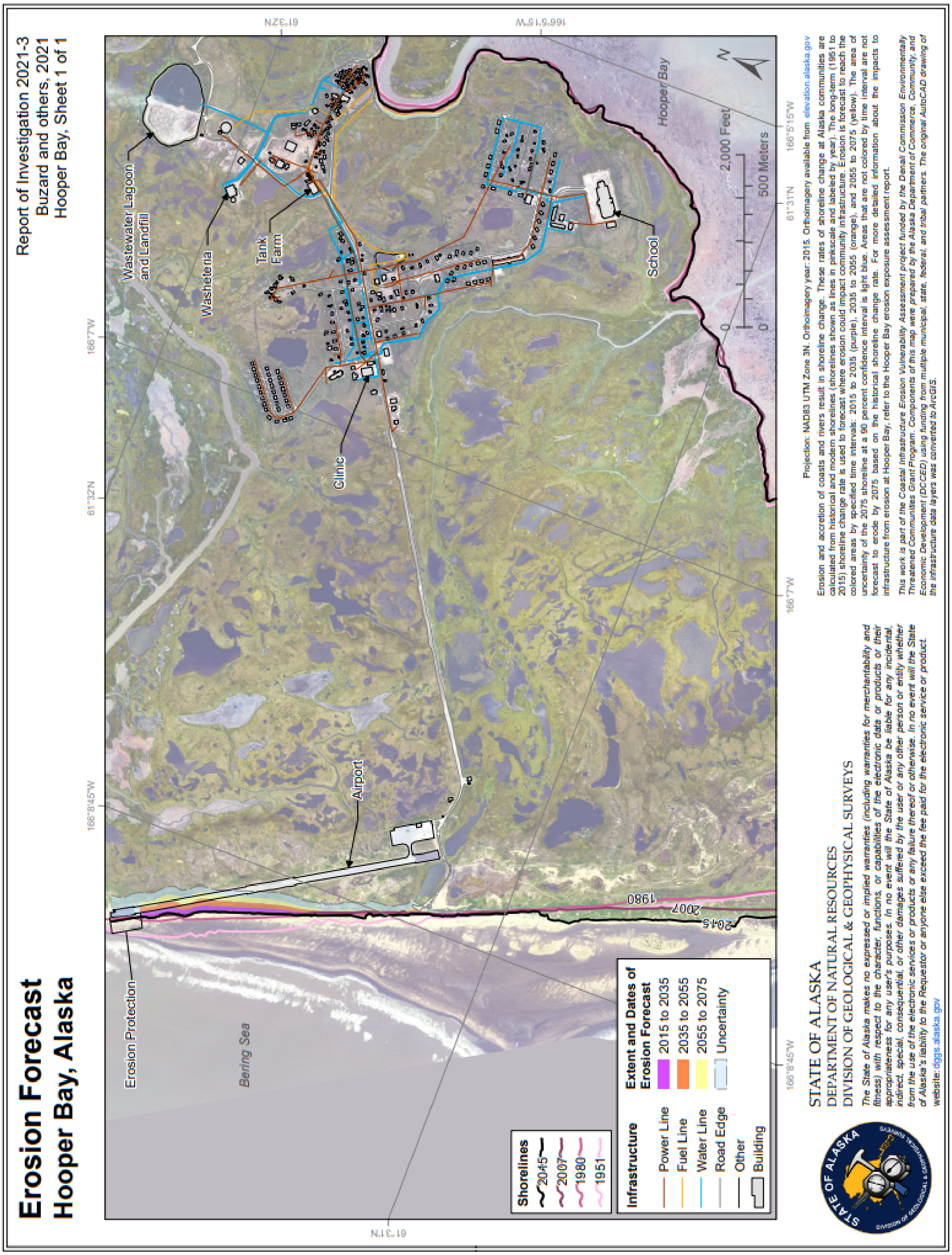

Figure A.4: Hooper Bay Erosion Forecast Map, Drawn from (Buzzard et al. 2021)

Quantity of Exposed Infrastructure						
Erosion Forecast Date Range	**Buildings & Tank Facilities (n)**	**Power Lines (LF)**	**Fuel Lines (LF)**	**Water Lines (LF)**	**Roads (LF)**	**Airport (LF)**
2015 to 2035	0	0	0	0	9	0
2035 to 2055	0	0	0	0	209	463
2055 to 2075	0	0	7	0	116	505
Combined Total	0	0	7	0	334	968

Table A.2: Quantity of Exposed Infrastructure, Drawn from (Buzzard et al. 2021)

Cost to Replace Exposed Infrastructure							
Erosion Forecast Date Range	**Buildings & Tank Facilities**	**Power Lines**	**Fuel Lines**	**Water Lines**	**Roads**	**Airport**	**Sum**
2015 to 2035	$0	$0	$0	$0	$200,000	$0	$200,000
2035 to 2055	$0	$0	$0	$0	$0	$4,630,000	$4,630,000
2055 to 2075	$0	$0	$20,000	$0	$0	$5,050,000	$5,070,000
Combined Total	$0	$0	$20,000	$0	$200,000	$9,680,000	$9,900,000

Table A.3: Cost to Replace Exposed Infrastructure, Drawn from (Buzzard et al. 2021)

Item Description	Cost
Mobilization and Demobilization	3,353,000 $
Workers meals and lodging, or Per diem	894,000 $
Field Office	100,000 $
Engineering Communications	10,000 $
Engineering Transportation (truck)	168,000 $
Engineering Transportation (ATV)	20,000 $
Construction Surveying By Contractor	70,000 $
Primary Armor Stone Class PA-1200 lb	530,000 $
Heating Fuel Tank (1000 gal)	20,000 $
Fuel (1800 gal)	12,600 $
Equipment Rental 75 HP Dozer (100 hrs)	20,000 $
Erosion, Sediment, and Pollution Control Admin	40,000 $
Temporary Erosion, Sediment, and Pollution Control	150,000 $
Spill Prevention, Control, and Countermeasure Plan	8,000 $
Geotextile, Drainage, Class 1	794.750 $
Total	6,190,350 $

Table A.4: List of costs from the Hooper Bay Airport Improvement compilation of bids that may be associated with the installation of armor stones. (Smith 2015)

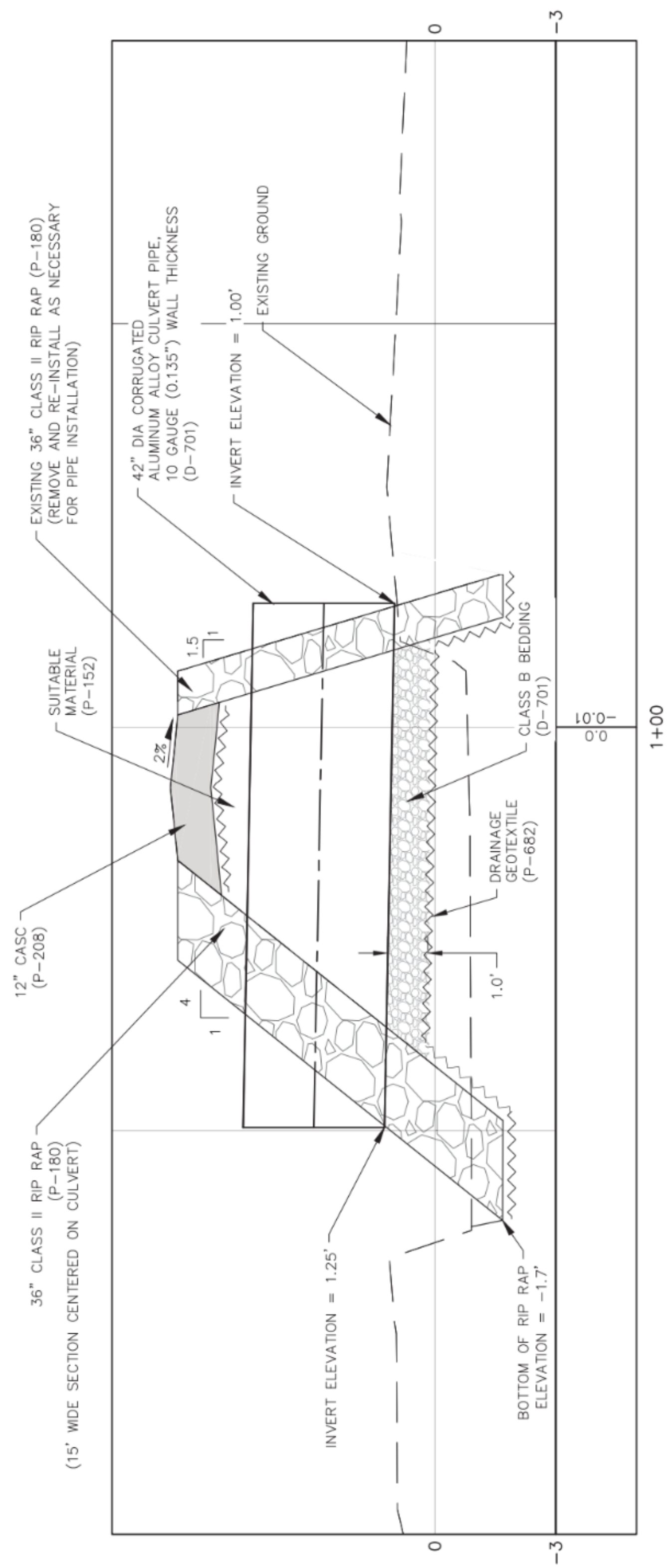

Figure A.5: A cross section of the Airport Access Road, Drawn From 16A of 31 (Beck 2015)