Bristol Alliance Fuels
Site Erosion Report

Dillingham, Alaska

Bristol Project No. 32170071

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ACRONYMS AND ABBREVIATIONS

&	and
@	at
°	degrees
$	dollars (US)
%	percent
ADF&G	Alaska Department of Fish & Game
BAF	Bristol Alliance Fuels
BESC	Bristol Engineering Services Corporation
CPI	consumer price index
ft	foot
h	horizontal
MHW	Mean High Water
MLLW	Mean Lower Low Water
O&M	operations and maintenance
USACE	US Army Corps of Engineers
v	vertical
yd^3	cubic yard
yr	year

1.0 INTRODUCTION

1.1 PROJECT SUMMARY

Bristol Alliance Fuels (BAF) has a retained Bristol Engineering Services Corporation to research and summarize the history of the shoreline protection at the BAF Site, to update previous construction cost estimates to current prices, and to estimate the cost and quantities of additional shoreline protection.

This report is intended to be used as a high level planning document for erosion protection measures for the BAF property adjacent to the Dillingham Small Boat Harbor.

1.2 BACKGROUND AND HISTORY

Dillingham is in southwestern Alaska, approximately 327 miles southwest of Anchorage. Dillingham serves as the economic, transportation, and public service center for western Bristol Bay. Commercial fishing, fish processing, cold storage, and fishing industry support services form the base of the local and regional economy. The Dillingham Small Boat Harbor accommodates about 350 fishing vessels and is vital for commercial salmon fishing interests. The Dillingham harbor was first constructed in 1960 by enlarging the channel of Scandinavia Creek where it enters the Nushagak River estuary, and has been labeled a "half-tide harbor" because it goes essentially dry at low tides. The harbor must be dredged annually to maintain functionality. The harbor is used seasonally as a commercial fishing base by residents of Alaska as well as by others from outside the state.

Erosion is a constant threat to Dillingham, which is on a bluff overlooking the Nushagak River estuary. Main infrastructure in the study area that will be affected in the near future includes both private and public property, the small boat harbor mooring and launching facilities, the BAF facility, and the city waterfront park.

Bristol Alliance Fuels owns the land to the west of the harbor and also owns the bulk fuel tanks that presently hold the fuel supply for the City of Dillingham and surrounding communities (shown in Figure 1). The Bristol Alliance Fuels operations site on the Nushagak River west the Dillingham harbor has been experiencing erosion issues and BAF is looking to protect their property and infrastructure. The BAF site is home to the largest fuel facility in the Bristol Bay area, a 2.95-million-gallon tank farm, marine fueling facility, docking, and barge haul-out services. BAF also supplies fuel to surrounding communities when the need arises (in recent years to Aleknagik, Manokotak, Clarks Point, and Koliganek) and to snowmachiners and boat operators in the region. BAF stores fuel for Crowley Marine barges (formerly Yukon Fuels) so that Crowley can avoid sending large barges upriver and bottoming out in shallow spots. The BAF dock is a good location for rolling on and off and supports the construction industry in the region with loading and off/loading capabilities.

BAF's goal is to protect and improve their existing facilities at the site with by expanding existing pad areas, improving the barge haul-out ramp, adding a separate public beach access road, high mast site lighting, adding a protected harbor side fueling station, and storage areas.

Figure 1: 2016 Aerial Photo of BAF Site

1.3 PREVIOUS STUDIES AND PROJECTS

There have been 15 previous studies by the U.S. Army Corps of Engineers (USACE) for the Dillingham area between 1960 and 2009. The two USACE studies done in 2009 were the Economic Analysis for City of Dillingham Shoreline Emergency Bank Stabilization and the City Shoreline Emergency Bank Stabilization, Dillingham, Alaska. These two reports are the foundation of this technical memorandum is the source of all technical and historical information unless stated otherwise.

Previous efforts to control riverbank erosion in Dillingham include:

- 1,600 feet of sheetpile bulkhead at Snag Point built between 1995 and 1998
- 600 feet of sheet-pile bulkhead built east of the harbor entrance
- 400 feet of riprap revetment on the east bank of the entrance channel in 1999
- The timber plank and pile bulkheads built in 1983
    - replaced by open cell sheet-pile bulkhead in 2004-2005

Buildings and a dock owned by the Bristol Bay Packing Company Cannery once stood where the BAF dock is currently located. The cannery was dismantled in the late 1960s and the Ball Brothers then used the site in the 1980s during which they constructed a wooden bulkhead. The bulkhead prevented further erosion of that area until a storm destroyed it sometime around 1997 or 1998. In the summer of 2004, BAF completed construction of a sheet-pile dock in same location as the old sheet-pile and timber bulkhead

1.4 CAUSES OF EROSION IN DILLINGHAM

Extreme tides, currents, storm surges, and wave and ice conditions are responsible for creating land erosion at the west bank of the Dillingham Harbor.

1.4.1 Tides

Tide levels at Dillingham range from 23.0 feet above mean lower low water (MLLW) at the extreme high water to -4.6 feet below MLLW at the lowest tide.

1.4.2 Currents

Nushagak Bay currents are affected by the marine influences of the Bering Sea and fresh water effects from Scandinavian Creek, Squaw Creek, the Nushagak River, and the Wood River. The predominant direction of the current is east to northeast. The maximum current recorded from all ship trackline data was an easterly velocity of 7.5 knots measured offshore in the vicinity of the city dock at flood tide. Current velocities within the project area ranged from 0.64 knot to 2.5 knots.

1.4.3 Storm Surges

Storm surges are increases in water elevation caused by a combination of relatively low atmospheric pressure and wind-driven transport of seawater over relatively shallow and large unobstructed waters. Storm induced surges can produce short-term increases in water level, which rises to an elevation considerably above tidal levels. Dillingham has low-pressure events that may cause an increase in the water levels at the shoreline. However, the many obstructions presented by bends and sandbars over the fetch are expected to prevent storm surges greater than 6 feet.

1.4.4 Wave Climate

The wave climate at Dillingham is generally moderate and is subject to short-period wind generated waves from the southwest to northeast. Waves coming from the southwest are predominant and are subject to diffraction, refraction, and shoaling as they pass through bends in the river. The longest fetch is from the southwest and is 25.7 miles. The 50-year design storm wave was determined to be a 6.22-foot breaking wave from the southwest with a period of 5.0 seconds.

1.4.5 Ice Conditions

Nushagak Bay generally begins to freeze up around the first of November. Break-up usually begins sometime in May. Ice ride-up on the shore is common and should be expected on any rubblemound structure. Controlling ice forces on the harbor side were listed at 13 kips/ft over the upper elevations.

1.5 SITE EROSION HISTORY

Erosion of the BAF-owned lands has been under constant threat of erosion as far back as 1899, as recorded on Plat 62-135 Bristol Bay Recording District when the land was transferred from the North Coast Packing Company to the New England Fish Company. See Figure 2 for historical erosion of the site.

The Dillingham Small Boat Harbor has historically been protected by the point of land near Scandinavian Beach. Surveys performed for the 1960 boat harbor project show Scandinavian Beach extending 700 feet from the top of the west bank, across the opening of Dillingham Harbor with a top elevation of 10 to 15 feet above MLLW. Topographic information collected in 2001 shows that this entire 700-foot section has eroded away, with the west top of bank receding by about 300 feet. It is hypothesized that this extreme rate of erosion as likely caused by a combination of factors. The most likely contributing factor is that the point forced a hard 90-degree bend in Scandinavian Creek. This bend was subject to the constant erosive forces of the creek. Very similar to any other meandering stream or creek in the region, banks erode away due to the loose sandy silt soils prevalent in the area, which are easily erodible. Figure 3 and Figure 4 are the historical photos of Scandinavian Beach, which depict the land lost from 1981 to 2001. In recent years, erosion along the west side of the un-stabilized bank area has progressed to an extent that it has washed away the point of land at Scandinavian Beach that protected the small boat harbor. In turn, exposure to open water has increased wave action within the harbor basin and subjected the fine soils along the inner harbor banks to erosion.

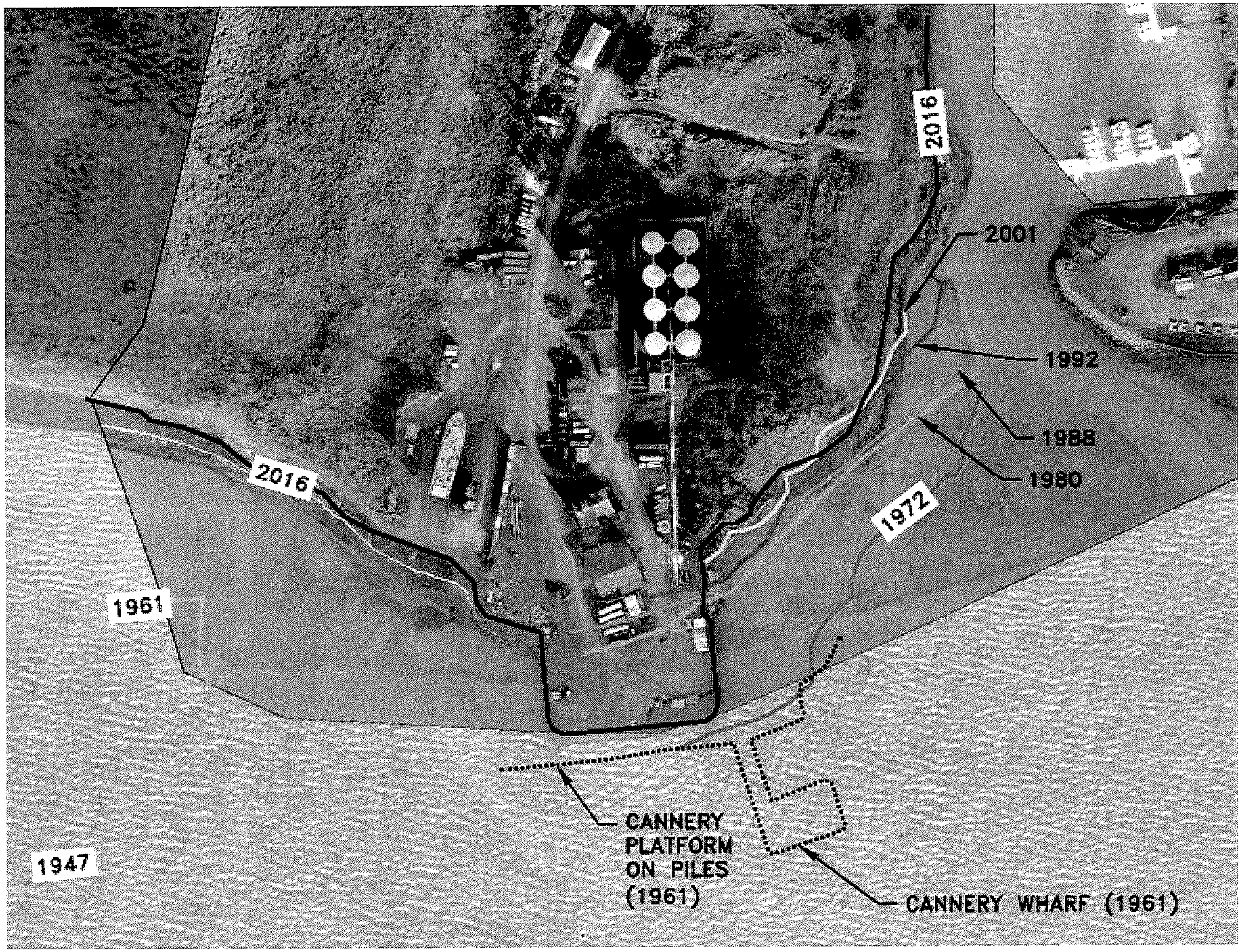

Figure 2: Shoreline Erosion History of BAF Site

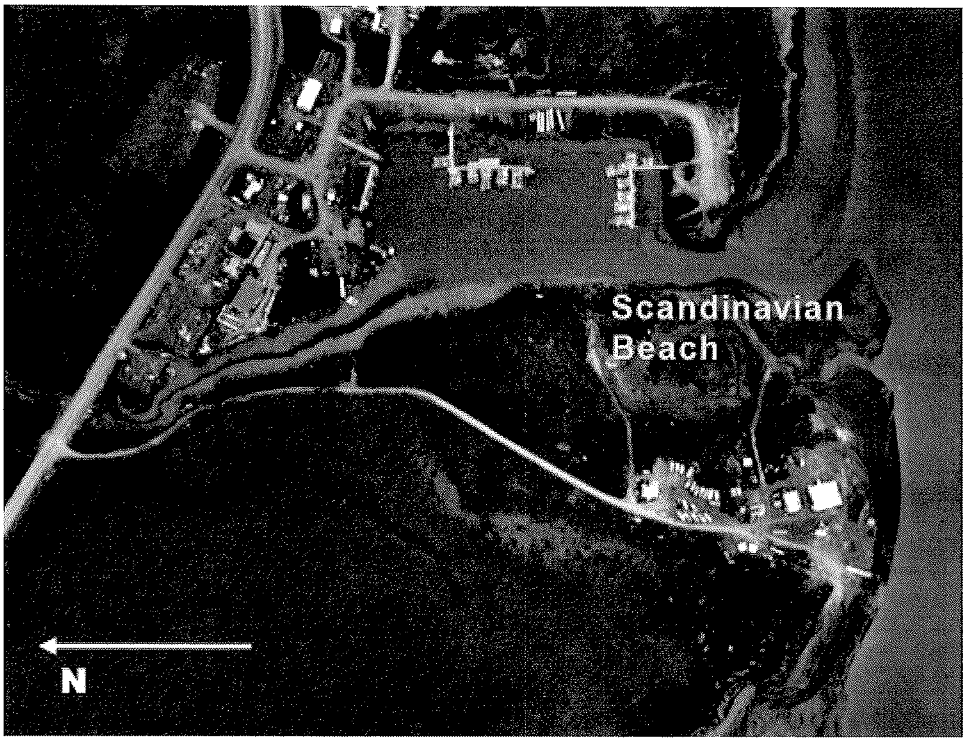

Figure 3: Scandinavian Beach in 1981

Figure 4: Scandinavian Beach in 2001

The USACE Reports outline different areas, and rates of erosion, for the land immediately adjacent to the small boat harbor. The erosion areas are broken into three zones. Zone 1 represents the western boundary of the BAF site, which lies outside of the small boat harbor. Zone 2 represents the western boundary of the BAF site, which lies within the small boat harbor. Zone 3 represents the western bank of the inner harbor. These zones are identified in Figure 5.

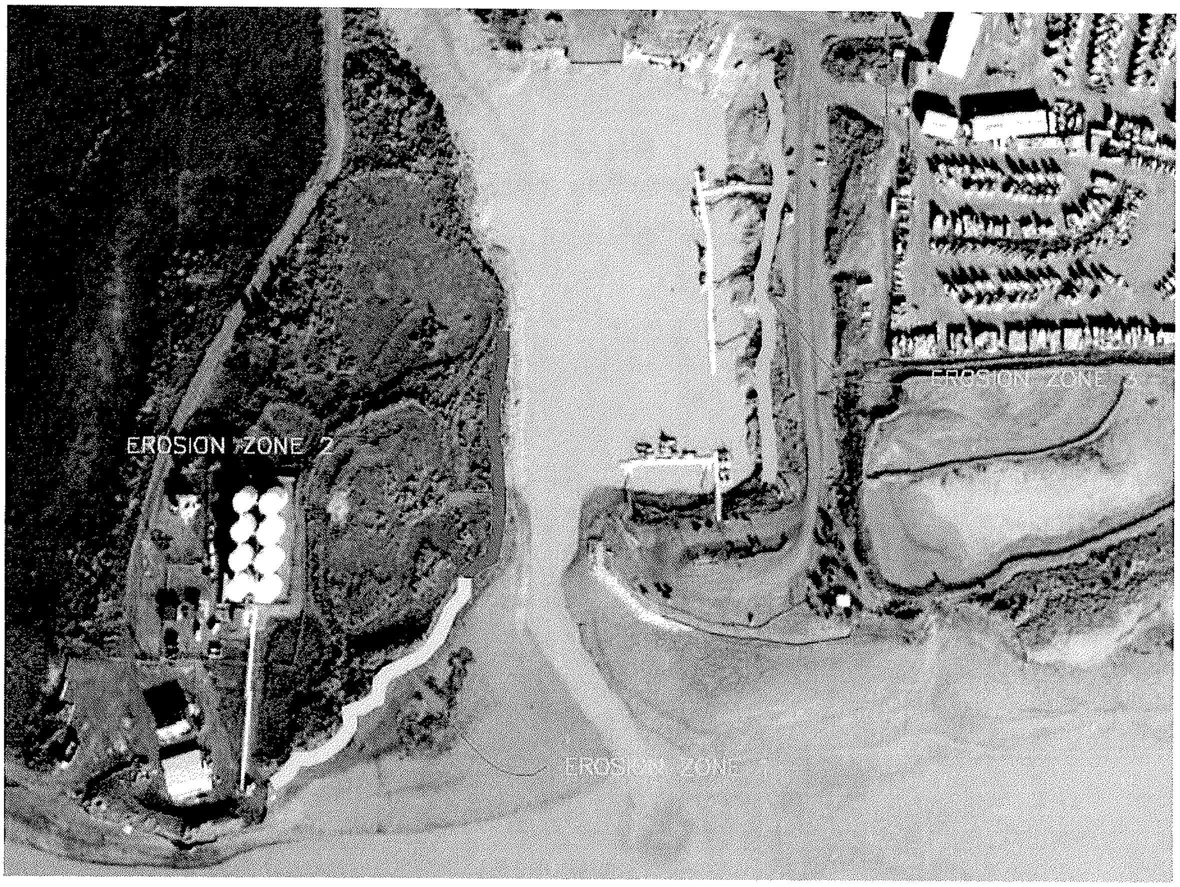

Figure 5: Erosion Zone Delineation

Table 1 shows the land lost from erosion for each zone and Table 2 shows the erosion rate for each zone. The USACE Reports indicated that the average erosion for the Western boundary of the BAF Site for the period of analysis from 1972 through 2001 was 10.8 linear feet per year, with an estimated 5.7 acres lost since 1972.

Table 1: Historic Land Loss (1972-2001)

ZONE 1	
Linear Feet of Landward Bank Erosion:	316
Lost Acreage:	4.5
Value of Lost Acreage:	$124,800
ZONE 2	
Linear Feet of Landward Bank Erosion:	40
Lost Acreage:	0.4
Value of Lost Acreage:	$11,600
ZONE 3	
Linear Feet of Landward Bank Erosion:	40
Lost Acreage:	0.8
Value of Lost Acreage:	$21,600
TOTAL ZONES 1-3	
Linear Feet of Landward Bank Erosion:	396
Lost Acreage:	5.7
Value of Lost Acreage:	$157,900

Table 2: Annual Erosion Rates

Erosion Zone 1	
Comparison Years	Erosion Per Year (ft/yr)
1972 to1980	17.14
1980 to 1988	3.11
1988 to 1992	15.54
1992 to 2001	7.75
Average Erosion Per Year – Zone 1	*10.89*
Erosion Zone 2	
Comparison Years	Erosion Per Year (ft/yr)
1972 to1980	2.06
1980 to 1988	2.24
1988 to 1992	0.042
1992 to 2001	1.22
Average Erosion Per Year – Zone 2	*1.39*
Erosion Zone 3	
Comparison Years	Erosion Per Year (ft/yr)
1972 to1980	1.06
1980 to 1988	0.28
1988 to 1992	3.45
1992 to 2001	0.71
Average Erosion Per Year – Zone 3	*1.38*

Historical documents do not mention erosion issues along the west bank of the interior of the harbor. This indicates that erosion problems likely developed over the last few decades. As previously mentioned, since 1972 the shoreline has eroded more than 200 feet, and lowered by at least 10 feet vertically, thus allowing waves to enter the harbor unimpeded. For example, the 1985 Dillingham, Alaska Final Detailed Project Report and Environmental Impact Statement does not mention waves entering the harbor. Since the late 1990's, waves from storms have been documented entering the harbor causing interior erosion, damage to vessels, and increasing the maintenance costs of existing harbor facilities.

In August 2005, a storm surge has inflicted major damage to the Dillingham shoreline. The August 2005 storm washed away up to 10 feet of the shoreline, overtopped the sheet-pile seawall at the parking lot by at least 2 feet, washed parked vehicles into the harbor, and washed boats that were moored in the harbor up onto dry land, see Figures 6 & 7. Water elevation at the time of overtopping included a tide elevation of about 20 feet MLLW. Based upon an estimated surge of 3 feet, the total height of water when the wave crest was at the wall was estimated at 23 feet MLLW.

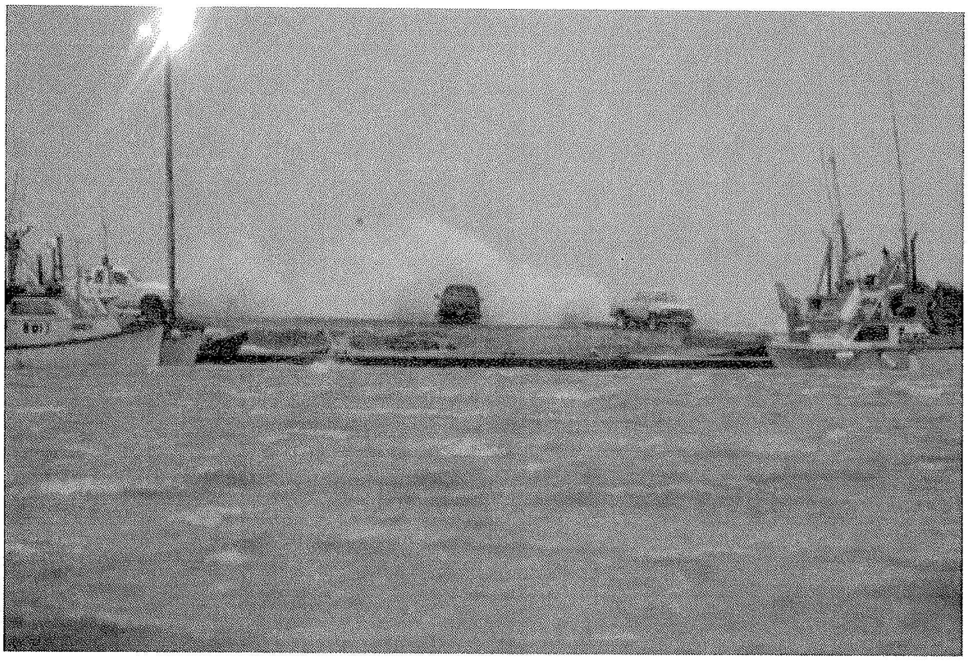

Figure 6: Waves breaking over outer bank

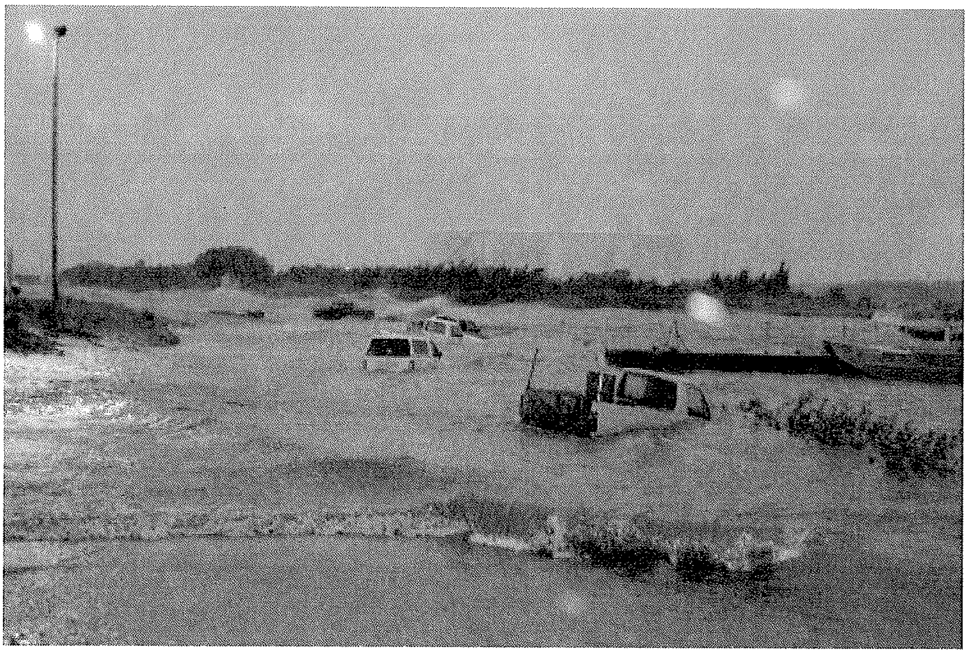

Figure 7: Storm surge in the harbor

In 2015, a large piece of the shoreline on the west side of Scandinavian Creek eroded away. This piece of land is adjacent to the BAF fuel tanks. Additional land on the west side of Scandinavian Creek north of the harbor has also recently eroded and is threatening the access road to the BAF facilities, see Figures 8 & 9.

Figure 8: Erosion that occurred in 2015 on west side of harbor

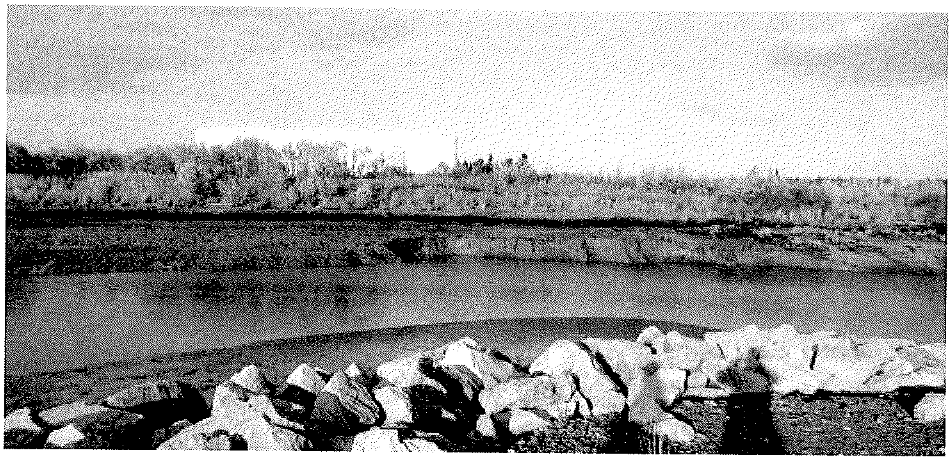

Figure 9: Looking west from harbor at the erosion adjacent to the fuel tanks

1.6 Ongoing Erosion Concerns

The continuous threat of erosion of the BAF-owned lands adjacent to the west entrance channel of Scandinavian Creek resulted in the need for BAF to construct shoreline protection measures approximately 650 feet southwest of the harbor entrance channel in 2003. This was only a stopgap measure as the threat of land and infrastructure loss due to erosion is still eminent. Earlier USACE reports (2009) stated that the tanks could be threatened as early as 2015. While this did not occur, BAF understands the importance of having a timeline of anticipated land loss in order properly plan for the protection of their assets. As a result of this need, Bristol Engineering Services Corporation (BESC) has developed updated erosion rates and figures depicting the bank location at mean high water (MHW) for the years 2020, 2030, and 2040.

To determine the rate of erosion each zone BESC used data developed by the USACE, displayed in Table 2 and a comparison of the 2001 bank location at MHW to the 2016 bank location, for Zone 1. There was not enough data to complete this exercise for Zones 2 and 3. The erosion rates for Zone 1 were determined to be 1.6 ft/yr. This combination of data was evaluated to determine the median value of the erosion rates from 1972 to 2016. The median value was used in lieu of the average due to the limited amount of data and lack of normalcy of the data sets. This data is presented as Table 3.

Table 3: Annual Erosion Rates - Updated 2016

Year	Zone 1	Zone 2	Zone 3
1972 to 1980	17.14	2.06	1.06
1980 to 1988	3.11	2.24	0.28
1988 to 1992	15.54	0.04	3.45
1992 to 2001	7.75	1.22	0.71
2001 to 2016	1.6	-	-
Median (ft/yr)	7.8	1.6	0.9

See Figure 10 for a visual representation of the predicted erosion limits, as a basis of time. Please note that this figure is for planning purposes only and is subject to the assumptions made as part of this analysis.

1.6.1 Zone 4 Erosion

The USACE reports only focused on erosion on the eastern boundaries of the BAF site. In order to have a comprehensive picture of erosion of the entire BAF site a new zone was added, Zone 4. Zone 4 represents the shoreline on the south and west of the BAF site. This area is shown on Figure 2, as the bank lines west of the all tide dock.

Based on a comparison of the shoreline locations from 1961 to 2016 it was determined that an annual loss of 5.9 feet occurred in Zone 4. This value was used in the visual representation of the predict erosions limits shown in Figure 10. The approximate area of area lost during this time period in Zone 4 is 7.2 acres.

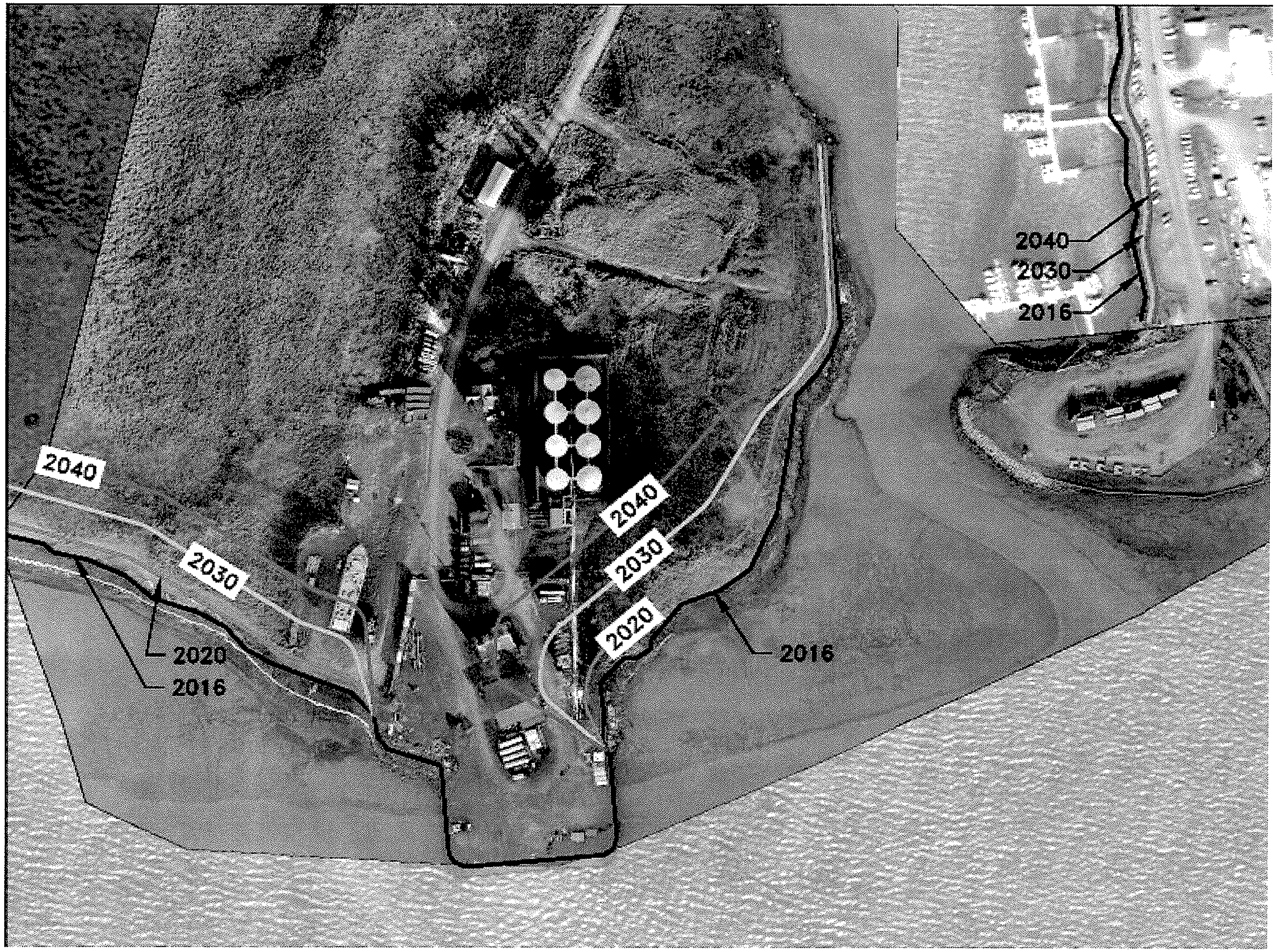

Figure 10: Predicted MHW Bank Locations over Time

1.7 Impact to the Local Economy

Damage to the BAF facility would be serious. There are other fuel providers in the area, but research has indicated that the loss of BAF would be a critical breakdown in fuel supply infrastructure, not only to Dillingham, but also to several outlying communities. The loss or severe damage of this facility would greatly impact the supply of fuel and other petrochemical supplies to the region. There would be significant life safety issues in that utilities and transportation in five communities would have their fuel supply opportunities greatly decreased. Any impacts to the fuel supply and storage could have a costly impact on fuel prices in the region. In addition to the economic impacts, there is the environmental concern that a spill of fuel oil or other petrochemical product would be extremely damaging to the environment, especially the highly valued salmon fishery.

The Bristol Bay commercial fishery is vital to the economy of the region. Dillingham is the primary operating center for fishermen and fish processing in the Nushagak District and has the only protected boat harbor in Bristol Bay. The Alaska Department of Fish and Game (ADF&G) reported that The Bristol Bay region had a salmon harvest with an ex-vessel value of $94,480,000 in 2015.

The salmon fishery is of great concern to the local population, and any project would need to have minimal impacts to the fishery, both during construction and for the project life. Residents use the tidal flats to the east and west of the boat harbor entrance as subsistence set net sites. It is important that any coastal stabilization construction project be designed to minimize interference with this activity that is of both economic and subsistence importance.

Damages associated with incremental maintenance and advanced replacement to harbor infrastructure are occurring as a result of erosion in the study area. Types of infrastructure damages include: repairs and advanced replacement of moorage floats, damage to moorage float swing arms, damage to concrete boat ramps, and damages to the harbor bulkhead.

The commercial fishing fleet utilizing Dillingham Harbor includes up to 750 vessels. The commercial fishing season out of Dillingham Harbor extends primarily from May through July. The peak number of commercial vessels that utilized the harbor at any one time was approximately 450 during a salmon fishing closure. The typical number of vessels utilizing the harbor at any one time during the fishing season is between 250 and 300 vessels. Harbor users typically incur vessel damages as a result of increased wave action during storms. Damaging storms were identified as those causing waves of 2' or higher within the harbor. Engineering analysis of wind and tide data for the study area confirmed local estimates of annual damaging storm frequency at 7 storms per year during the May-September fishing and boating season.

2.0 USACE ENGINEERING STUDY

The purpose of the 2009 USACE study was the reduction of current and future damages to existing structures and facilities as caused by wave action. The 2009 USACE study looked at six design alternatives including a "No-Action" plan. The Alternatives are described throughout this section and shown in Figures 11-16.

2.1 ALTERNATIVE W1

Alternative W1 consists of a rock revetment on both the west and east sides of the inner harbor, see Figure 11. This alternative is designed to eliminate the erosion problems along the west bank and inside the harbor itself, but would not replace the protection that had been provided by the Scandinavian Beach spit, before it eroded away. Although this project would be able to claim benefits from eliminating erosion, there would still be residual damages from waves entering the harbor.

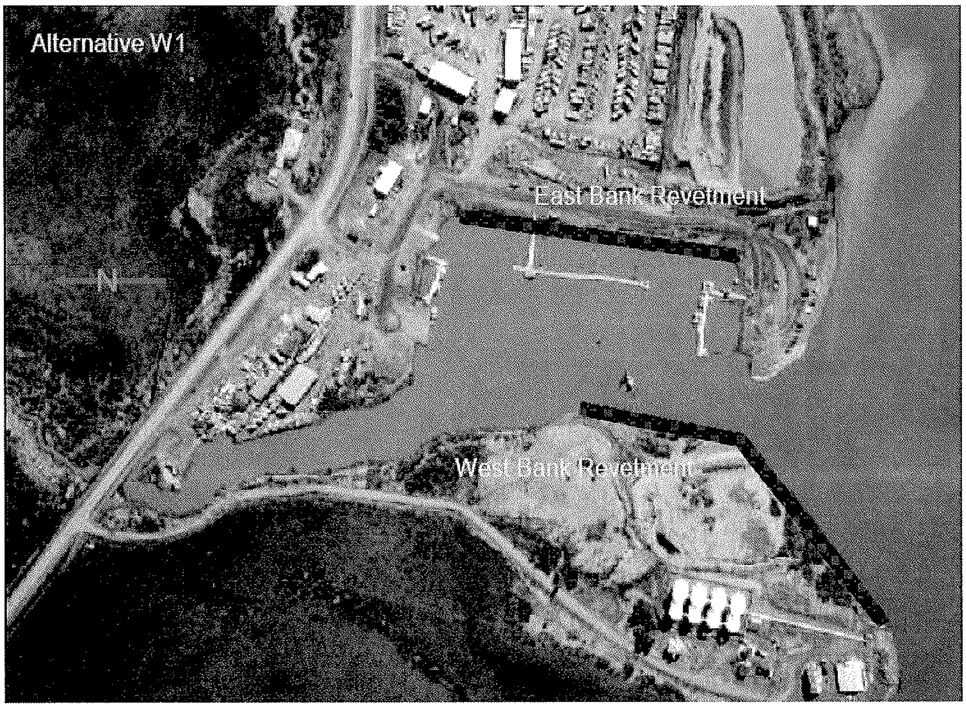

Figure 11: Alternative W1

2.2 ALTERNATIVE W1A

Alternative W1A consists of a combination of sheet-pile wall and rock revetment on the west side of the harbor and a rock revetment on the east side of the harbor, see Figure 12. This alternative was prepared in response to a request of BAF. BAF wanted the option for potential fueling and barge loading operations, for which the sheet pile option would be ideal.

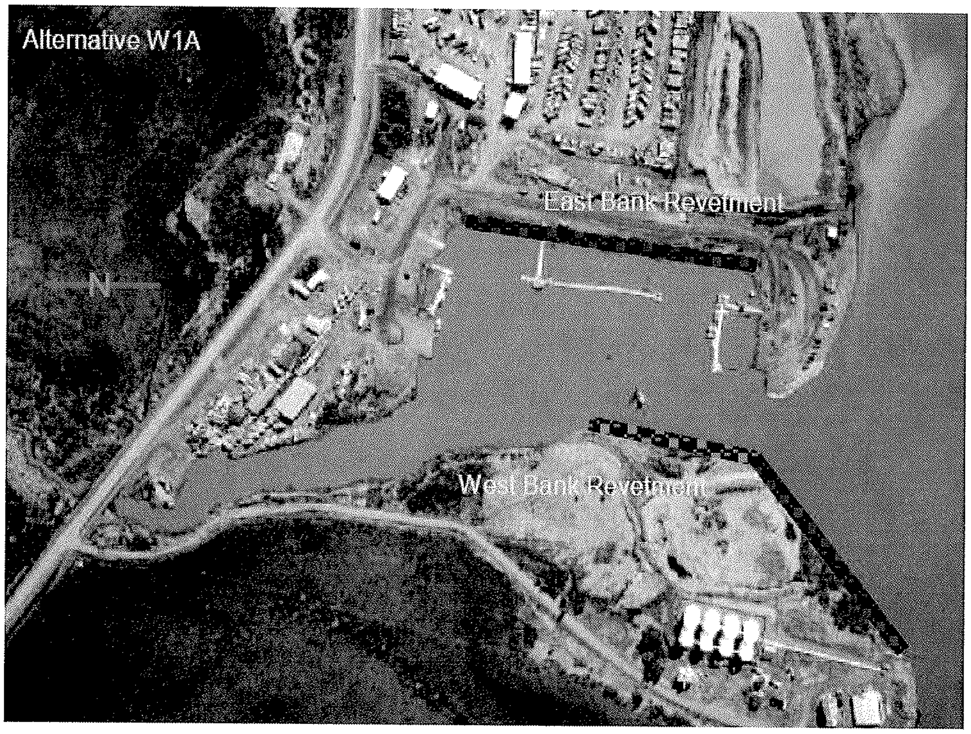

Figure 12: Alternative W1A

2.3 ALTERNATIVE W2

Alternative W2 consists of a rubble mound breakwater and a rock revetment on the west side of the harbor. see Figure 13. This alternative utilizes both a breakwater and revetment to prevent future erosion damages. The breakwater would prevent large waves from entering the harbor, thus eliminating much of the erosion problem within the harbor. The revetment along the west bank is necessary to prevent erosion in the areas of the west bank still exposed to the adverse wave climate. Because waves that would impact the interior west bank would be much smaller than those that are currently impacting the west bank, the revetment cross section for this interior section would not require material as large as that required in Alternatives W1 and W1A. The armor rock thickness for the revetment would be reduced from 5.0' to 3.0' thick and the size of the armor rock would be reduced from rocks in the 3,000 lb. range to rocks in the 300 lb. range.

While the erosion occurring on the east side of the harbor has no direct impact to BAF, the breakwater installed in this option would reduce waves entering the harbor from 6' to 1' and would significantly reduce damage to harbor facilities and vessels as well as eliminating the need for a revetment on the east side of the harbor. This breakwater would be also beneficial to BAF if an interior harbor fueling or barge loading location is added in the future.

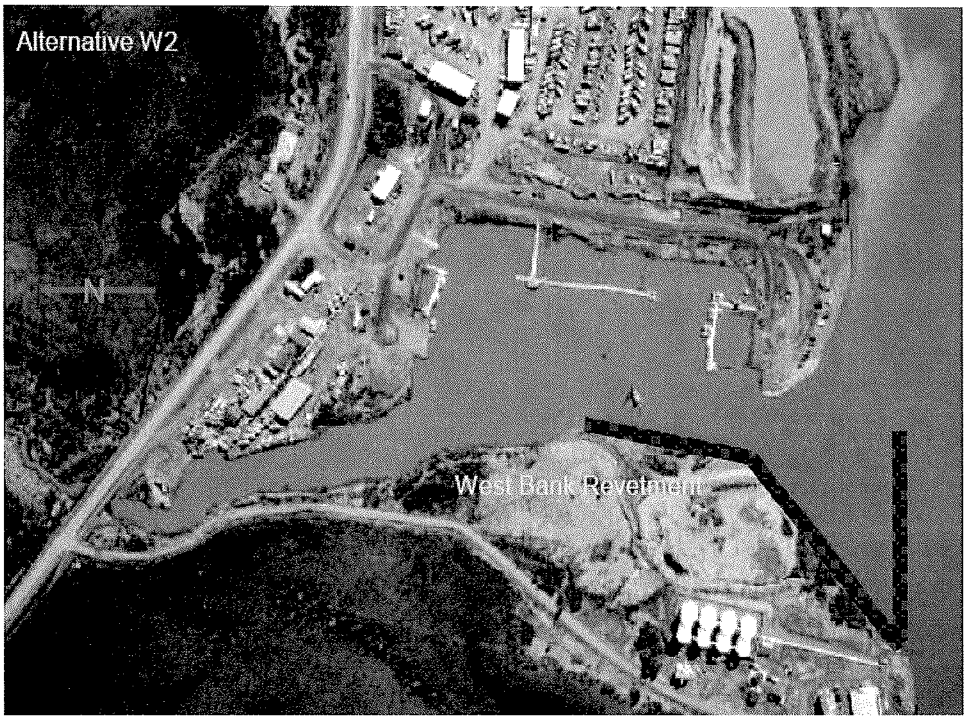

Figure 13: Alternative W2

2.4 Alternative W3

Alternative W3 is essentially the same as alternative W2, except for including the east revetment and a somewhat different alignment for the breakwater, see Figure 14. This alternative accomplishes the same as alternative W2 but includes added protection for the east bank to prevent further erosion from the residual 1-foot wave in the harbor. This additional increment of protection would be expected to provide very little in the way of additional damages prevented. This alternative also used a different size breakwater to see if a lesser cost breakwater could be found.

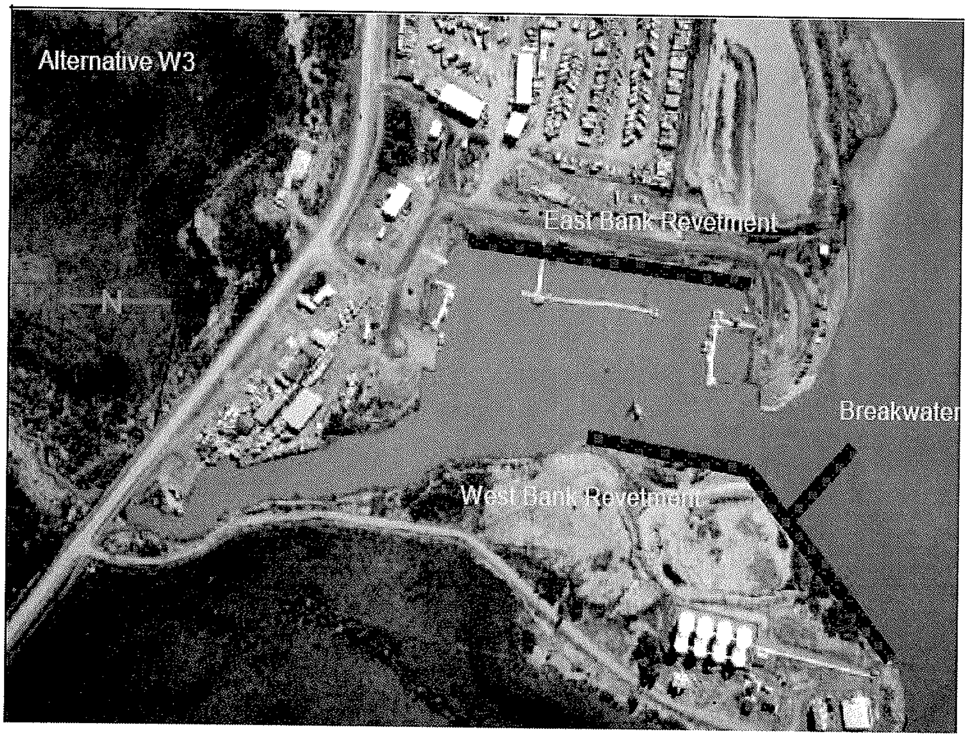

Figure 14: Alternative W3

2.5 ALTERNATIVE W4

Alternative W4 is essentially the same as alternative W2 and W3, except for including the east revetment and a somewhat different alignment for the breakwater, see Figure 15. The purpose of this alternative was again to discover if a different breakwater alignment would provide protection at a lesser cost.

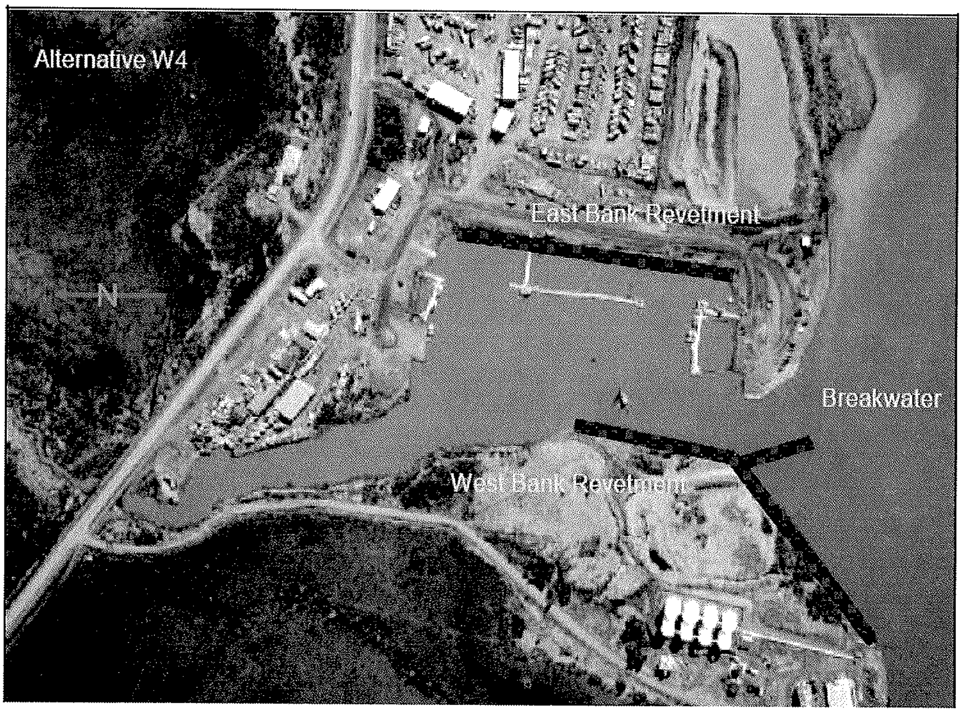

Figure 15: Alternative W4

2.6 Alternative W5

Alternative W5 has the same breakwater and rock revetments on the west side of the harbor as Alternative W2 and the revetment on the east bank, see Figure 16. This alternative was added later in the analysis after Alternative W2 was found to be the most cost effective alternative. This alternative adds the east revetment to Alternative W2 to determine if the additional increment of the east revetment would be cost effective.

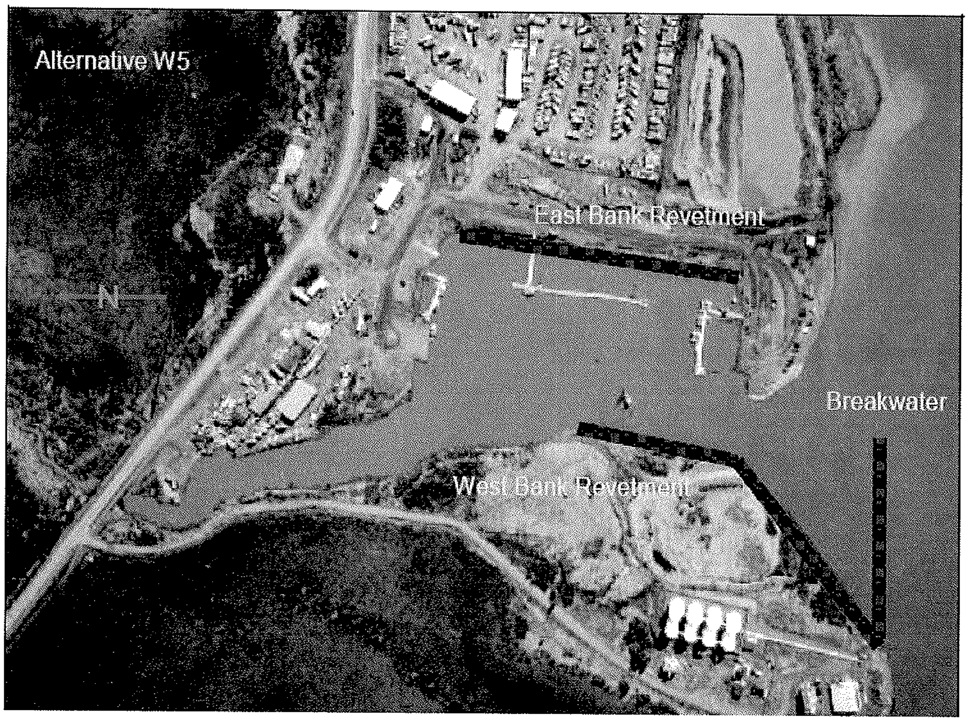

Figure 16: Alternative W5

2.7 Alternative W6

Alternative W6 is the No-Action plan and only meets the objectives of minimizing impacts to fishing habitat and maintenance dredging of the harbor.

2.8 USACE Study Conclusions

The USACE analyzed the alternatives based on damages avoided, a benefit to cost ratio, an evaluation of the advantages and disadvantages of the materials and alignments, and comparison to determine the most cost effective alternative. Construction cost, total and average annual first cost, annual operation and maintenance, and total annual costs were developed for each alternative.

2.8.1 Eliminated Alternatives

After the initial analysis, Alternatives W1A, W3, W4 and W6 were eliminated from further consideration. W1A was eliminated because sheet-pile was deemed to be cost prohibitive when compared with the cost of riprap. Alternatives W3 and W4 were eliminated because, when the effectiveness of these alternatives was analyzed, they appeared to have identical benefits as W5. Furthermore, the costs of Alternatives W3 and W4 are much higher because they require a substantial amount of additional riprap along the revetment to prevent the same amount of damages. Alternative W5 requires less riprap armor than W3 and W4 because the breakwater is located farther out, which causes the wave energy to be dissipated sooner, resulting in less armor needed behind the breakwater. Due to the decreased riprap armor, initial cost estimates showed that Alternative W5 had the lowest cost when compared to W3 and W4 while it provided identical benefits, and thus was the most logical to keep. The no action plan, Alternative W6, was eliminated because it did not meet the primary objective of significantly reducing erosion damages and protecting the harbor.

2.8.2 Preferred Alternatives

For the remainder of this report, the focus will be Alternative W1, Alternative W2, and Alternative W5.

2.8.3 Alternative W1

It is estimated that alternative W1 would effectively stop land loss from erosion on the West Side; however, it does not replace the natural protection that had been provided by Scandinavian Beach, and does nothing to reduce the damages caused by wave energy within the harbor. Arresting erosion in the harbor would eliminate the need for future emergency actions to protect the BAF facility and future repairs to the sheet-pile swing arms. This alternative also does not address the identified damages to moorage floats, concrete boat ramps, the harbor bulkhead, and vessel damages. See Figure 17 for the estimate of wave heights entering the harbor using Alternative W1.

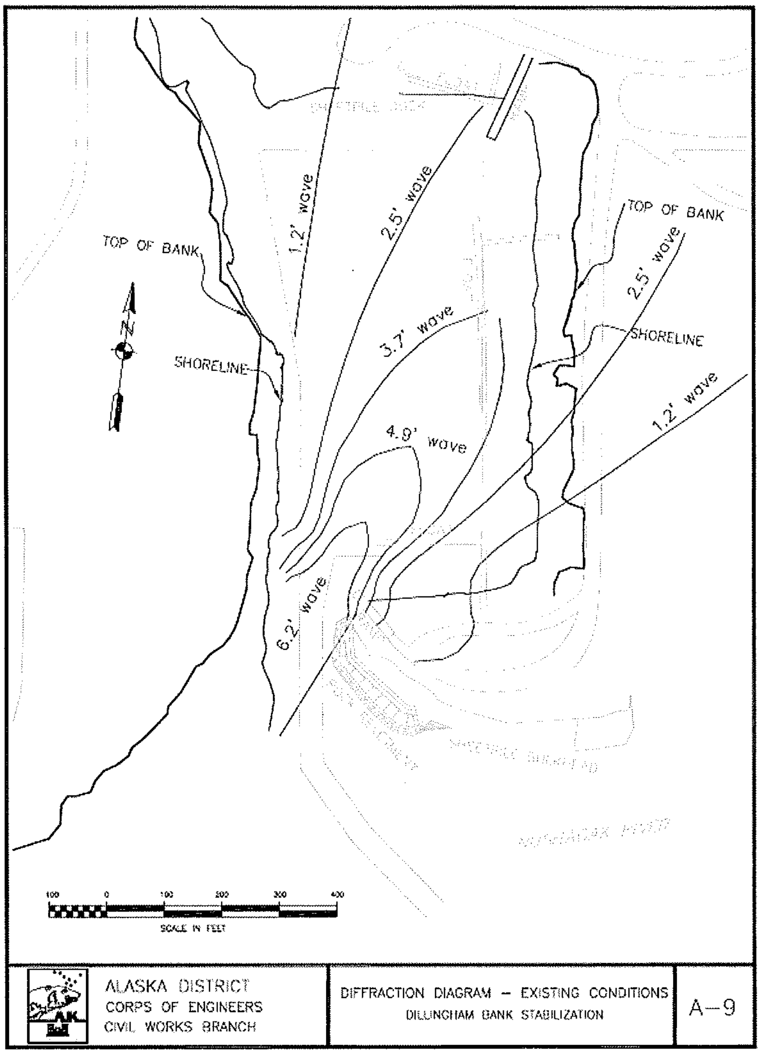

Figure 17: Wave heights using Alternative W1

2.8.4 Alternatives W2 & W5

It is estimated that alternatives W2 and W5 would effectively halt erosion in the study area and eliminate effects of land loss and damages to near-shore harbor infrastructure. Consistent with USACE shore stabilization design standards, alternatives W2 and W5 were formulated such that wave height in the harbor would be maintained at less than 1 foot, eliminating the incremental damages to floats and vessels in the harbor, see Figure 18. As such, each alternative as designed is expected to eliminate the identified incremental damages associated with erosion in the study area.

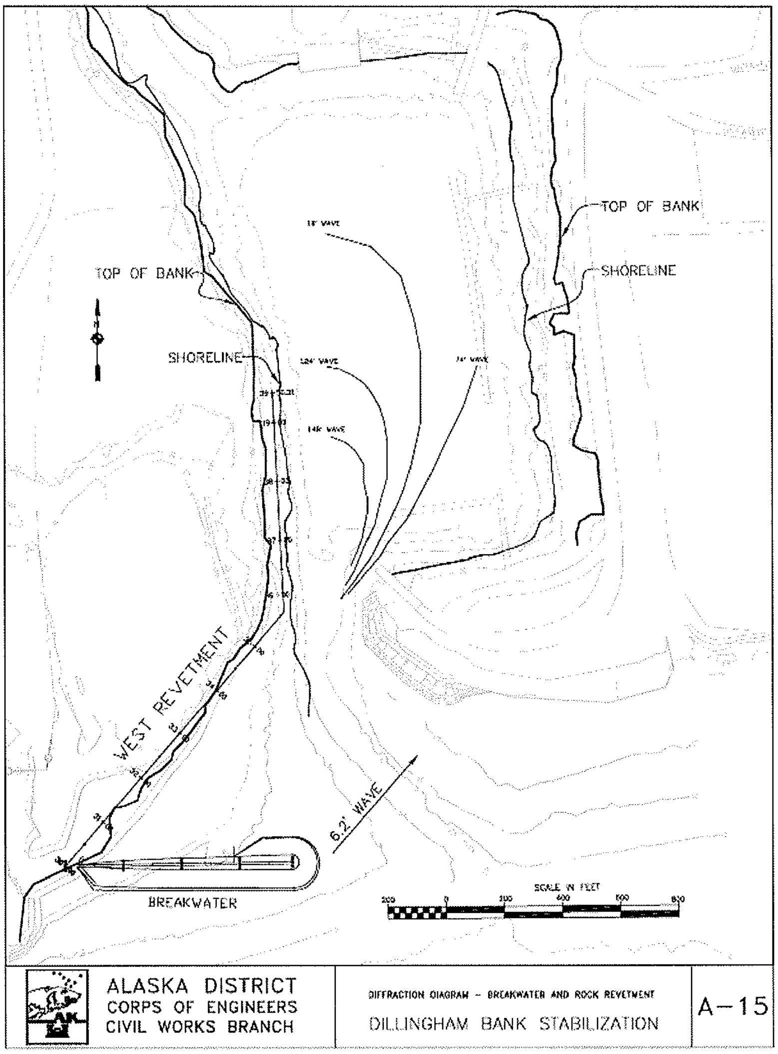

Figure 18: Wave heights using Alternative W2 & W5

2.9 Costs Comparison

Of the five construction alternatives, the USACE developed preliminary cost estimates for the three most viable alternatives, W1, W2, and W5. The preliminary cost estimates, in 2008 dollars, for these alternatives are shown in Table 4.

Table 4: Preliminary Project Alternatives Cost Comparison

	Alt W1	Alt W2	Alt W5
Project Costs	$12,924,000	$8,780,000	$10,238,000
Annual O&M Costs	$64,700	$43,900	$51,200

After developing these preliminary project costs, the USACE then did a comprehensive analysis of the least cost alternative W2. This analysis placed the estimated cost of the project at $12,245,000, a 39.5% increase from the preliminary estimate. Due to the similar nature of all three alternatives presented in Table 4, we anticipate the error in the initial project cost to be systemic therefore; we have updated the preliminary project cost to reflect the cost of W2. These updated project cost are shown in Table 5.

Table 5: Preliminary Project Alternatives Cost Comparison (Updated)

	Alt W1	Alt W2	Alt W5
Project Costs	$18,029,000	$12,245,000	$14,282,000

2.10 USACE Recommended Alternative

As can be seen in Table 4, the Alternative W1 was approximately 50% more expensive than Alternative W2. Both W1 and W2 provide the same amount of shoreline protection for the BAF site. Because of the protection offered by the breakwater in Alternative W2, the armor rock thickness for the revetment is reduced from 5.0' to 3.0' thick and the size of the armor rock would be reduced from rocks in the 3,000 lb. range to rocks in the 300 lb. range. Combined with the additional protection offered to the City side, alternative W2 was recommended over alternative W1. Alternative W5 is the same on the west side of the harbor as W2 but includes additional protection on the City side. The USACE found that the benefits from that additional protection did not outweigh the costs. Alternative W2 was chosen as the recommended alternative.

Alternative W2 consists of a 391-foot rubblemound breakwater and a 950-foot rock revetment on the West Side of the harbor with no bank stabilization on the east bank, see Figure 18. This alternative uses both a breakwater and revetment to prevent future erosion damages. The breakwater would prevent large waves from entering the harbor, thus eliminating much of the erosion problem and damages to the harbor facilities and vessels. The west bank revetment is required to prevent further erosion from residual waves or from rare storms that would bring a wave in from the east. Because waves impacting the interior west bank would be much smaller than those currently impacting it, the revetment cross section for this interior section would not require material as large as that required for Alternatives W1 and W1A. No adverse impact on the Bristol Fuel's dock or the existing harbor is expected to occur from construction of this Alternative. Erosion inside of the harbor would be reduced due to the decreased wave climate.

The revetments would be constructed as a three-layer system of core, secondary, and armor stone. The rock would extend up to an elevation of +32 feet MLLW with 1V:3H side slopes, see Figure 19. From elevation +29 MLLW to elevation +32 MLLW, the slope would be graded to transition to the existing top of bank. The top elevation of the revetment was determined from 6 feet of wave run-up with a design high water level of 26 feet. The design water level equates to mean higher high water (+20 MLLW) plus 6 feet of storm surge. This upper section of revetment would be planted with live willow stakes and sprigging of grasses of species common to the Dillingham area. This planting would replace vegetation lost either to erosion or during the construction of the project.

The west revetment would require approximately:

- 11,000 yd^3 of armor rock, ranging in size from 350 to 200 pounds
- 7,200 yd^3 of Secondary rock, ranging in size from 200 and 20 pounds
- 3,800 yd^3 of core rock, ranging in size from 20 pounds to 1 pound
- 3,600 yd^3 of porous fill to be placed behind the revetment

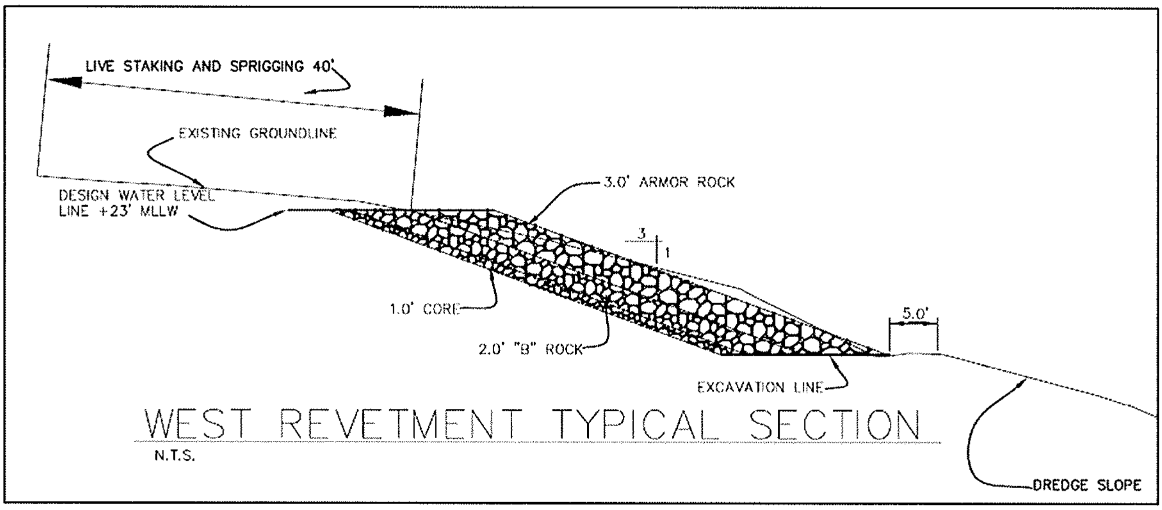

Figure 19: West revetment typical section

The breakwater would be constructed using a three-layer system of core, secondary, and armor stone. The breakwater would have a crest elevation of +32 feet MLLW and have 1V:1.5H side slopes, see Figure 20. The breakwater is designed to be an overtopping structure.

The breakwater would require approximately:

- 5,500 yd³ of armor, ranging in size from 3,826 and 2,295 pounds.
- 3,250 yd³ of secondary rock, ranging in size from 2,295 to 230 pounds
- 4,300 yd³ of core rock, ranging in size from 230 to 21 pounds.

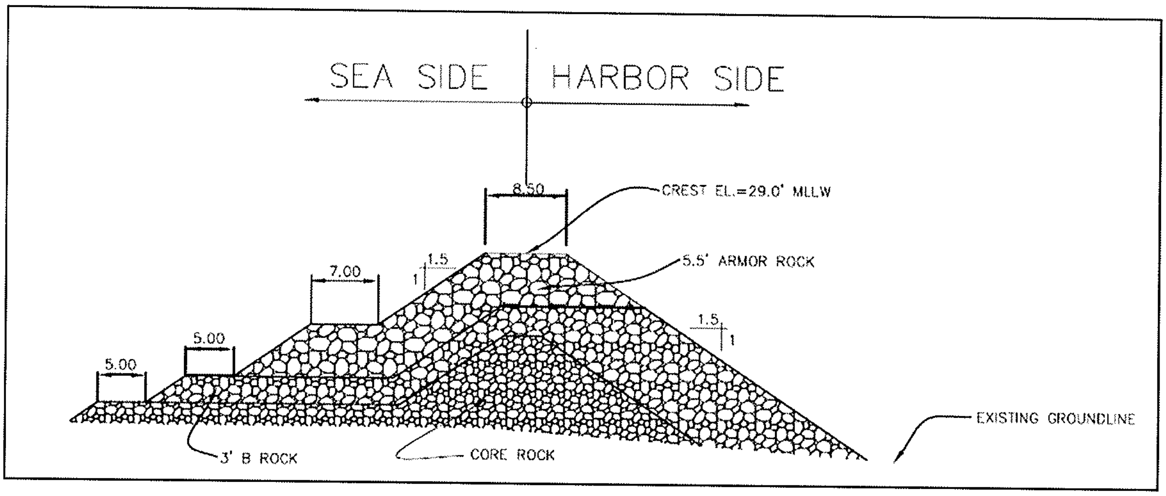

Figure 20: Breakwater typical section

The detailed construction and project costs for Alternative W2 are shown in Table 6. The costs are broken down by sections with the breakwater and revetment costs listed individually. Please note that this is in 2008 dollars.

Table 6: Detailed Project Cost, Alternative W2

Item	Cost	20% Contingency	Total Cost
Mob and Demob	$973,000	$194,600	$1,167,600
Revetment	$5,152,600	$1,030,52	$6,183,120
Breakwater	$3,044,100	$608,820	$3,652,920
Total Construction Costs	$9,169,700	$1,833,940	$11,003,640
Lands and Damages	$91,000		$91,000
Planning and Design	$225,000	$45,000	$270,000
Construction Management	$734,000	$146,800	$880,800
Total Project Costs	$10,219,700	$2,025,740	$12,245,440

2.11 Construction Considerations

Mitigation for this project consists of minimizing in-water work to protect juvenile salmon as much as possible along with vegetating and contouring disturbed areas behind the revetment to minimize surface erosion from rain and overtopping waves.

Much of the revetment construction below the mean high water line (+18 MLLW) would be done during lower tides when the tide flat is dewatered, but some construction on the breakwater might be necessary when the tide flats are flooded. Both the West Side and City Dock Side revetments would be built at the base of former disposal site berms. The riverbanks behind the west side revetment would be sloped to grade before construction.

2.12 Operations and Maintenance

Maintenance of the rock revetment and breakwater would be the responsibility of the City of Dillingham. The USACE, Alaska District would conduct periodic site inspections to verify whether maintenance is warranted on the revetment and breakwater. Both the revetment and breakwater were designed to be stable for the 50-year wave condition. Therefore, it is not anticipated that there will be significant loss of stone on the structures during the life of the project. Typically rock revetments and breakwaters have a 50-year design life, even though they may last much longer. Maintenance of a rock revetment and breakwater may require replacement of 2 percent of the armor stone every 25 years.

Whereas the expected operation and maintenance (O&M) requirements for these projects are expected to be minimal, there are tasks necessary to ensure long lasting protection for the areas of concern. Typical O&M requirements would include routine inspection of the structures and the occasional addition of armor stone to areas that are experiencing excessive wear. The West Side project has an estimated annual O&M requirement of $50,300. These amounts are based on having to replace a minimal percentage of rock every 10 to 15 years.

3.0 USACE COST CORRECTIONS FOR INFLATION

In order to discuss the USACE developed alternative costs outlined in this report it was necessary to adjust the values from 2008 to 2016 dollars. The method used for this transformation was a comparison of the 2008 and 2016 consumer price index (CPI). The 2008 and 2016 CPI was found to be 189.497 and 216.999, respectively, for Anchorage which was the closes major city were data was available.. This change in the CPI is quantified as an increase in the construction cost by 14.5%. The updated project costs are displayed in Table 7.

Table 7: Project Alternatives Cost Comparison in 2016 Dollars

	Alt W1	Alt W2	Alt W5
Project Costs	$20,643,000	$14,021,000	$16,353,000

4.0 ALTERNATIVE W1 MODIFIED

During a planning session with BAF management BESC was directed to determine what the cost of Alternative W1 would be with the absence of the East Bank Revetment. The logic being, if BAF was to construct some type of erosion protection structure independent of the City then there would be no need to construct the East Bank Revetment.

Based on our analysis of the USACE cost reports we estimate the cost of the East Bank Revetment to be approximately $4,339,000 in 2008 dollars. Adjusting this cost to 2016, as outlined in Section 3.0, yields an anticipated cost of the East Bank Revetment at $4,986,000. Therefore, the cost of Alternative W1 Modified is anticipated to be $15,657,000.

Based on a comparison of the alternative cost presented in Table 7 and Alternative W1 Modified is appears that Alternative W2 would still be the preferred solution for BAF if cost was the deciding factor.

5.0 OTHER EROSION PROTECTION AREAS FOR BAF SITE

Two other locations of erosion were identified that are not covered in the USACE 2009 reports. One area is along the BAF site access road due south of the culvert that Scandinavian Creek passes through at Kanakanak Road. The other site is along the shoreline of the BAF property west of the sheet pile dock, Figure 21.

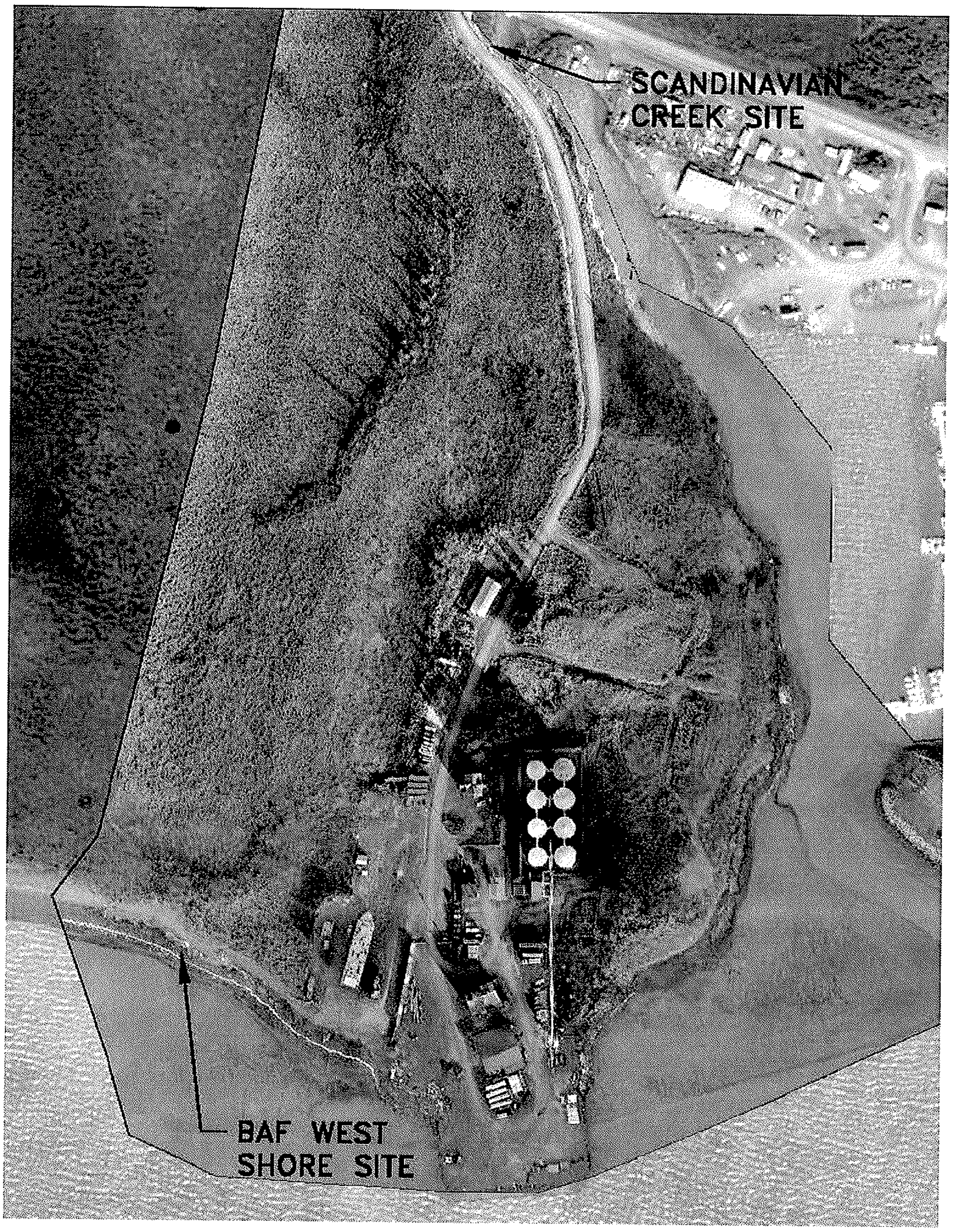

Figure 21: Other Erosion Protection Areas

5.1 Scandinavian Creek Site

For the purpose of the memo, it is assumed that a revetment similar to Alternative W2 as shown in Figure 19 will be used to prevent further erosion from occurring in this area. The length of this revetment will be approximately 220 feet long. The rock revetments would have a top of +22 feet MLLW to match the existing road elevation and a bottom elevation of +15 feet MLLW. The top elevation of the revetments was does not include wave run-up. The design water level equates to the mean higher high water level plus 6 feet of storm surge. approximately 540 yd^3 of armor rock would be used that range in size from 350 to 200 pounds. Secondary rock size would be from 200 to 20 pounds and would require 360 yd^3. 180 yd^3 of core rock would be placed behind the secondary layer and would range in size from 20 to 1 pounds. Using costs previously established in the USACE report and adjusted to 2016 values, the cost of this section of erosion control would be approximately $829,720. See Table 8 for a breakdown of costs.

Table 8: Scandinavian Creek project costs

Item	Cost	20% Contingency	Total Cost
Mob and Demob	$222,840	$44,570	$267,410
Erosion Control	$3,660	$730	$4,390
Clearing and Grubbing	$12,830	$2,570	$15,400
Excavation and Hauling	$109,020	$21,800	$130,820
Textile	$24,730	$4,950	$29,680
Backfill and Prep	$95,730	$19,150	$114,880
Construction Survey	$20,150	$4,030	$24,180
Armor Rock	$48,800	$9,760	$58,560
B Rock	$32,190	$6,440	$38,630
Core Rock	$15,980	$3,200	$19,180
Total Construction Cost	$585,930	$117,190	$703,120
Planning and Design	$58,600	$11,720	$70,320
Const. Management	$46,900	$9,380	$56,280
Total Project Costs	**$691,430**	**$138,290**	**$829,720**

5.2 BAF WEST SHORE SITE

BAF has plans to expand and upgrade their existing pad and barge haul-out ramp, see Figure 21. Armor stone has already been placed between the sheet pile dock and the barge ramp. The shoreline west of the barge ramp will need to be protected from wave erosion. For the purpose of the memo, it is assumed that a revetment similar to Alternative W1 as shown in Figure 23 will be used to prevent further erosion from occurring in this area. This revetment is thicker than the revetment used in Alternative W2 and assumes there is no breakwater to reduce the wave impact on the shore.

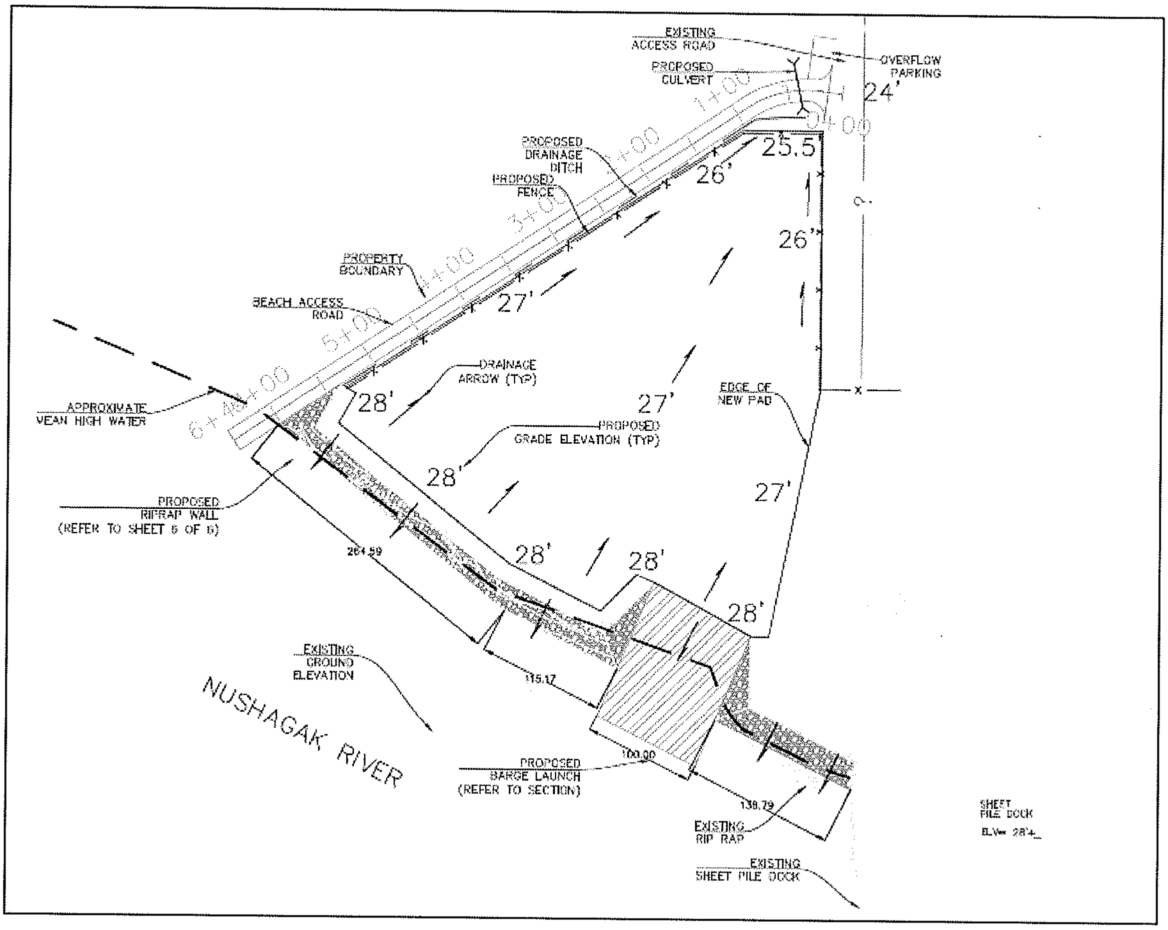

Figure 22: Planned BAF expansion.

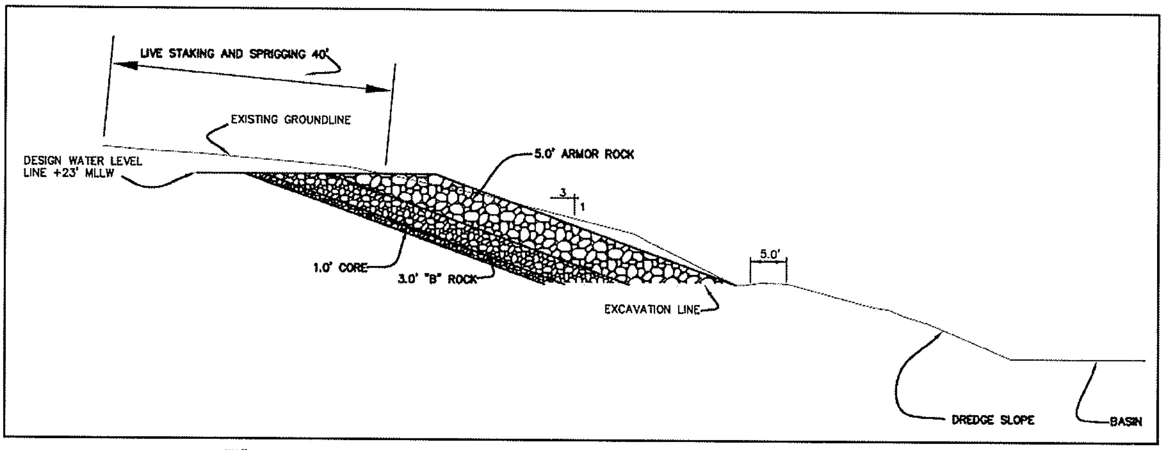

Figure 23: West shore revetment typical section.

The rock revetments would have a top of +32 feet MLLW. The top elevation of the revetments was determined from 6 feet of wave run-up with a design water level of 26 feet. The length of this revetment will be approximately 380 feet long. The design water level equates to the mean higher high water level plus 6 feet of storm surge. approximately 3,560 yd^3 of armor rock would be used that range in size from 1,914 to 1,148 pounds. Secondary rock size would be from 1,148 to 115 pounds and would require 2,140 yd^3, and 710 yd^3 of core rock would be placed behind the secondary layer and would range in size from 115 to 11 pounds. Using costs previously established in the USACE report and adjusted to 2016 values using a CPI increase of 14.5% from 2008, the cost of this section of erosion control is estimated to be approximately $2,122,900. See Table 9 for a breakdown of costs.

Table 9: BAF West Shore protection project costs

Item	Cost	20% Contingency	Total Cost
Mob and Demob	$384,910	$76,980	$461,890
Erosion Control	$6,330	$1,270	$7,600
Clearing and Grubbing	$22,150	$4,430	$26,580
Excavation and Hauling	$188,300	$37,660	$225,960
Textile	$42,720	$8,540	$51,260
Backfill and Prep	$165,360	$33,070	$198,430
Construction Survey	$34,810	$6,960	$41,770
Armor Rock	$379,660	$75,930	$455,590
B Rock	$211,560	$42,310	$253,870
Core Rock	$63,480	$12,700	$76,180
Total Construction Cost	$1,499,280	$299,860	$1,799,140
Planning and Design	$149,900	$29,980	$179,880
Const. Management	$119,900	$23,980	$143,880
Total Project Costs	**$1,769,080**	**$353,820**	**$2,122,900**

6.0 SUMMARY OF PROJECT COST

The purpose of this section is to provide a final summary of the project cost, in 2016 dollars, developed as part of this report.

Table 10: Summation of Project Cost

Work Item	Cost
Alternative W2	$14,021,000
Scandinavian Creek Site	$830,000
BAF West Shore	$2,123,000
Total Project Costs	**$16,974,000**