U.S. Army Corps
of Engineers
Alaska District

Design Services for Kenai Bluff Stabilization

Initial Design Documentation Report

December 2012

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EXECUTIVE SUMMARY

The City of Kenai, Alaska lies at the mouth of the Kenai River where it meets Cook Inlet. The ongoing erosion of a one-mile stretch of steep bluff along the north bank of the Kenai River has required the relocation of buildings, utilities, and other City of Kenai infrastructure. Engineering investigations have shown that as groundwater emerges along the bluff, it destabilizes the slope, carrying eroded material to the toe. River currents and wave action, in combination with high tides, carry the accumulated material into Cook Inlet, leaving the steep slope prone to further erosion. This report presents a recommended, long-term solution to halt the erosion of the bluff and stabilize the slope.

Previous conceptual designs presented alternatives for reducing or eliminating groundwater discharge from the bluff; these dewatering alternatives are not carried forward. The design presented in this report relies on the results of geotechnical investigations at the site, which concluded that in the absence of toe erosion resulting from wave action and river currents, a stable slope would allow the establishment of vegetation. In this design, groundwater discharge is conveyed through a subsurface filter layer of granular fill material or alluvial borrow material. Alternative configurations were developed and assessed, with individual alternatives varying in terms of their earthwork balance, the location of the revetment relative to the slope toe, and other configuration details.

The design earthwork balance considers the tradeoffs between additional the acquisition of real estate on the top of the bluff (required for the cut back slope) versus the impact of protruding the project footprint out into the river (required for placement of fill and rock at the toe of the slope). The affected bluff area was divided into zones in order to evaluate the relative costs and impacts of balancing cut and fill material against net excavation or placement of fill within each zone. This design generally balances earthwork within individual zones of the bluff, minimizing the net import or export of sediment to and from the site as well as between each zone.

The adopted solution was developed to effectively halt the erosion of the bluff, maintaining a stable slope under extreme conditions while minimizing impacts to the sensitive environmental habitat and cultural resources in the area. Long-term environmental impacts are not expected to be significant; however, these preliminary findings are to be revisited upon further environmental review of the proposed design.

The estimated construction cost is $30.8 million, with a total project cost of $41.4 million. The design and costs are based on a 50-year design life with a 4.5-foot design wave at the Kenai River mouth. The top of revetment is designed to accommodate the design wave runup occurring in conjunction with highest observed tide. Base mapping for the proposed design is based on aerial photography and detailed site topography acquired in September 2007. This report describes the project background, design criteria, engineering approach, and individual features of the design, with supporting documentation and previous studies included as attachments.

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1.0 INTRODUCTION

1.1 Authorization

This work is authorized and funded under the Energy and Water Appropriations Act of 2002, Senate Report 107-039.

1.2 Problem Definition

For many years the City of Kenai has been concerned with the ongoing erosion of a one-mile portion of steep bluff along the north bank of the Kenai River. Over the past few decades the bluff has been significantly receding, requiring the relocation of privately owned buildings and public utilities. Unless measures to control the erosion and protect the bluff are implemented, bluff erosion is expected to continue, threatening additional cultural resources, public utilities, and residential, commercial, and public structures.

1.3 Project Purpose

This report documents the design criteria, alternative solutions, design analyses, design plans and cost estimates for a proposed bluff stabilization design. During the development of project alternatives, the costs of individual project components were compared against each other in the alternative formulation process in order to identify the least-cost option for addressing the project purpose while limiting environmental impacts. No economic analysis of without-project damages was performed as part of this study to quantify expected future damages to facilities and real estate if no action is taken. No with-project analysis of the potential increase in property values associated with a stabilized bluff was conducted as part of this study. These factors may be weighed separately during future project phases.

The data presented in this report are intended to assess and evaluate the causes and nature of the bluff erosion and to provide a basis of design for implementing a practicable, long-term solution. The primary objective in this endeavor is to stabilize the bluff against future erosion, utilizing a design approach that accounts for influences from wave action, river and tidal currents, overland flow, groundwater seepage, and other contributing forces. The design approach, as presented in the following chapters, recognizes the environmentally sensitive nature of the lower Kenai River Basin, particularly the fisheries resource and the marshlands habitat on the shore opposite the eroding bluff.

1.4 Project Location

The project is located in the City of Kenai, a home rule city within Alaska's Kenai Peninsula Borough. The City of Kenai has a population of approximately 7,200 (U.S. Census Bureau 2011) and is situated where the Kenai River meets Cook Inlet. The eroding bluff is located along the north bank of the Kenai River, just upstream of the river mouth. Figures 1 and 2 show the project vicinity and location. The project area is divided into three zones referenced in this report. Zone A extends from the Kenai River mouth to Riverview Drive (Station 0+00 to 20+00 along the primary control line shown in Attachment G). Zone B extends from Riverview Drive to Ryan's Creek (Station 20+00 to 36+00). Zone C extends from Ryan's Creek to the Pacific Star Seafoods dock.

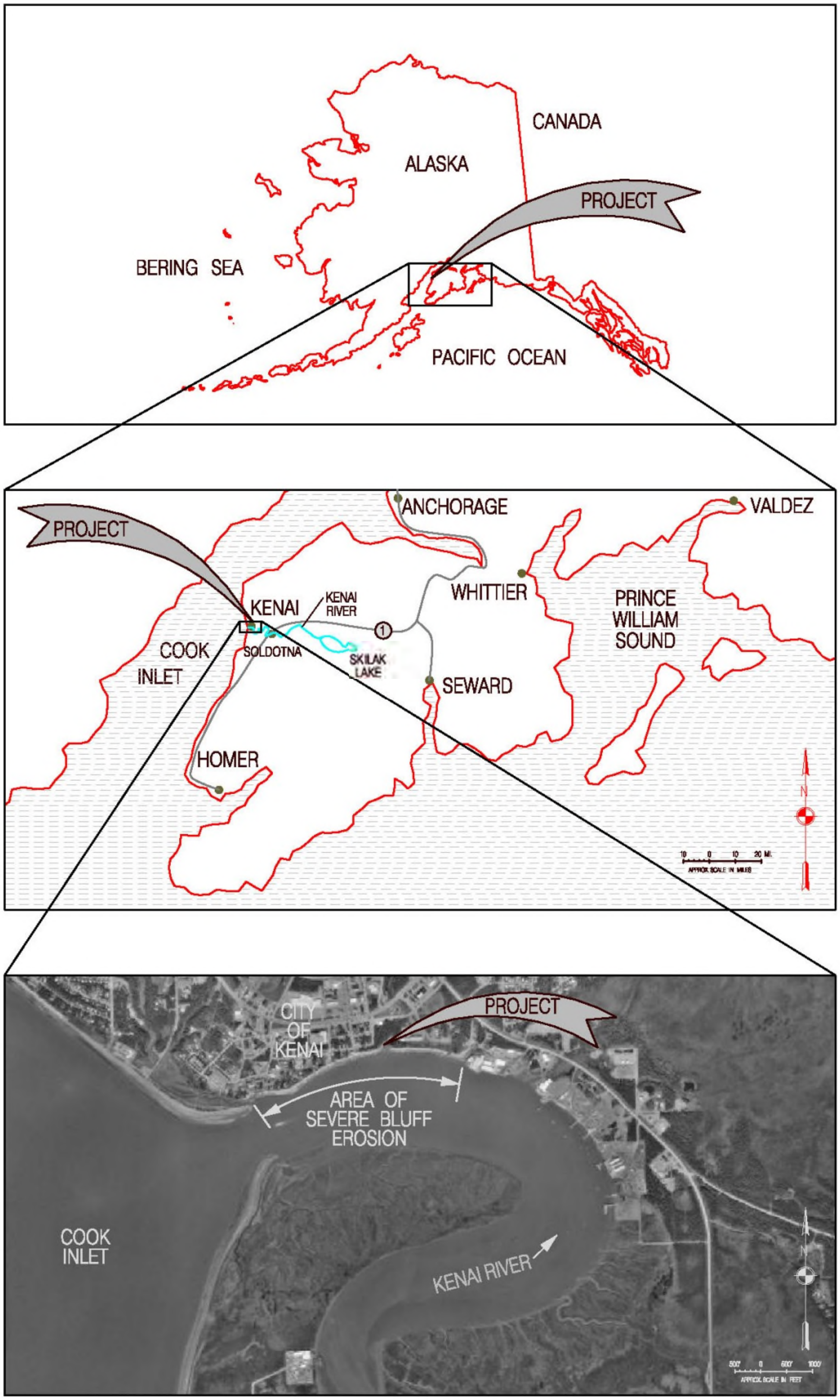

Figure 1. Project Vicinity

Figure 2. Project Location

Note: Background image provided by Kenai Peninsula Borough under limited use agreement

1.5 Previous Studies

Several previous studies have been conducted in the project area to document the existing condition, propose alternative solutions, and predict the potential effects of the proposed stabilization measures:

- TAMS Engineers conducted a Bluff Erosion Study in 1982 that developed alternative design solutions for stabilizing the bluff and presented the associated costs for comparison (TAMS 1982). Alternatives considered included bluff dewatering scenarios along with the construction of a sheet pile bulkhead or rock revetment incorporating a coastal trail.
- The Corps completed a navigation improvement study in 1997 that made recommendations regarding dredging of the Kenai River and use of the spoils in stabilizing the bluff (USACE 1997).
- PND Engineers presented a preliminary design of a rock revetment, coastal trail, and cut back slope in a 2002 Design Concept Report for the City of Kenai.
- The Corps completed a technical study of existing conditions, causes of erosion, potential solutions, and impacts of solution measures along the lower reach of the Kenai River. The results of the investigations are documented in the July 2006 Kenai River Bank Erosion Technical Report (USACE 2006b). Recommendations for obtaining data supplemental to the Technical Report were presented in an August 2006 Work Plan (Tetra Tech 2006).
- In February 2007 R&M Consultants completed a Geotechnical Investigations Report in accordance with the Work Plan recommendations (Attachment M, R&M Consultants 2007). The accompanying Groundwater Monitoring Report, summarizing the results of one year of groundwater monitoring efforts, was finalized in January 2008 (Attachment N, R&M Consultants 2008).
- Tetra Tech completed a Design Alternatives Report in 2008 resulting in the tentatively selected alternative that is refined further in this Initial Design Documentation Report (Tetra Tech 2008).

Attachment A includes a bibliography and summary of contents and results for these and other previous studies.

1.6 Contents of Document

This Initial Design Documentation Report is prepared by Tetra Tech for the Corps in accordance with the Scope of Work for Contract #W911KB-06-D-0010, Delivery Order #1, dated December 21, 2006. The findings in this report build upon the recommendations set forth in Tetra Tech (2006, 2008) and R&M Consultants (2007, 2008). This report summarizes the design criteria, design decisions, construction methods, and anticipated impacts of the bluff stabilization project. Supporting documentation is provided in attachments, including annotated comments, correspondence, meeting minutes, and trip reports.

2.0 EXISTING CONDITION

The existing condition of the project area has been described in several previous reports, including the Corps Kenai River Bank Erosion Technical Report (USACE 2006b). As documented in previous report and confirmed through supplemental field investigations, the primary, existing erosion mechanisms are shown schematically in Figure 3.

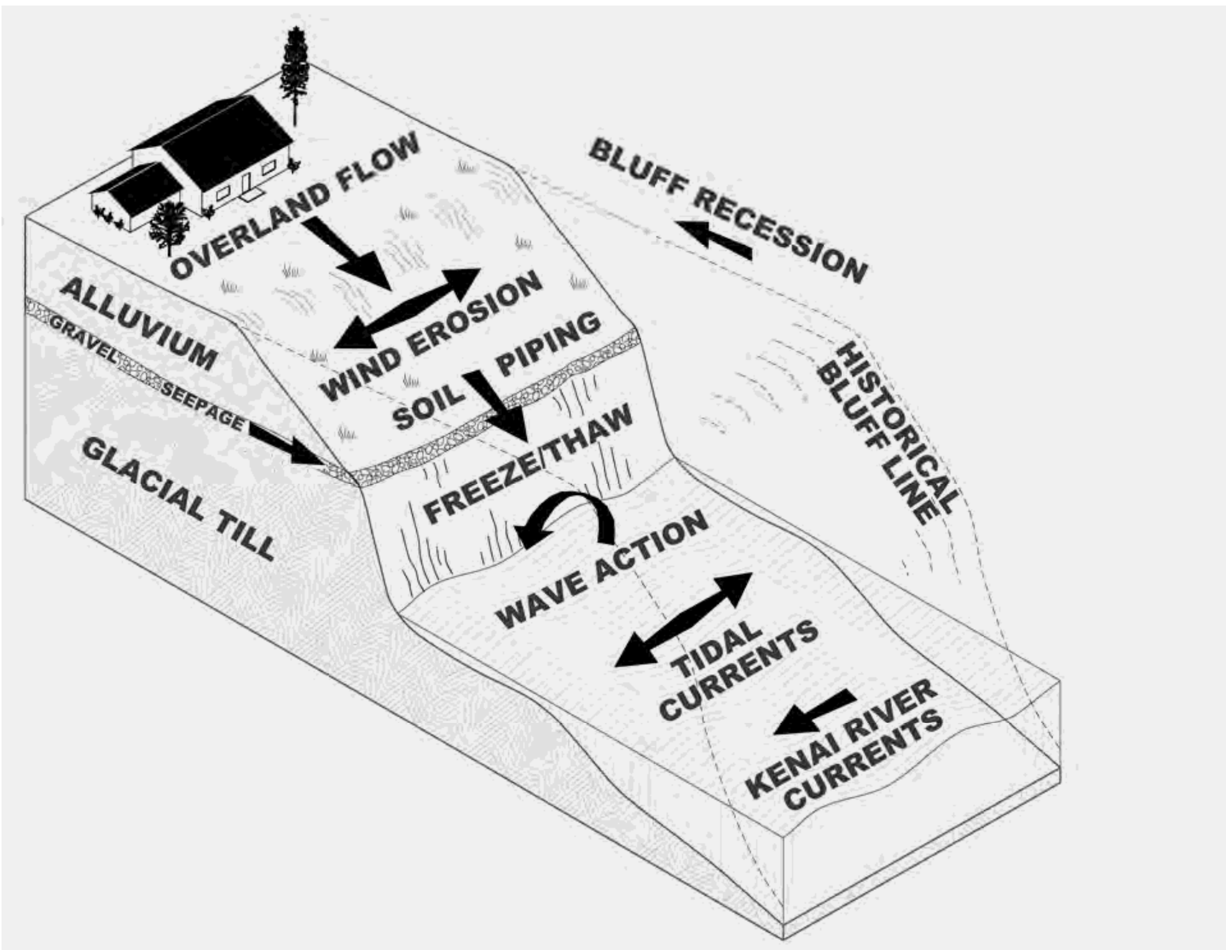

Figure 3. Erosion Mechanisms

The existing condition is described below for individual areas of study, including summaries of the findings of the Corps report and other previous reports.

2.1 Climate

Temperature, precipitation, and snowfall data are available for the Kenai FAA Airport gage dating to 1949. Climate data are compiled by the Western Regional Climate Center (WRCC). Extreme temperatures have ranged from -47ºF to 93ºF. Temperatures typically stay above freezing for approximately 100 days during the summer season. The area receives approximately 19 inches of precipitation annually. The mean annual total snowfall is approximately 61 inches, with an average of approximately 12 inches of snow depth during winter months. Summary climate data are presented graphically for selected parameters in Attachment B.

2.2 Tides and Currents

Tide elevations at Kenai typically fluctuate with a typical daily range of approximately twenty vertical feet. Figure 4 shows the bluff face at high and low tides.

Figure 4. Kenai River Bluff at High (left) and Low (right) Tides

The nearest measured tidal data are taken at Nikiski, approximately 10 miles north of Kenai. Mean Higher High Water (MHHW) at Nikiski is 20.42 ft above Mean Lower Low Water (MLLW), and Mean Sea Level (MSL) is 11.18 feet above MLLW. The toe of the Kenai Bluff is located at an elevation of approximately 22 to 23 feet MLLW, just above MHHW. Tide levels typically reach the toe of the bluff several times per month, as shown in further detail in Attachment B. Tidal predictions for the Kenai River are available from NOAA for the Kenai

City Pier and the Kenai River Entrance. Tidal predictions at Kenai apply correction factors to NOAA measurements at the reference site in Seldovia. Following are selected summary statistics for Kenai based on the tidal predictions.

Table 1. Tidal Data at Kenai

Station	Mean Range (ft)	Spring Range (ft)	Mean Tide (ft)
Kenai City Pier	17.5	19.8	10.4
Kenai River Entrance	17.7	20.7	11.0

An adjustment of -0.26 feet was made to the Kenai datum relative to the Nikiski gage in March 2008 and submitted to and approved by the National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey (NGS). The adopted regulatory high tide elevation is 25.2 feet MLLW, and regulatory high water is 19.1 feet MLLW. Additional data related to the tidal records, including gage locations, hyperlinks to online data repositories, correction factors, datums, and tidal predictions, are presented in Attachment B.

Tidal currents in the project area are generally masked by the Kenai River currents. Tidal channels are present on the flatter slopes of the bank opposite the bluff; however, the bluff side does not exhibit typical tidal channels. Longshore currents were estimated in order to determine longshore sediment transport in conjunction with the ERDC Sediment Impact Analysis (USACE 2006b). The study determined that the project area does not appear to be subject to direct contact with longshore currents, since the longshore currents generally bypass the inlet area.

2.3 Wind and Waves

When storms coincide with high tide conditions, breaking waves attack the toe of the bluff directly. Figure 5 shows a breaking wave at the inlet.

Figure 5. Breaking Wave Conditions at Kenai River Mouth (USACE 2006b)

Wind data near the project site are collected at the Kenai Airport FAA station. Metadata for the station are presented in Attachment B. The Corps Navigational Study included directional wind speed data (USACE 1997). The University of Alaska, Anchorage conducted an hourly directional wind speed analysis on historical measurements taken at the Kenai Airport from 1973 to 2000 (UAA 2001).

The Corps Technical Report includes wave height estimates based on historical wind data, bathymetric cross sections collected by the Corps in 2003, and general observations of the bathymetry of the coastal zone adjacent to the project site (USACE 2006b). PND (2002) also includes estimates of the wave height and period. No direct wave height measurements or storm surge data are available at the Kenai River mouth other than visual observations. Oceanweather, Inc. developed a wave model and conducted continuous hindcast verification, with storm production based on 50-year conditions at Nikiski (Oceanweather 2009).

Although some Kenai Peninsula communities in Lower Cook Inlet experienced up to 40-foot high earthquake-generated tsunami waves in March 1964, the relatively shallow depth of Upper Cook Inlet with respect to the distance from Lower Cook Inlet substantially decreases the tsunami risk in Kenai.

2.4 Kenai River Hydrology

The stage of the Kenai River in the project area is influenced by both the discharge in the river and the tidal elevation in Cook Inlet. As a result, there is no direct stage-discharge relation at Kenai. The nearest stream flow gaging station is USGS Gage Number 15266300, located at the Sterling Highway Bridge in Soldotna, approximately twenty river miles upstream of the mouth. Daily discharge data for the Soldotna gage are available from 1965 to present. The maximum recorded instantaneous peak flow was 42,200 cubic feet per second (cfs). The historical average daily discharge for the entire period of record is shown graphically along with the station metadata in Attachment B. Historical USGS data for the Soldotna gage must be interpreted with caution, as some data are missing or estimated. The gage goes dry during certain periods of the summer, for example, and ice inhibits measurements during much of the winter.

Peak annual discharges were compiled and sorted to estimate the flow frequency using the Hydrologic Engineering Center's Flood Frequency Analysis Software (HEC-FFA). Table 2 lists the top ten annual maximum daily average discharge rates in the Kenai River as measured at Soldotna using the entire period of record (43 years of data).

Table 2. Kenai River Maximum Annual Average Daily Flow, 1965-2007

Rank	Year	Discharge (cfs)
1	1995	41,400
2	1977	33,200
3	1969	29,600
4	1974	26,800
5	1989	26,800
6	1979	26,500
7	2002	25,100
8	1967	24,900
9	1966	24,000
10	1993	23,600

Using distribution factors from a USGS Regional Skew Analysis, the expected probability flows were computed as follows:

Table 3. Kenai River Expected Probability Flow

Flood Frequency>>	2-year	5-year	10-year	50-year	100-year	500-year
Discharge (cfs)>>	18,900	24,000	27,900	38,200	43,500	58,400

Additional statistical data, including confidence limits corresponding to the discharges in Table 3, are presented in Attachment B.

2.5 Kenai River Hydraulics

An HEC-RAS model of the project area was developed based on 2003 bathymetric survey data and FEMA river bed profiles. The HEC-FFA discharges were used as the flow rates. The results show that velocities and other hydraulic characteristics of the Kenai River in the project area are generally governed by tidal elevations rather than stream flow. The maximum Kenai River velocities occur during the lowest tidal levels. The project area river velocities associated with a 50-year discharge, for example, drop from approximately 6 feet per second at low tide to approximately 1 foot per second at high tide. At tide levels above mean higher high water (MHHW), even base flood flows in the Kenai River are almost completely masked by the tidal backwater; under these conditions (when Kenai River water surface elevations are governed by tidal conditions in Cook Inlet) flood flows generally do not introduce significantly higher velocities or higher water surface elevations near the river mouth than do typical daily flows. Table 4 shows the velocities, depths, and widths associated with various flows during extreme low and high tide events in the project area.

Table 4. Typical Kenai River Hydraulics in the Project Area

Profile	Discharge (cfs)	Tide Level	Tide Elevation (ft MLLW)	Water Surface El (ft)	Maximum Depth (ft)	Channel Velocity (fps)	Top Width (ft)
Minimum Flow	770	Low	-0.9	-0.9	12.8	0.2	530
Mean Flow	13,000	Low	-0.9	-0.3	13.4	3.5	725
10-year	27,900	Low	-0.9	1.2	14.9	5.9	1110
50-year	38,200	Low	-0.9	2.3	16.0	6.8	1175
100-year	43,500	Low	-0.9	2.8	16.5	7.2	1231
Minimum Flow	770	High	26.0	26.0	39.7	0.0	2206
Mean Flow	13,000	High	26.0	26.0	39.7	0.4	2206

Profile	Discharge (cfs)	Tide Level	Tide Elevation (ft MLLW)	Water Surface El (ft)	Maximum Depth (ft)	Channel Velocity (fps)	Top Width (ft)
10-year	27,900	High	26.0	26.0	39.7	0.9	2206
50-year	38,200	High	26.0	26.0	39.7	1.2	2206
100-year	43,500	High	26.0	26.0	39.7	1.4	2206

The flow characteristics in Table 4 correspond to bathymetric Cross Section #3 near the center of the project area (See Attachment C for section locations). Water surface elevations and velocities at other cross section locations are shown graphically in Attachment B.

The FEMA Flood Insurance Study for Kenai includes a Flood Insurance Rate Map (FIRM) with coastal wave zones (Community Panel Number 020012 2030 A, effective date May 19, 1981.) An excerpt of Panel 2030 is shown in Attachment B. The water surface profile is essentially flat in the project area; the base flood (100-year event) water surface elevations correspond to the Cook Inlet starting elevation for approximately ten river miles from the mouth at Kenai to near Soldotna. The mapped elevations on the FIRM are higher near the river mouth than at Soldotna due to the influence of coastal waves. The FEMA model includes two cross sections within the project area. The toe of the bluff in the project area lies in Zone V (Coastal Wave). The mapped water surface elevation for the project area is approximately 29.5 feet MLLW, approximately equal to the highest recorded water surface elevation in Kenai (29.0 ft MLLW, observed 12/26/1976).

2.6 Historical Bluff Erosion

As documented by the Corps, several sources have measured historical bluff retreat in Kenai (USACE 2006b). A UAA study (2002), for example, compared the top of bluff in 1976 and 1999. The geospatial data used in the UAA study were obtained as part of the draft design development along with additional historical aerial photography. 2006 aerial photography was overlaid to update the existing condition. A high-resolution scan of the bluff area in 1950 was acquired from USGS and georeferenced to expand the range of historical data. A comparison of the four bluff lines (1950, 1976, 1999, 2006) is shown in Attachment C. In the project area, the bluff retreated between 100 and 250 feet (approximately 2 to 4 feet per year) between 1950 and 2006.

With the exception of the project area, the upstream Kenai River banks have shown remarkably little change. Measurements along a 10-mile stretch upstream of the Kenai River mouth show that bluff retreat has been much more pronounced in the 1-mile project area than in the remaining area. Additional high-resolution orthophotography acquired in October 2010 indicate very little change in the top of bluff since 2006, particularly in Zone C. The historical thalweg and top of bluff location are shown in the figures in Attachment C. Hydrographic cross section data collected by the Corps in 2003 are also presented in Attachment C.

A Sediment Impact Analysis was conducted as part of the Corps technical studies in order to assess the relative contribution of the eroding bluff to the overall sediment load. According to the findings of the report, the bluff area supplies approximately 10,000 tons of sediment per year to the Kenai River and Cook Inlet, representing a relatively small percentage of the overall sand flux into the system (USACE 2006b).

2.7 Overland Flow

The two most significant local drainages in the project area are Cemetery Creek and Ryan’s Creek. Cemetery Creek enters the Kenai River at the mouth near Cook Inlet along the west side of the project area. Ryan’s Creek enters the Kenai River within the project area approximately 3,000 feet upstream of Cemetery Creek. Neither Cemetery Creek nor Ryan’s Creek appears to be affecting the bluff face directly, as the stream channels are not in contact with the bluff toe, and the adjacent slopes are heavily vegetated, limiting undercutting. Most of the local stormwater drainage from the top of the bluff is routed through the City of Kenai’s storm drain network. In some areas, such as along Mission Avenue, overland flows have been rerouted into drainage swales that convey runoff parallel to the slope. In other areas, surface drainage is directed overland toward the bluff, causing head cuts in several locations where the drainage flows over the edge of the bluff. Figure 6 shows one of the most pronounced head cuts near Broad Street.

Figure 6. Head Cut at the Top of the Bluff

A comparison of historical aerial photographs indicates that several large drainages along the bluff face have been filled in previous decades, with the runoff presumably routed through the City of Kenai storm drain network. The Kenai Watershed Forum developed a preliminary model of the storm drain network in the City of Kenai, including the top of bluff area. The model identifies components of the storm drain network, including properties of pipes, flow paths, and drainage delineations. Figure 7 shows the City of Kenai storm drain network, as mapped by the Kenai Watershed Forum (KWF 2008). The isolated points along the bluff in Figure 7 represent irrigation pipes protruding from the bluff face near the ground surface; these pipes convey small amounts of water that run directly down the bluff face.

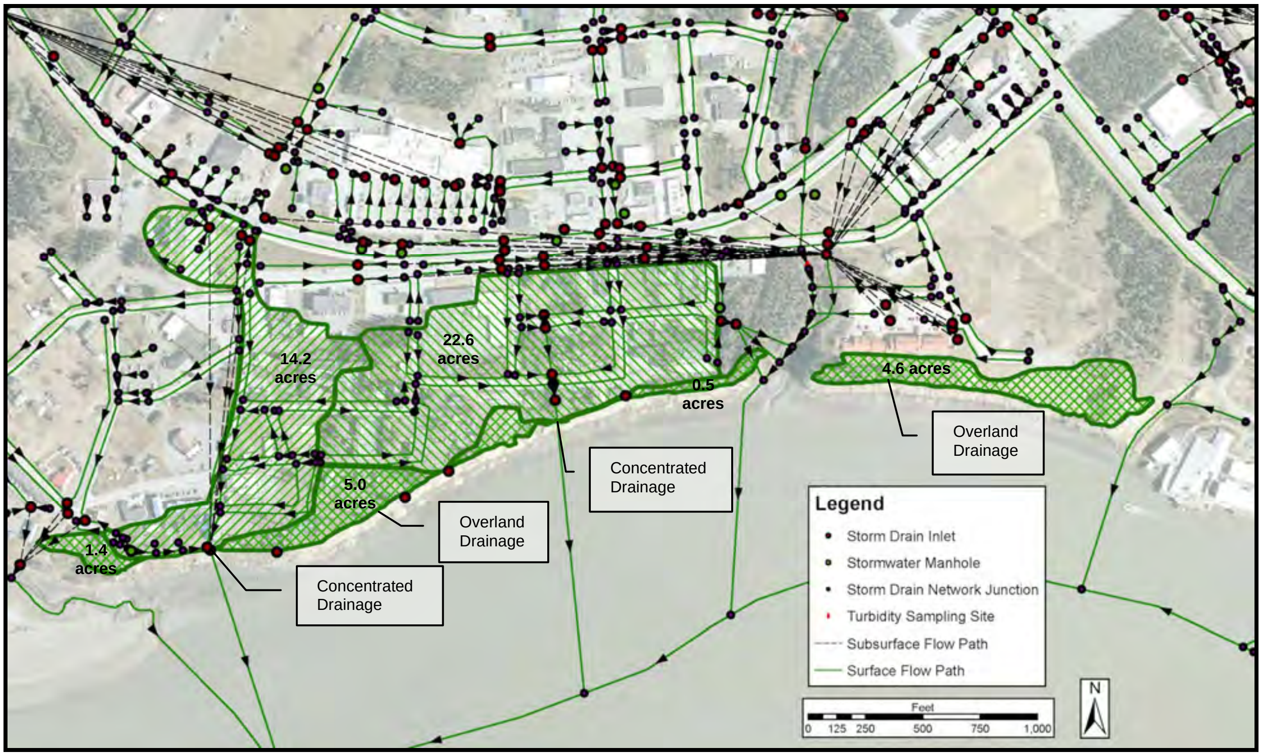

Figure 7. Local Drainage Patterns along the Bluff Face (KWF 2008)

The KWF drainage area delineations were refined based on the September 2007 topographic mapping. Topographic mapping and elevation measurements taken during supplemental site visits indicate that stormwater runoff accumulates in two primary concentration points along the top of the bluff. Approximately 14 acres of drainage concentrates along Mission Avenue, and approximately 23 acres of drainage accumulates in a basin near Bluff Street. An additional 7 acres drains to the bluff as overland flow west of Ryan's Creek. East of Ryan's Creek, approximately 5 acres of overland flow drains over the bluff face. The contributing areas are based on concentration points along the top of the bluff; the bluff face itself represents an additional 10 acres of drainage. The stormwater system delineations show additional drainage areas routed to Cemetery Creek just west of the project, Ryan's Creek just north of the project, and an unnamed drainage ditch within the commercial development just east of the project. Dye testing has been planned by KWF in order to verify flow paths, allowing the development of a storm drain model for the City; however, the implementation of the dye testing program is currently pending receipt of additional funding.

2.8 Ice

River ice is prominent in the Kenai River during winter months. Both sea ice and river ice collect at the toe of the bluff. Because of the large tidal range, most of the ice in Cook Inlet remains broken, and the formation of shorefast ice is inhibited. Figure 8 shows typical winter ice conditions along the toe of the bluff. Freeze-thaw action along the bluff face actively erodes the bluff, contributing to the bluff recession. The formation of river ice does not appear to contribute significantly to the bluff recession relative to freeze-thaw action on the bluff face.

Figure 8. Ice at the Toe of the Bluff

Glacier-dammed lakes are present upstream along the Kenai River. When the lakes begin releasing snowmelt, the rise in water levels can cause the ice cover to break up, forming ice jams and localized flooding. Some peak flows in the USGS gage records note a corresponding, upstream ice dam breach. Rapid water level increases and moving ice in the Kenai River have caused significant property damage in the Soldotna area. Figure 9 shows a shoreline access ramp damaged by an ice jam flood event that was triggered by the release of glacier-dammed Skilak Lake in 2007. No damage claims were filed in Kenai for the 2007 event. Under extreme circumstances, ice jam flood events could potentially damage facilities in the Kenai area, particularly the marine infrastructure just upstream of the project area; however, backwater conditions from Cook Inlet generally prevent the high velocities that would otherwise result in significant damage.

Figure 9. Ice Damage along the Kenai River in Soldotna (KWF 2007)

2.9 Geology and Soils

The Kenai area is generally designated as glacial lowland. Details on the regional geology are included in the Geotechnical Investigations Report (R&M Consultants 2007). The bluff itself generally consists of alluvial deposits over glacial till, separated by a layer of lag gravel. Bedrock is located at a considerable depth below the toe of the bluff.

Kenai is located in a seismically active area. Although the overall region sustained significant damage during the 1964 magnitude 9.2 Great Alaska Earthquake, long-time residents present at a 13 December 2008 public meeting at the City of Kenai did not recall any mass slope failures or any other visible damage to public infrastructure within the City of Kenai. According to the USGS, the 1964 earthquake produced marginal pressure ridges and cracks in the ice of small lakes on the Kenai Peninsula as well as some intense local fragmentation visible in surface ice in Skilak Lake, possibly indicating underwater landslides.

Figure 10 shows an oblique aerial photograph of the City of Kenai immediately following the 1964 earthquake along with an image from a similar vantage point four years later. In several areas along the bluff near Bluff Street and Mission Street (Areas 4 and 5 in Figure 10), the 1964 photo shows alluvial material at the toe of the bluff, where the 1968 photo shows a distinct layer of glacial till underlying the alluvial material. A 1950 aerial orthophoto likewise shows the underlying till exposed. Whether the sloughing of the alluvial material from the upper layer to the toe of the slope was a short-term result of the earthquake or part of the overall cycle of erosion and transport is unknown. In any case, the alluvial material present at the toe in 1964 was carried away, most likely by river and tidal currents, by 1968. Subsidence may have accelerated the toe erosion after the earthquake. The toe of the bluff near Riverview Drive (Area 3 in Figure 10) appears to be undercut in the 1964 photo but has a smooth slope in the 1964 photo.

As shown in Figure 10, fill has been placed along the bluff face in several locations, most prominently between Upland Street and Main Street (Areas 1 and 2) and at the end of Bluff Street (Area 4). Additional details on nearby faults, seismic activity, and other geologic conditions at the project site are covered in R&M Consultants (2007).

Figure 10. Kenai after the 1964 Earthquake (above) and in 1968 (below)

Note: Photographs courtesy of Anchorage Museum Archives

2.10 Hydrogeology

Groundwater conditions at the project site are documented in the Kenai Bluff Geotechnical Investigations Report (Attachment M, R&M Consultants 2007). A supplementary one-year monitoring program of groundwater levels concluded in December 2007 (Attachment N, R&M Consultants 2008). Monitoring efforts consisted of monthly readings at seventeen wells in the bluff area along with real-time readings in selected wells. The groundwater readings show aquifers at different elevations; the upper aquifers exhibit very little seasonal variation. The deep wells exhibit greater fluctuation due to tidal influence. Real-time pressure transducer readings taken in August 2007 from two of the wells are shown in Figure 11. The results show a dampened tidal effect on Well 614, the deeper of the two wells extending to a depth of 100 feet below ground surface (bgs). Well 614 exhibited a vertical range of approximately 5 feet and a lag of 2 to 3 hours. The shallower well (Well 615, 75 feet bgs) showed no tidal influence and exhibited only a 0.1 foot fluctuation during the entire month. Minor daily fluctuations on the order of a hundredth of a foot did occur; these fluctuations are potentially attributable to temperature changes in the piezometer casing or air pressure changes in the air trapped in the piezometer. Several rainfall events occurred during the one-month monitoring period, totaling approximately 2 inches of rainfall depth. The rainfall did not appear to affect the groundwater elevations significantly. Further details on vertical and lateral variation in the discharge rate are discussed in Attachment N.

The Corps estimated a total potential flow of approximately 7,000 gallons per minute (gpm) in the aquifer behind the bluff resulting from annual rainfall (USACE 2006b). The aquifer discharges along the Kenai River bluff, the coastal bluff to the west of Kenai, and in adjacent creek channels and local drainages. Within the project area along the Kenai River, most of the discharge from the bluff face occurs along a seepage plane in the lag gravel interface, which exhibits much higher conductivities than the underlying glacial till or overlying alluvial deposits. Surface discharge was quantified using physical measurements in 2006 and 2007. Measurements were taken in December 2006 just below the lag gravel layer in three areas of concentrated flow. Additional measurements were taken in July and August 2007 along the entire toe of the bluff. These measurements indicate a total surface discharge of approximately 100 to 200 gpm in three distinct zones of groundwater flow. The zones are described further in Attachment N. The measurements account for visible surface flow only; however, there are also signs of groundwater seepage entering the Kenai River just below the river's water surface.

As a comparison to measured rates, calculations of the rate of groundwater discharging from the bluff face were performed based on the soil's porosity and other parameters presented in the Geotechnical Investigations Report (R&M Consultants 2007). As described further in Attachment N, the calculations assume saturated conditions to 15 feet above the seepage plane. The calculated values for groundwater flux from the alluvial deposits and glacial till are approximately 300 to 400 gpm. These values are higher than the measured values, which might be expected due to the presence of unseen subsurface flows, particularly where granular sediments have been placed as fill or eroded to the toe of the bluff, covering the till layer.

In winter months, the flow paths are apparent from the formation of aufeis. As mentioned above, the preliminary groundwater monitoring results indicate very little seasonal variation in the upper aquifers. The lack of seasonal variation in the groundwater table measurements indicates that groundwater discharge from the bluff likewise remains relatively constant year-round, as a higher discharge rate would generally require a steeper groundwater gradient.

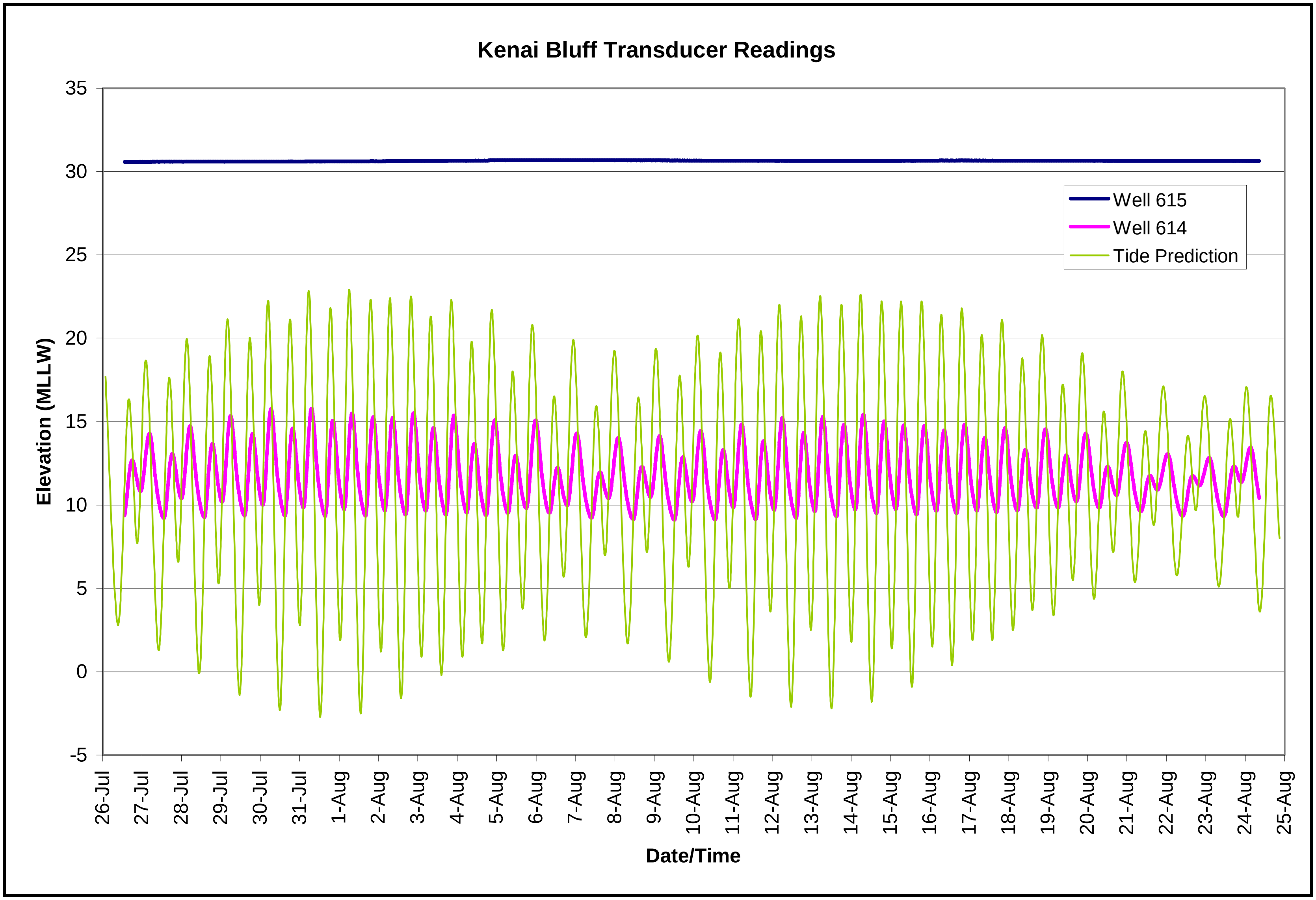

Figure 11. Real-Time Groundwater Readings at Kenai, August 2007

2.11 Water and Sediment Quality/HTRW

No sediment quality or HTRW data for the soils in the bluff face have been located for this study. The geotechnical investigations encountered construction debris throughout the surficial soils along the bluff crest. Asphalt, concrete, perforated steel matting, and other miscellaneous debris was observed at the toe of the bluff (R&M Consultants 2007).

No water quality data have been located for the groundwater discharging from the bluff or for urban runoff flowing over the edge of the bluff as part of this study. The Kenai Watershed Forum (KWF) conducts annual water quality sampling at index sites in the Kenai River from Cooper Landing to Cook Inlet. Testing is conducted in partnership with the Kenai Peninsula Borough and other agencies. Parameters tested include metals, nutrients, hydrocarbons, and bacteria. Monitoring equipment has been deployed on a permanent buoy near the river mouth, transmitting real-time water quality data for water temperature, dissolved oxygen, conductivity, turbidity, and pH. Historical daily water temperatures in the Kenai River are available from USGS for 1998-2003. Additional water quality data are cited in the Corps Technical Report (USACE 2006b), which notes that time series temperature and salinity data reflect the highly dynamic nature of the Kenai River estuary.

2.12 Wetlands and Riparian, Upland, and Aquatic Habitat

Undeveloped areas along the top of the bluff are characterized as Bottomland Spruce-Poplar forest. A wetland delineation of the project site has not been conducted but may be included in future project phases in preparation for permitting support. The bluff itself is largely unvegetated with the exception of the Ryan’s Creek canyon walls and the banks of Cemetery Creek. The shoreline and wetland habitat in the area support seasonal use for nesting, foraging, and staging. Additional data on the existing aquatic habitat and wetlands in the project area are included in the Corps Technical Report’s Environmental Appendix (USACE 2006b).

2.13 Fish and Wildlife

The Kenai area supports a wide array of fish and wildlife. The Kenai River is well known as a prime fishing location, and the tide flats on the bank opposite the bluff are particularly abundant in terms of wildlife. The Environmental Appendix of the Corps Technical Report includes sampling results for birds, mammals, fish, and benthic invertebrates. Benthic invertebrate samples were taken in the upper and lower intertidal zones near the toe of the bluff and on the opposite bank in 2003. Invertebrates including clams and marine polychaetes were found in one of twenty samples. Some sampling activities were limited due to hard substrates.

Monthly bird and marine mammal observations were recorded from April 2003 to March 2004, including spatial and seasonal distribution of gulls, bald eagles, mallards, goldeneyes and other birds. Beluga whales and harbor seals were also observed in the area. The Kenai River estuary is noted for supporting abundant fishery resources, including all 5 species of salmon. A baseline fisheries assessment documented the occurrence of 6 freshwater species, 11 anadromous species and 14 marine species of fish in three studies from 1986 to 1996. Species observed in the assessment included stickleback, lamprey, eulachon, rainbow trout, Dolly Varden, juvenile marine species such as walleye pollock, Pacific cod, tom cod, sole, Pacific herring, sand lance, Pacific sandfish, sculpins, snail fish, and shrimp species (USACE 2006b). Partial food webs were constructed for the estuary based on stomach content analyses. See the Environmental Appendix of the Corps Tehnical Report for additional details (USACE 2006b).

2.14 Threatened and Endangered Species

Existing environmental data are covered in the Corps Technical Report Environmental Appendix (USACE 2006b). Additional evaluation in terms of threatened and endangered species may be required under the Endangered Species Act. Further details regarding threatened and endangered species will accompany future design and permit submittals as appropriate.

2.15 Cultural Resources

The Kenai River bluff and the surrounding lands in the project area are rich in archaeological and historical resources. Russian settlers constructed Fort St. Nicholas in the area as early as 1791. The U.S. Military established Fort Kenai, named after the native tribes, in 1869 (Orth 1967). Three archeological sites have been documented in the project area (USACE 2006b). In order to minimize disturbance to these resources during development and implementation of a selected solution, additional cultural resources activities have been proposed. These activities include evaluating project area buildings for the National Register of Historic Places, examining and evaluating the log structures along the bluff face for eligibility in the National Registers, evaluating the Shk'ituk't (KEN-00020) and the two other archaeological sites for eligibility in the National Register, and surveying the project area for unreported archaeological sites. These efforts will also include consulting local people and elders to obtain information about cultural resources within the project area. Further details will accompany future design and permit submittals as appropriate.

2.16 Economy and Recreation

Oil and gas drilling and exploration, fishing, and tourism are the primary contributors to the economy of the Kenai area. Other important economic sectors include fish processing, timber, agriculture, transportation services, construction, and retail trade (USACE 2006b). The Kenai area is a popular tourist destination for both in-state and out-of-state visitors. Trophy King and Silver Salmon inhabit the Kenai River; dip-net fishing attracts approximately 20,000 visitors per year during the three week dip-net season, often with over 1,000 people concurrently accessing the dunes near the mouth of the Kenai River (Poynor 2008). The toe of the bluff is currently off limits for fishing and other public access due to safety concerns. Along the top of the bluff near the Kenai River mouth, Hansen Park provides recreational uses such as birdwatching. Hansen Park includes safety railing along the bluff edge, whereas other areas of the top of bluff are unprotected with warning signage posted. Near the Kenai Senior Center, the unobstructed views from the top of the bluff likewise provides birdwatching opportunities. A gravel parking area provides some public access for recreational use; however, safety concerns limit use of the bluff.

2.17 Land Use and Real Estate

Land use along the top of the bluff in the project area is primarily residential. Fish processing, boat storage, and other commercial facilities are located adjacent to the upstream extent of the project. The top of the bluff intersects approximately 46 parcels in the project area. Parcel numbers, appraised values, and other details included in Attachment D. Four areas with structures located in the immediate vicinity of the bluff line are also shown in Attachment D. According to the Kenai Peninsula Borough's GIS maps, several parcels that appear to have previously been located at the top of the bluff in the past are now entirely along the toe of the bluff or even beyond the Kenai River edge due to bluff recession.

3.0 DESIGN CRITERIA

This chapter presents the design criteria applied to the Kenai River Bluff stabilization project design by category. Table 5 summarizes the design criteria with details following by category.

Table 5. Summary of Design Criteria

Category	Design Criteria
Design Life	50 years
Design Wave	4.5' in Zone A, 3.5' in Zone B, 2.5' in Zone C
Hydrologic and Hydraulic Design Criteria	Velocities based on 50-year event in Kenai River (38,200 cfs) with Cook Inlet at 0' MLLW. Wetting and drying for revetment design based on full tidal cycle exchange (extreme tide to MLLW).
Top of Revetment Elevation	Highest observed tide + design wave runup (top of revetment at 34.5 feet elevation in Zone A, 33.0 feet in Zone B, and 31.5 feet in Zone C).
Toe of Revetment Elevation	Toe buried at 4.2 feet below existing ground in Zone A, 3.3 feet in Zones B and C. No increase for thalweg shift (to be monitored by periodic hydrographic survey and locally controlled if necessary.)
Ice Design	Use design wave for armor sizing, with minimum W_{50} of 600-lb stone size to resist ice.
Rate of Allowable Bluff Retreat	0 ft/year (design will effectively halt bluff erosion)
Lineal Project Extents	Mission Avenue to Pacific Seastar Foods
Design Storm	100-year, 24-hour local rainfall event (approximately 4 inches)
Geotechnical Design Criteria	Stable slope with seismic event at 10% probability of exceedance in 50 years, 475 year return period at 0.38 g: (1.5 horizontal to 1 vertical maximum slope)
Design Seepage Rate	400 gpm of flow, divided into three zones
Real Estate Constraints	Avoid impacts to non-residential physical facilities (senior center, Pacific Star Seafoods), minimize impacts to residential areas and infrastructure
Survey/CAD Standards	AK district standards, NAD83 horizontal control, MLLW vertical control
Environmental Constraints	To be adopted based on further input by the Corps and stakeholders
Public Use and Safety Criteria	Access to bluff slope restricted, toe of bluff access prohibited

3.1 Design Life

A 50-year design life is used in material specifications and in the calculation of costs. Estimated maintenance costs for the duration of the project life are amortized and included in the cost estimate as a present value. The cost of any material expected to need replacement within the project life is added to the project costs as operation and maintenance costs.

3.2 Design Wave

The design wave is used in determining the recommended top of revetment elevation, toe depth, and armor sizing. The design wave height was selected in coordination with the Corps of Engineers based on the results of the Extreme Wave Study (Oceanweather 2009). The selected design wave height varies along the bluff; a 4.5-foot wave height is applied to the 1,500 lineal feet of bluff nearest the Kenai River mouth (Zone A); a 3.5-foot wave height is applied to the remaining portion of the bluff extending upstream to Ryan's Creek (Zone B); and a 2.5-foot design wave is applied from Ryan's Creek to the Pacific Star Seafoods dock (Zone C).

The runup associated with the design wave is taken as 1.5 times the total wave height (6.8 feet in Zone A, 5.3 feet in Zone B, and 3.8 feet in Zone C.) This value assumes a sloping revetment. Figure 12 shows the approximate locations of the two design wave zones. Although Figure 12 shows a specific point at which the design wave height changes, the boundary indicates a transition zone. In the Cemetery Creek and Ryan's Creek areas, the design wave is limited by the bathymetry and is adjusted accordingly.

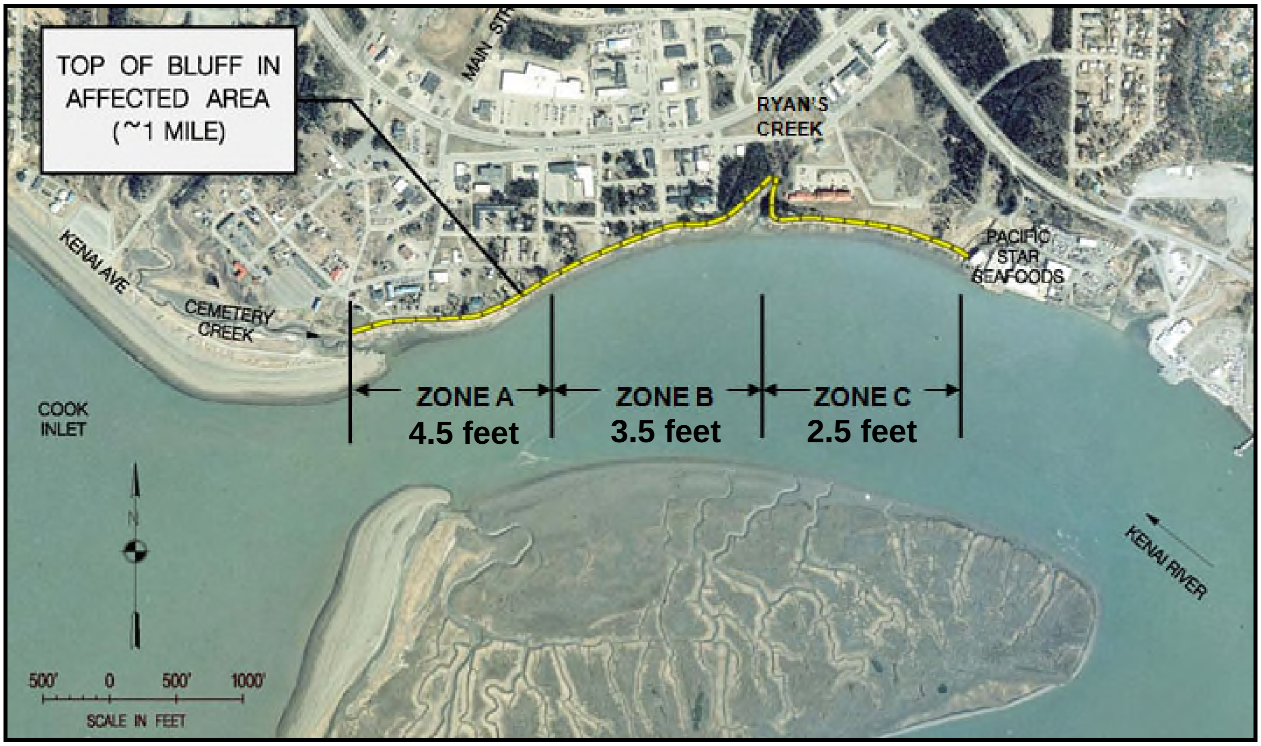

Figure 12. Design Wave

The PND Design Concept published in 2002 utilized a design wave 8 feet in height along the entire bluff line (PND 2002), and the Alternatives Analysis (Tetra Tech 2008) applied a 9-foot design wave at the river mouth, with a 6-foot design wave applied to the upstream areas. The reduction in wave height was made possible by results of the supplemental extreme wave study (Oceanweather 2009).

Although earthquake-generated tsunami waves are possible along the project site, Upper Cook Inlet is relatively shallow, limiting the tsunami risk. Because of the limited wave heights and low frequency of occurrence, tsunami conditions are not directly accounted for in the design wave height (KPB 2005). Although not a direct design constraint, the effect of a tsunami wave on any implemented project should be presented to local jurisdictional authorities in the development of emergency action plans.

3.3 Hydrologic and Hydraulic Design Criteria

Based on the current hydraulic model, river velocities under most tidal conditions appear to be negligible in comparison to the forces introduced by waves; any significant velocities occur when the Kenai River water surface is well below the proposed toe of the revetment. As provided by the Corps in the scope of work (USACE 2006a), the design accommodates the forces associated with a 50-year event in the Kenai River. The HEC-FFA 2% discharge, corresponding to the 50-year return period, is 38,200 cfs. Because the highest velocities occur at low tides, the 50-year Kenai River runoff event was modeled with tidal conditions in Cook Inlet at MLLW to determine the effect of river currents on the project area. As expected, the proposed project location remains dry under this scenario. In order to capture the maximum design condition, the 50-year event was modeled through a complete tidal cycle with 1-foot increments on the downstream boundary condition. These forces vary along the proposed project alignment. The maximum design condition encountered at the upstream end of the project differs significantly from the downstream end, where a different tidal elevation yields the highest velocities and shear stresses. The revetment system is designed to accommodate the wetting and drying corresponding to an extreme tidal cycle (reaching 26 ft MLLW and lowering to MLLW within 6 hours).

Longshore currents have an overall effect on the river mouth as material is transported along the shore; however, as described in Chapter 2, the project area does not appear to be subject to direct contact with longshore currents. Likewise, tidal currents are minimal in comparison to river currents, so the project design does not account for hydraulic forces resulting from longshore or tidal currents.

3.4 Top of Revetment Elevation

A combination of tidal, coastal wave, and river conditions is used in determining the top of revetment elevation and the depth of toe protection. The calculated heights and depths vary along the bluff. Tidal elevations at Kenai are based on calculated transformations of the Seldovia gage data rather than actual measurements, so a rise due to meteorological conditions is added to the calculated tidal elevations. The wind fetch, bathymetry, and coastal hydraulics of Cook Inlet and the Kenai River mouth area do not allow for significant storm surge due to wind action alone. In determining the top of revetment elevation for both waves, a storm surge of approximately 1.5 feet is added in both zones to account for lower barometric pressure. The design criteria for extreme tide, wave height, and river conditions are applied independently. The probability of a combination of all three conditions occurring simultaneously (the design wave occurring during the extreme tidal condition with a 50-year event in the Kenai River) is lower than practical for application to the revetment design. Several more reasonable combination events were investigated and compared to check their suitability as a design condition.

Potential combinations for establishing the top of revetment elevation were narrowed down to the four scenarios presented in Table 6. As shown in Table 6, Condition 4 is the most conservative of the scenarios and is adopted as the design criterion for the top of revetment. Despite this conservatism, the public risks of greater-than-design events should be presented to jurisdictional authorities for development of emergency action plans.

3.5 Toe of Revetment Elevation

The proposed depth of toe protection accommodates the greater of two-thirds of the design wave height or one armor stone plus the B-layer thickness. In accordance with the selected design wave, an apron or trenched toe design would thus accommodate an equivalent vertical scour depth of 4.2 feet in Zone A and 3.3 feet in Zones B and C. Sheet pile has previously been dismissed as an option. If it is introduced in specific areas, a reflective wave would need to be adopted and the design depth for scour adjusted according to the Shore Protection Manual guidance (Corps 1984).

In order to assess the adequacy of the toe scour depth, changes in the morphology of the Kenai River were considered over the design life of the project. A plan view plot of the thalweg location based on the hydrographic cross sections shows that in 2002, the thalweg was located at the approximate location of the 1950 top of bluff in some areas. If the rate of bluff retreat observed during the previous 50 years were to continue at its measured rate, the future thalweg could potentially reach the current location of the top of bluff in the next 50 years. The thalweg is an average of 200 to 300 feet seaward of the bluff toe and approximately twenty vertical feet below. If a project design were to account for a thalweg shift of that magnitude, the depth of scour protection would need to extend at least twenty vertical feet below the existing slope toe.

A review of the cross section plots (see Attachment C) indicates that at the locations in which the bluff is retreating most rapidly (Section 2 and Section 3) there is a slope of approximately 14% from the toe of the bluff to the point at which the slope flattens near the thalweg elevation. The limits of this slope correspond roughly to the elevation of the maximum and minimum extreme tides (with the Kenai River at mean flow) as computed in the Corps Technical Report (USACE 2006b). Where the bluff is retreating more slowly (Section 4) the slope is approximately 20%. At Section 5, where the bluff has not retreated, the slope is about 25%. The fastest-retreating areas have averaged a recession rate of 2.5 to 4 feet per year while the more slowly retreating areas are characterized by a rate of approximately one foot per year or less. The most rapidly retreating areas are on the portion of the bluff with the greatest exposure to wave action. The flat slopes of these sections are indicative of a wave and tidally influenced environment in contrast to the steep bank toe slope typically identified on the outside of a prominent bend. Based on these observations, it is likely that the material that is generated from the erosion of the bluff face is being predominantly conveyed away from the toe by wave action. The vertical extent and sizing of scour protection should therefore be based upon wave conditions rather than riverine conditions.

Review of the cross section geometry shows rather flat-bottom sections without a well-defined thalweg along the outside of the bend. This factor, along with the observation that transport of eroded material away from the toe of the bluff appears to be primarily the result of wave action, leads to the conclusion that designing the scour protection for the bluff stabilization measures to account for a thalweg shift against the bank would not be immediately warranted. Such a design would greatly increase the cost of construction. Continued migration toward the proposed stabilized bluff line is expected to occur as a steepening of the river’s bank line within the river section rather than a wholesale shift in the river section. Because some of the protruding points have been smoothed by wave erosion and because of other constraints affecting the wave environment, the future migration is anticipated to be slower than the historical bluff erosion. Slope protection becomes more viable on the steeper slopes; therefore, it is recommended that potential scour from the channel migrating toward the bluff protection be addressed through a monitoring program that would identify any areas of excessive scour along the protected bluff. Additional toe protection could be applied to these localized areas as needed.

Table 6. Revetment Height and Toe Protection Depth

Parameter	**Zone A (Sta. 0+00 to 15+00)**	**Zone B (Sta. 15+00 to 45+00)**	**Zone C (Sta 45+00 to 70+00)**
MHHW	20.7 feet MLLW	20.7 feet MLLW	20.7 feet MLLW
Extreme Tide	26.0 feet MLLW	26.0 feet MLLW	26 feet.0 MLLW
Highest Observed	27.7 (6/14/95)	27.7 (6/14/95)	27.7 (6/14/95)
Design Wave	4.5 feet	3.5 feet	2.5 feet
Top of Revetment for Condition 1 (MHHW + design wave runup + storm surge)	29.0 feet MLLW	27.5 feet MLLW	26.0 feet MLLW
Top of Revetment for Condition 2 (extreme tide + nominal wave runup + storm surge)	32.0 feet MLLW	30.5 feet MLLW	29.8 feet MLLW
Top of Revetment for Condition 3 (highest observed tide + nominal wave runup)	32.2 feet MLLW	30.7 feet MLLW	30.0 feet MLLW
Top of Revetment for Condition 4 (highest observed tide + design wave runup)	**34.5 feet MLLW**	**33.0 feet MLLW**	**31.5 feet MLLW**
Effective Toe Depth (Greater of 2/3 wave height or 1 armor stone + B layer thickness)	4.2 feet	3.3 feet	3.3 feet

3.6 Ice Design

On similar projects designed by the Corps, armor designed to withstand wave action is sized sufficiently to resist transport or other damage by ice forces. Because Zone C is relatively protected from wave action, however, the computed armor size requirement warrants an increase. A 600-lb minimum W_{50} is recommended to withstand forces from river ice and sea ice, and the bluff face shall resist erosion from freeze-thaw cycles. All rock specifications were compared to ice design calculations based on recommendations by the Corps Cold Regions Research and Engineering Laboratory as set forth in the appropriate design manuals. Historical ice jams and the potential for flood waves from the breakup of ice jams were also considered in the minimum weight criteria.

3.7 Rate of Allowable Bluff Retreat

The intent of any project alternative considered in this report is to effectively stop bluff retreat. As such, the future with-project conditions erosion rate will be 0 feet per year along the entire project extent, in contrast to the existing historical rate of 2 to 4 feet per year. The design criterion of 0 feet per year is adopted regardless of any further analysis of the historical rate of recession along the bluff.

3.8 Lineal Project Extent

The historical bluff retreat analysis results (see Attachment C) were used to determine the necessary extent of revetment, establishing bounds for the lineal project extents. The Geotechnical Investigations Report (R&M Consultants 2007) includes a soil profile (SP-A) near Hansen Park. Historical aerial photographs indicate that fill was placed in this area in the 1960’s. Although some of the fill areas have eroded, particularly at the toe of the slope, the historical aerial photographs indicate that the area around profile SP-A has remained stable for at least several decades. The geotechnical investigations likewise show a stable, vegetated slope with an absence of toe erosion. The Corps Technical Report (USACE 2006b) determined that large wave action in this area is generally limited due to protection afforded by coastal dunes, the wetlands to the south, and the shoal at the river mouth. This area marks the western extent of the proposed bluff stabilization measures.

As shown in Attachment C, the historical bluff retreat analysis indicates a rate of bluff retreat that is significantly less east of Ryan’s Creek (Zone C) than in the near-mouth area (Zones A and B). In the vicinity of the existing Pacific Star Seafoods dock, historical aerial photographs show that fill was placed seaward of the historical bank line in conjunction with sheet pile and other marine structures. Although some erosion is apparent directly adjacent to the bulkheads, the bank line has been stable in this area since the structures were constructed in the 1940's. The waterfront development at the Pacific Star Seafoods dock marks the eastern extent of the project. The overall lineal project extent covers approximately 5,000 feet from Hansen Park to the Pacific Star Seafoods dock.

The rate of historical bluff retreat gradually decreases upstream along Ryan's Creek Canyon. Historical aerial photos show no discernible lateral erosion at a point measuring approximately 200 feet upstream of the mouth of Ryan's Creek.

3.9 Design Storm

The design accommodates the surface water runoff associated with a 100-year, 24-hour rainfall event as predicted by an analysis of data from the Kenai FAA gage site. As shown in the USGS isopluvial maps in Attachment B, the 100-year 24-hour rainfall depth in Kenai is approximately 4 inches. An analysis of 70 years of rainfall data spanning intermittently from 1899 to 2004 shows a 2-year, 24-hour rainfall depth (50% chance of exceedance in any given year) of approximately 1.1 inches. The maximum recorded rainfall event was October 10, 1986, when 4.3 inches of rain fell in a 24-hour period. As depicted in the design plans (Attachment G), all surface water runoff associated with the design event currently draining over the bluff face or through drainage pipes within the project area shall be diverted around the site, routed through surface or subsurface conveyance, or otherwise accommodated in the project design without adverse effects. Likewise, any irrigation pipes or other potential flow sources currently protruding from the bluff face will need to be intercepted and controlled under project conditions. The slope surface treatment is designed to prevent the formation of rills, gullies, and headcuts that could affect the integrity of the slope. See Attachment B for additional details regarding historical rainfall data. The effect of events exceeding the design event should be presented to jurisdictional authorities for use in preparation of emergency action plans.

3.10 Geotechnical Design Criteria

Slope stability calculations have been performed to supplement the findings of the Geotechnical Investigations Report (Attachment M, R&M Consultants 2007). The design earthquake used in the analyses has a 10% probability of exceedance in 50 years, or a 475-year return period. According to Wesson et al (1999), this results in a force of 0.38g. The stability of the bluff was evaluated both qualitatively by field observations, and quantitatively with analytical methods. The stability analysis was performed by limit-equilibrium methods using computer programs ReSAA(2.0), and PCSTABL4. Several models were set up, including global stability of the entire bluff, global stability of the upper alluvial soils, as well as global and surficial stability of the bluff regraded to various slope angles. Based on these analyses, it was concluded that the bluff regraded to 1.5 horizontal to 1 vertical (1.5H:1V) or flatter will be stable with respect to global failures, absent further erosion of the toe. The calculations indicate that the slope would be stable in both the alluvium and the glacial till soil. The lower till layer could accommodate a slightly steeper slope; however, because of the gravel lenses and other inconsistencies in the material, a uniform slope is recommended for the entire bluff face. The potential for slope failures in greater-than-design events should be presented to jurisdictional authorities for use in emergency action plans.

In previous conceptual designs, the TAMS study included a 1.25H:1V slope (TAMS 1983) and the PND concept included a 1.5H:1V slope. In light of the findings of the Geotechnical Investigations Report, the steeper slope as presented in the TAMS report is not recommended as it would not provide a sufficient safety factor without the application of significant supplemental bank stabilization and/or dewatering techniques.

A qualitative evaluation of the slope stability was initially conducted and was primarily based on observation of the existing areas of the bluff which are not currently subject to active toe erosion. Specifically the areas at the west end of the bluff in the vicinity of Cemetery Creek, and the slopes at the mouth of Ryan’s Creek were studied. These natural slopes appear to have stabilized and become vegetated at angles of about 1.5H:1V. The seepage from the base of the alluvial deposit is generally not visible in these areas, and appears to remain subsurface beneath the mantle of colluvium, except in the winter when aufeis becomes visible in these areas. This presence of ice on the slope in winter supports the conclusion that groundwater flow is present in these vegetated areas, but remains subsurface most of the year. R&M Consultants’ 2007 Geotechnical Investigations concluded that in the absence of river and tidal action, the slope would naturally flatten to an angle between 35 and 40 degrees (approximately 1.5H:1V) and become vegetated as was observed on the slopes around the bends near Cemetery Creek and Ryan's Creek (see Figure 13). Protecting the toe of the bluff would minimize the impact of water seepage on bluff erosion and may eliminate the need for a dewatering scheme.

Figure 13. Ryan's Creek Canyon

Based on these conclusions it is recommended that the slope be regraded to no steeper than 1.5H:1V. Benching is not considered to be necessary from a long-term slope stability standpoint.

3.11 Design Seepage Rate

The preliminary gradation and thickness of the filter layer is designed to accommodate a total groundwater discharge of up to 400 gpm. The gradation is also designed to prevent piping of the in-situ materials to the surface. The design is also intended to prevent the formation of aufeis on the bluff face. Supporting calculations of discharge rates and other hydrogeological parameters, including hydraulic conductivity and groundwater flux calculations, are presented in Attachment N. Filter designs follow procedures outlined in Forrester (2001) and Corps engineering manuals as appropriate. The proposed filter layer gradation is provided in Attachment E.

Measurements of the discharge along the toe indicate three separate zones of flow rates, as described and shown graphically in Attachment N. The design accommodates surfacing groundwater. Solutions for conveying discharged water down the slope and through the revetment account for the length of the zones with multiple discharge points to allow flows to equalize between each set of points. Icing likewise is considered at flow concentration points. Preliminary analyses indicate that local drainage from rainfall runoff during the design event (see Local Drainage above) exceeds groundwater flow by an order of magnitude. The conveyance system for the bluff face and revetment is therefore designed for local surface water runoff with a slight overdesign to account for the groundwater flux.

The groundwater data collected from the monitoring wells indicate that the groundwater flow from the alluvial deposit is quite uniform across the entire project area, and exhibits little seasonal variation. A comparison of water table gradients extrapolated in the direction of the bluff and toward the Ryan’s Creek canyon walls indicates that similar groundwater seepage conditions would be encountered along a cut slope. Although quantitative flow measurements are not available in this area, there is no reason to expect that the groundwater flow from the slopes at the west end of the project (Cemetery Creek), or slopes in Ryan’s Creek should be significantly different than along other portion of the bluff.

3.12 Real Estate Constraints

As tabulated in Attachment H, the top of bluff intersects approximately 46 parcels consisting of a combination of public, commercial, and private residential parcels. As such, all alternatives will involve temporary construction easements or permanent acquisition of some properties to accommodate the revetment and cut back slope. Parcel data, including values, are based on the latest assessor’s information provided by the Kenai Peninsula Borough. The design seeks to minimize impacts to non-residential physical facilities, such as the Kenai Senior Center and Pacific Star Seafoods dock.

3.13 Survey/CAD Standards

The base map for the current design is based on aerial photography acquired September 27, 2007 by AeroMetric, Inc. at a nominal scale of 1”=300’. Metadata and projection details for aerial photography are included in Attachment D. The design CAD files utilize the Alaska State Plane Zone 4 NAD 83 projection with units in U.S. Survey feet. The contour interval is 1 foot and maps are produced for output at a scale of 1”=100’. Topographic mapping complies with ASPRS Class II horizontal and vertical accuracy standards. Previous Corps hydrographic surveys utilize a NAD 83 projection; however, the Kenai Peninsula Borough maintains parcel maps and other layers in NAD 27. These layers have been reprojected for use in the CAD drawings using ArcMap software. River stationing is referenced according to the USGS river miles. The revetment is stationed from the downstream point of beginning separately from the river stationing. All vertical references are adjusted to the MLLW datum revised and approved by NOAA NGS in March 2008. Additional details regarding the datum adjustment are included in Attachment D. CAD plans for the selected alternative apply Alaska District CAD standards for AutoCAD 2008. Property lines, street rights-of-way, street names, and other geospatial data are taken from the Kenai Peninsula Borough (KPB) Geographical Information Systems (GIS) website.

3.14 Environmental Constraints

The design seeks to minimize adverse environmental impacts. Any construction debris or other materials that could contribute to possible contamination or instability of the bluff that are encountered during project excavation will be removed and replaced as necessary with clean backfill. Specific environmental design criteria, including target construction windows, will be developed by the Corps and documented in future reports under separate cover.

3.15 Public Use and Safety Criteria

Public access to the bluff slopes will be restricted by safety fencing except at controlled access areas along the bluff. Public access to the toe of the bluff will be restricted, with fishing and other activities prohibited along the entire extent of the bluff toe as at present

4.0 DESIGN ALTERNATIVES

In developing the project design, variations in individual project components were examined. The primary project components selected for variation included the approaches for controlling groundwater seepage, regrading the bluff face, and protecting the toe. Each component had several associated attributes that were varied in screening alternatives. The selected design configuration ultimately represents the optimal combination of individual components in terms of cost and effectiveness while limiting environmental impacts and balancing interdependencies. The development and refinement of design alternatives is covered in further detail in the Design Alternatives Report (Tetra Tech 2008.)

4.1 Groundwater Seepage Control

The following alternatives for addressing groundwater issues along the Kenai River Bluff were evaluated:

1) No action (allow present rate of groundwater seepage without water table modification or interception).
2) Construct a cutoff wall with a pump system that intercepts the groundwater landward of the bluff face.
3) Construct draw-down wells landward of the bluff face that lower the water table.
4) Construct a horizontal drain system on the bluff face that collects and diverts the groundwater.
5) Construct a network of drainage channels that alter the groundwater gradient.
6) Construct a free-draining retaining system that holds back the bank material while allowing free drainage of water from bluff face.

After consideration of the relative costs, maintenance requirements, and existing hydrogeological parameters, Option #6 (free-draining soil layer) was selected for the draft design.

4.2 Bluff Face Regrading

The following options for regrading the bluff face were evaluated:

1) No action (allow the bluff to reach a stable slope naturally).
2) Construct a stable slope by balancing the cut and fill areas along the bluff.
3) Construct a stable slope by cutting the bluff back from the existing slope toe.
4) Construct a stable slope by adding imported fill from the existing top of bluff.

A matrix of potential slope configurations was developed to represent combinations of the above options by zone. The balanced alternative (Option #2) was selected with local variation to protect public infrastructure along the top of the bluff and the sensitive riparian zones of Cemetery Creek and Ryan's Creek along the toe of the bluff.

4.3 Toe Protection

Various toe protection materials were considered along with potential variation in the location of the toe protection. A wide spectrum of toe protection applications was considered for use along the affected bluff area, ranging from "soft" solutions involving vegetation or soil treatment to "hard" solutions such as armor rock or sheet pile. Following is a sample of assessed options.

1) No action (leave existing bluff toe unprotected)
2) Bioengineering (combination of vegetation with geotextile, terracing, soil reinforcement, or other bank stabilization methods)
3) Articulated concrete revetment (Armorflex®, Petraflex®, Shoreblock®, or similar technology)
4) Flexible hydraulic fill containment (Geotube® or similar technology)
5) Rock (revetment or breakwater)
6) Precast concrete armor unit (Tetrapod or similar application such as Core-Loc®, Tribar, Accropode®, Ecopode®, Dolos, Stabit, Akmon, Seabee, A-jack, Xbloc®, Gassho®, Modified Cube, etc.)
7) Bulkhead (concrete seawall or sheet pile)

After consideration of the relative costs and engineering properties of each of the materials, armor rock (Option 5) was selected as the most practical toe protection material.

Variation in the configuration of the toe protection was also considered. Two potential locations for placing the armor rock toe protection are considered:

1) Construct a rock revetment at the toe of the slope (attached alternative).
2) Construct an offshore breakwater (detached alternative).

The detached alternative (Option #2) would protect the toe from wave action and allow the bluff to reach a stable slope naturally. Due to the uncertainty and concerns regarding environmental impacts and public safety, the detached alternative was dismissed in favor of Option #1.

4.4 Alternative Evaluation

Alternative combinations were developed with the revetment location and the balance of cut and fill varying within each of the three project zones (A, B, and C as shown in Figure 2). The previously proposed concept (PND 2002) included a coastal trail along the top of the revetment. The coastal trail component was not carried in the current design alternatives; however, multi-use applications for benches were considered. The design criteria outlined in Chapter 3 were held common to each alternative combination. As presented in the Design Alternatives Report (Tetra Tech 2008), four alternative combinations were selected from a matrix of 24 combinations. These alternatives were evaluated in terms of cost, engineering performance, and environmental impacts, with impacts of individual design features on cultural resources, real estate, recreation, and other areas of concern covered qualitatively.

4.5 Alternative Selection

The four proposed alternatives were presented to agencies and individuals in public meetings December 13, 2007. Feedback was collected on each alternative. Design refinements were further evaluated with the Corps, Tetra Tech, and R&M Consultants in meetings held December 14, 2007 and April 30, 2008. The tentatively selected alternative was presented at additional public and agency meetings on November 19, 2008. Agency representatives, residents, and the Corps favored proceeding with the proposed design development. The design presented in this report was refined from the adopted alternative that provides an optimal balance between costs, impacts, and performance.

5.0 DRAFT DESIGN

This chapter presents design details related to individual features comprising the draft design. The draft design is shown as a 24-sheet plan set in Attachment G.

5.1 Seepage Control

A typical cross section showing the seepage control approach is shown on Plate C-11 in Attachment G. The design applies a minimum 10-foot thick layer of free-draining soil to convey the groundwater seepage to the toe of the bluff. The layer thickness of this free-draining soil is sized to adequately convey the design seepage rate described in Chapter 3. In areas where this soil is less permeable than the underlying soils (where the lag gravel layer or gravel lenses are exposed, for instance) there may be a rise in the water table due to the damming effect. Geotechnical analyses of the in situ alluvial material indicate a permeability ranging from 0.00013 to 0.00018 ft/second. Assuming a hydraulic gradient of 0.55 (1.5H:1V) to 0.71 (1H:1V) and a 10-foot thick blanket of alluvium, the analysis yields an equivalent flow rate capacity of 0.3 to 0.6 gallons per minute per lineal foot of bluff. This capacity is adequate as an average; however, in isolated areas, there may be some risk of flow concentration surfacing. These flow concentration areas would be extremely difficult to predict and may require localized maintenance efforts involving the placement of a rock mattress or other erosion mitigation following construction. Mixing the native stockpiled soil with imported coarse-grained material or placement of a drainage geotextile could reduce the potential for future maintenance but would add significant project costs. These solutions would tend to result in an overdesigned system in most areas if applied project-wide; a localized maintenance approach is therefore recommended.

An additional factor that can decrease the permeability of the soil blanket and thus contribute toward potential damming issues is the frost depth. There are some uncertainties in the frost depth related to the exposed slope and the contribution of groundwater heat in melting ice below the surface. The maximum frost depth along the bluff face is estimated as four to five feet below the surface. The provision of a minimum blanket thickness of ten feet allows for a factor of safety against freezing within the layer.

In order to provide this minimum thickness, a bench is incorporated into the typical cross section. This allows the excavation of additional alluvial material from the top of the bluff while providing a free-draining layer of sufficient thickness for groundwater flow conveyance. Although the bench is similar in dimensions to the bench proposed in the PND concept (2003), the function differs. The bench in the PND concept was located below the lag gravel layer with the intent of concentrating and collecting groundwater seepage as surface water flow. The draft design approach places the bench above the lag gravel layer to prevent flows from surfacing. The bench also serves additional purposes for constructability and maintenance. The design includes security fencing to prevent public access except at designated overlook locations; however, some public use of the bench may be accommodated in the future with the construction of fencing and access points by local agencies.

In this concept, the groundwater is intended to surface within the armor rock zone. Some of the excess till material excavated from the slope is used at the toe of the slope. Some mixing with alluvial soil may be required for compaction in a recommended 60:40 alluvium:till mix. It is anticipated that this material would inhibit flow in the vertical direction and force the seepage out through the filter fabric behind the revetment. This would reduce the potential for piping below the revetment.

5.2 Revetment

The typical revetment section is shown on Plate C-12 in Attachment G. The draft design utilizes a layered armor rock armor design that varies by zone with the design wave. Armor sizing, layer thickness, and gradations are designed according to the Shore Protection Manual (Corps 1984) as presented in Attachment E. The armor section includes a buried toe. Geotechnical analyses indicated that trenching efforts may encounter difficulties in specific areas. In these areas, the equivalent toe depth might be provided as an apron of launch material. For an assumed foreslope of 2H:1V, the horizontal projection of the toe material would be twice the design depth. Any trenching from land-based equipment would have to be done at low tide and backfilled in sections prior to high tide. This would require construction of the entire cross section in lateral sections rather than vertical layers across the entire project site.

Preliminary bearing capacity analyses based on the results of borings at the toe of the slope indicate that no additional compaction would be required at the toe once the initial overexcavation for the bedding layer is completed. Settlement is anticipated to be on the order of several inches; therefore, a slight overbuild is recommended in terms of the top of revetment elevation. Filter fabric is recommended beneath the revetment bedding to prevent piping of material through the revetment while relieving the buildup of excessive pressure from the groundwater and/or tidal cycles. The revetment face and foreslope toe must remain continuous and smooth to avoid scour from incoming wave refraction; a transition zone (Station 19+50 to 21+50) is therefore applied to provide a gradual decrease in revetment height, armor size, and layer thickness between Zones A and B.

5.3 Earthwork

The typical cross section applied to the bluff is shown on Plate C-11 in Attachment G. In developing the typical section for the draft design, templates with varying side slopes were run along the primary control line using Bentley InRoads software, and the resulting earthwork quantities were tabulated. Templates were developed with slopes varying between 1.5H:1V (the steepest recommended slope based on the results of the geotechnical analysis) and 3H:1V. The template offset from the primary control line was also varied within each zone to determine the earthwork quantities associated with moving the typical section landward or seaward. Moving the typical template further seaward increases the amount of imported fill required at the toe along with the associated cost. Moving the typical template further landward decreases the required imported fill, but significantly increases the amount of excess glacial till that would have to be hauled offsite. The draft design is based on the offset that optimizes the costs by minimizing the net import or export of material.

The draft design resulting from this optimization procedure yields a typical section with a 2H:1V bluff face slope above the bench and a 1.5H:1V slope below the bench. The milder slope within the alluvial layer provides native borrow material for reuse onsite, reducing the amount of imported fill required. The milder slope also promotes better vegetation survivability in the areas most visible from the top of the bluff and from the bench. Applying the milder slope rather than maximizing the slope for geotechnical stability alone results in additional acquisition costs due to the larger footprint but optimizes the earthwork while simplifying maintenance procedures in the areas with the greatest aesthetic impact. An even milder slope, such as a 3H:1V slope, increases the factor of safety against localized erosion but would also significantly increase the volume of earthwork (construction costs) and the project footprint (acquisition costs) associated with the project if applied to the entire slope. A secondary disadvantage of a milder slope may also be an increase in unauthorized public access to the toe.

The slope stability analysis indicates an acceptable factor of safety for the design earthquake conditions as described in Chapter 3. Under this scenario, there is potential for some deformation up to about 25 feet back from the slope crest. Setback ordinances for future development along the top of the bluff are thus recommended to minimize structural losses during the design event or during earthquakes potentially exceeding the design events. To accommodate maintenance access and drainage requirements along the top of the bluff, a permanent easement measuring approximately 20 feet from the edge of the constructed bluff slope is recommended. According to the International Building Code (International Code Council 2006), a 40-foot minimum setback is recommended for foundations constructed near a descending slope. This easement would apply to new construction; existing structures located within the easement zone (between 20 and 40 feet from the bluff edge) would be treated on an individual basis and may be subject to further review by a structural engineer to assess the long-term stability.

Although a 1.5H:1V slope is considered stable from a long-term geotechnical standpoint, the height of the slope causes some concern for construction equipment during placement of the fill. Placement of a geogrid, as shown on Plate C-11 in Attachment G, is recommended to alleviate concerns regarding constructability. Geogrid placement is recommended at every second compaction lift (18-inch vertical spacing) with a minimum width of five feet. A list of potential products is included in Attachment E. For products manufactured in six-foot rolls, a six foot width would be recommended in favor of cutting the roll. Uniaxial products would need to be rolled with frequent cuts and excessive overlap requirements; a biaxial geogrid is therefore recommended. The opening size should be at least one inch square to accommodate roots from the vegetation planted along the bluff face. The geogrid should be flexible fabric rather than stiff plastic so that establishment of roots reinforces rather than destabilizes the slope.

The draft design also includes erosion control fabric, vegetation, and other measures to control erosion along the bluff face as shown in Plate C-11 in Attachment G; however, even with these measures, careful installation and ongoing monitoring and maintenance are required to promote vegetation survivability and to prevent local sloughing.

Excavation activities will most likely uncover some material unsuitable for reuse onsite that will have to be hauled for offsite disposal. Some reuse of the excess till material is assumed within the toe trench backfill in order to minimize voids and reduce the potential for fish stranding. During construction, any loose and/or saturated debris should be removed from the face of the bluff prior to placing the fill material. Benching into the bluff face is recommended to expose undisturbed material. Control of the seepage water will also be important during construction. The fill should not be allowed to become excessively wet prior to compaction. An open-graded gravel material against the bluff face is recommended to aid in drainage as necessary. The proposed gradation is provided in Attachment E. The gradation requirements are loosened somewhat beyond the ideal permeability in order to allow the inclusion of most of the existing alluvial material. A coarser material specification would allow for a thinner cover layer but would potentially preclude the use of existing alluvial deposits. To help facilitate drainage, a layer of coarser gravel is proposed in localized areas where the seepage is greatest. The localized improvements are part of ongoing monitoring and maintenance work (see OMRRR below). Further geotechnical analyses of slope stability and seismic design criteria are included in Attachment E.

5.4 Stormwater Management

In accordance with the design criteria, the draft design prevents overland runoff from flowing over the edge of the bluff in order to reduce the risk of head cuts and other associated drainage problems. As described in Chapter 2, runoff concentrates in three primary locations in the project area (one within each zone). A discussion of options considered for accommodating the runoff is included in Attachment E. These include the following:

1) Construct bioswales and vegetated basins to treat stormwater runoff and allow infiltration.
2) Route concentrated flows away from the bluff and into the City of Kenai storm drain network.
3) Construct rock V-ditch slope drain
4) Construct pipe slope drain

As shown in Plate C-11 in Attachment I, the draft design proposes a small berm approximately 6 inches in height along the edge of the bluff; the twelve-foot wide access route adjacent to the berm is graded with a reverse cross slope (sloping away from the bluff at 2-3%), and a small ditch varying from 1 foot to 2 feet in depth is proposed on the landward side of the road to collect sheet flow runoff. The ditch should be vegetated in order to act as a bioswale for filtering stormwater runoff. At the three key concentration points, vegetated settling basins are proposed. The swales route flow into the settling basins, which attenuate peak flows while allowing pollutants to settle, and the vegetation within the basins filters urban runoff from adjacent streets prior to being released. The bed of the ditches and basins should be lined with either a pond liner (impervious geomembrane) or bentonite seal to prevent infiltration that might otherwise surcharge the groundwater table.

As shown on Plate C-2 in Attachment G, a settling basin is proposed in Zone A near Mission Avenue. Approximately 18 acres of drainage area collects in the basin. An existing culvert that conveys stormwater runoff through the existing subsurface network to the bluff edge is redirected into the basin. A flashboard riser structure is proposed as a basin outlet to allow adaptive management of water levels and optimize detention times. The riser would preferably be connected to the portion of the City of Kenai storm drain network draining away from the bluff; however, additional analysis of the existing storm drain system is required to assess the feasibility of this option prior to further design. Routing flows away from the bluff through the City's storm drain network would most likely require additional infrastructure improvements outside of the project footprint. Development of a storm drain model by KWF is pending funding availability; in the interim, the proposed design routes flows from the riser pipe to a rip rap V-ditch that extends to the toe of the bluff, as shown on Plate C-13 in Attachment G. Infiltration basins may be incorporated if the basins are a minimum of 500 feet from the bluff face. Additional property acquisition or easements would be required to construct set-back infiltration basins.

As shown on Plate C-4 in Attachment G, an existing basin with a flashboard riser is present along Peninsula Avenue in Zone B. Regrading the basin is proposed to accommodate the access road, with the drainage swale flows routed into the basin for a total drainage area of approximately 25 acres. An existing corrugated metal pipe (CMP) culvert drains from the flashboard riser to the toe of the bluff. The existing culvert has failed in several locations, causing severe erosion along the slope. The proposed design removes the existing inlet and pipe and replaces them with measures similar to the Mission Avenue basin.

In Zone C, the drainage swale concentrates at the low spot along the top of the bluff with a total drainage area of approximately five acres. The approach for routing the flow to the toe of the bluff is similar to Zones A and B; however, a reduction in size and thickness of the rip rap is recommended as the design flows are significantly less. In addition, the armor rock at the eastern, upstream extent of the project near the Pacific Star Seafoods dock intercepts a ditch flowing along the edge of the bluff. A rip rap V-ditch is proposed in this location.

Additional details regarding the rip rap gradation and hydraulic characteristics are included in Attachment E. The risers, culverts, and V-ditches are sized to accommodate a 100-year rainfall event; however, a rain-on-snow event occurring while the culvert is blocked by ice or a design rainfall event occurring over frozen ground with highly limited infiltration may result in exceeding the system capacity. Should a greater-than-design event occur, immediate inspection is recommended to address potential erosion problems and prevent large-scale slope failure.

For runoff resulting from rainfall on the bluff face itself (approximately 10 acres), allowing sheet flow and preventing accumulation of erosive, concentrated flows down the face is recommended in favor of terracing and trenching the bluff face to accumulate and feed surface water into collector channels or slope drains. Several considerations regarding grading, compaction, layering, and special placement of geotextiles are required to prevent erosion prior to the establishment of vegetation. These recommendations are presented under the *Vegetation* section below. Other Best Management Practices (BMP's) may be implemented to address water quality issues pending analysis of the runoff source.

5.5 Vegetation

The existing bluff face is unvegetated, except in areas where material at the toe is not carried away by waves or currents (Cemetery Creek and Ryan's Creek). Groundwater seepage is present in these areas, and the draft design approach presumes that a stable bluff slope with a protected toe would allow the establishment of vegetation in similar manner. The establishment of vegetation on the slope face will reduce the risk of erosion of the slope face during heavy rainfall and during spring breakup. As determined in the geotechnical analyses, surficial stability and resistance to erosion will be greatly enhanced once vegetation is established on the regraded slope face. During the period immediately following construction, prior to the establishment of vegetation, the slope will be more susceptible to erosion, and the placement of topsoil and a high-performance erosion control mat is recommended in order to speed the greening process. Erosion control fabric is recommended for the entire bluff face above the armor rock. Replacement of some plants may be required during establishment, particularly if design-level or greater-than-design rainfall events occur during the establishment period.

A phased planting approach is recommended to maximize survivability. Grasses should be allowed to establish first as a mandatory construction item, with willow and alders plantings proposed after several seasons as an optional construction item. Following establishment of the alders, spruce trees would be planted on the upper slope, likewise as an optional construction item. Because of the high degree of exposure to wind and ice, spruce would have higher survivability if protected by other surrounding vegetation.

The planting plan for the project includes the following components:

- During Construction: Place, key in and stake erosion control fabric along entire bluff face.

- Phase I (Mandatory): Seed entire area with emergent native grasses, including beach wildrye (Elymus mollis), blue joint reed grass (Calamagrostis canadensis) at 5 lb/ac and tufted hairgrass (Deschampsia cespitosa) at 5 lb/acre.
- Phase II (Optional): Plant riparian vegetation. Plant willow stakes immediately uphill of the revetment 5 feet on center. Extend the willows 3 feet along the slope uphill from the revetment in the near mouth area and 4.5 feet in the remaining area. Plant one row of alders adjacent to willows spaced 10 feet on center.
- Phase III (Optional): Plant upland vegetation. Plant rows of spruce 15 feet on center to the top of the bluff.

Additional details regarding the recommended planting and seeding plan are included in Attachment E and on Plates L-1, L-2, and L-3 in Attachment G. The planting plan has been prepared in coordination with Mr. Stoney Wright at the Alaska Plant Materials Center. Preliminary discussions with Mr. Wright indicate that there has been some local success planting alders and/or spruce trees in a phased manner. Success has been site-dependent; however, forestry replantings have typically been successful and the forestry-focused sources may have plants available. Of the seed species, wildrye is best applied where there will be salt spray or tidal influences. For the Kenai Bluff, this zone would be at the base of the slope. The remaining proposed grass seeds (reed grass and tufted hair grass) can be mixed in and generally do well in wet situations. Upland grasses should be seeded in on the upper slope.

A layer of alluvial sand is recommended over the entire bluff face, including areas excavated into glacial till. The alluvial layer is recommended for groundwater seepage; care should be taken to ensure that the layer is not so porous as to leave the roots of the vegetation completely dry. The current proposed recommendation is to place a minimum of 10 feet of alluvial material, capped with 1 foot of topsoil. The top soil should be smoothly compacted and graded to allow a flush contact with the erosion control fabric.

A 100% biodegradable erosion control blanket is recommended. Woven coir erosion control mats have a functional life of 4-6 years, but often last longer. Specifications for the erosion control fabric recommended for this application by Rolanka are included in Attachment E. Any similar product may be applied, so long as it meets the ASTM testing standards. Due to the relatively harsh environment at Kenai, several considerations should be followed during installation to extend the life and functionality of the product. Because the bluff face is south-facing, UV exposure will be intense, particularly in the summer months. A heavy-grade fabric is recommended in order to resist degradation from UV exposure. Because of the steep slope, high winds, and freeze-thaw action, the standard spacing for stakes should be doubled (quadrupling the number of required stakes) from the standard vendor recommendations. Particular care must be taken to ensure the mat lies flush against the topsoil. Key-in and overlap requirements should also be strictly adhered to.

Wherever the fabric is sliced for planting (including phased planting in seasons following completion of construction), the flaps should be buried into the hole for the rootball as a key-in. Plantings should be mulched as needed above the fabric. Some seeding can be completed prior to installation. In some cases, plugs can be planted through the openings in the blanket without slicing. Prevention of rilling and gullying along the bluff face relies on the infiltration. The subsurface material is likewise designed to be a pervious layer. As such, irrigation may be required during the initial phases until root depth are sufficiently established to prevent dessication. The costs of vegetation, as described in the following chapter, assume replacement of plants as needed to establish specified survivability rates within the establishment period.

5.6 Real Estate

The draft design involves some easement acquisition as well as potential condemnation and removal of several structures located within the excavation footprint. Approximately 46 parcels, 34 of which are privately owned, are located within the anticipated project area. The real estate plan and additional details regarding the affected parcels are included in Attachment D.

5.7 Recreational Features

The draft design includes one overlook with signage in each zone. Additional recreational features are not included in the draft design; local entities may add features such as public trails at a later point. Safety fencing is included at the edge of the proposed easement to control public access. The bench that has been incorporated into the design to promote groundwater conveyance presents an opportunity for additional recreational use. Agencies and residents have expressed a preference to have a birding trail in place of the multi-use bicycle trail proposed in previous concepts. The trail surfacing, aesthetic fencing, signage, and other features would require additional coordination with the City of Kenai. Transitioning the trail to the top of the bluff at the ends may also require further coordination. As presently shown in Attachment G, the trail is separated by Ryan's Creek Canyon; if there is a future desire to connect the trails with a crossing over Ryan's Creek, further coordination would be required.

5.8 Construction Sequence

The draft design approach assumes that the bluff face is cut back a minimum of 10 feet below the proposed bluff face, with the alluvial material stockpiled for placement as backfill. The cut and fill process could be looped by providing two access ramps, one near Cemetery Creek and one near the Pacific Seastar dock. Staging could be in the open area at the top of the bluff just west of the dock. A partial ramp exists in this area. It may be beneficial to temporarily span Ryan's Creek with rock and temporary culverts to allow continuity of the operation. Material could then be scraped at the top, transported around the ramp and dropped below with compactors running behind in a continuous loop. Alternatively, material could be pushed down by equipment at the top of the bluff, with additional compaction and earthmoving equipment located at the toe to allow placement and compaction in layers. The existing bluff face in any proposed fill areas would be notched first to avoid a smooth interface between soil types. The proposed construction sequence does not include driving vehicles on the sloping bluff face but rather filling in horizontal layers with a bucket or other extension performing the final smoothing and compaction of the immediate face.

Rock could be imported through a combination of barging and land-based equipment with the barge placing apron material at high tide, and the land-based equipment placing the remaining armoring at low tide. It is anticipated that the material behind the revetment would be constructed as an access road first. Complete segments of the armor section would be completed during each low tide cycle to at least the elevation of the maximum tide lines. Additional details regarding the proposed construction equipment, sequence, and other assumptions are included in Attachment F.

5.9 Monitoring Plan

The implemented project would require ongoing monitoring of vegetation, armor rock, bluff face integrity, river thalweg location, and other aspects of the project throughout the project life. The planting plan utilizes a phased approach, with implementation of each phase dependent on the success of the previous phase. As such, an annual inspection of vegetation is required. Results of the annual inspection will drive the timing of subsequent phases, should they be required. The monitoring plan should also include periodic hydrographic surveys to determine whether the thalweg is migrating toward the bluff face.

5.10 Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRRR)

The implemented project would require ongoing maintenance of the bluff face, vegetation, and toe protection throughout the project life. OMRRR needs will be assessed, prioritized, and implemented based on the results of the monitoring plan. The proposed access routes along the top of the bluff and along the bench are vegetated with grasses that would need to be maintained to provide continued access. Depending on the required frequency of access and the type of access vehicles, additional stabilization of the access routes, such as an open-celled mat, may be warranted. Without a bench, the reach length is excessive from the top of the bluff, and the types of equipment that could be mobilized to implement maintenance activities would be limited; however, the location of the bench above the lag gravel layer leaves the bench higher than ideal for maintenance purposes. If concentrated groundwater flows were to surface and require a rock mattress over the slope, the placement would most likely need to be manual.

Specifications of maintenance equipment, including width requirements for extensions, would need to be coordinated in further detail prior to use of equipment on the bench. Placement of additional rock at the toe in areas threatened by a thalweg shift would be guided by the results of the hydrographic survey. The top of the armor layer is not suitable as a driving surface, and the reach length from the bench is excessive. In addition, rock protruding from the top layer is proposed to deter public access along the top of the armor rock, as shown in the typical section on Plate C-12 in Attachment G. Because of these constraints, maintenance of the rock may need to be provided with barge access at high tide. Additional details on estimated OMRRR activities are included in the cost notes in Attachment H.

5.11 Quantities

Details on quantity takeoffs are included in Attachment H. A summary of the primary line items is presented in Table 7.

Table 7. Summary of Quantities

Line Item	Quantity	Unit
Excavate and Backfill	159,000	Cubic yards
Excavate and Haul Offsite	74,000	Cubic yards
Import, Place, and Compact	8,900	Cubic yards
Place Filter Fabric	83,000	Square yards
Place Filter Rock	15,400	Tons
Place “B” Rock	17,200	Tons
Place Armor Rock	35,200	Tons
Place Geogrid	34,000	Square yards
Place Top Soil	27,000	Cubic yards
Place Erosion Control Fabric	83,000	Square yards

5.12 Costs

The accompanying cost engineering report is included as Attachment H. The costs are presented with a breakdown of equipment, labor, and materials using the Microcomputer-Aided Cost Engineering System Second Generation (MII) software and cost databases. Attachment J includes notes, assumptions, quotes, and contacts related to the cost estimate. Hauling costs and the availability of rock from nearby quarries vary significantly over time and should be revisited with any updates to the design. Innovative approaches to construction sequencing, rock transport and placement, or earthwork components may result in lowered costs as the project proceeds. In addition to the first costs shown in Attachment H, annual operation and maintenance costs for annual rock and vegetation inspections, hydrographic surveying, and vegetation, drainage swale, settling basin, recreational feature, and revetment maintenance are assumed. These costs amount to approximately $20,000 per year, yielding a present value of approximately $350,000 over the 50-year project life.

5.13 Schedule

Costs are based on May 2012 unit prices, with an assumed initiation of construction activities in the summer of 2013. A preliminary construction schedule is included in Attachment H. The dates are adopted as a point of reference and do not reflect actual anticipated construction dates. Because of uncertainties in the anticipated construction schedule, costs would need to be escalated to account for the actual construction period as future project design phases are refined. Construction of each zone could vary in terms of implementation schedule. Because of the anticipated amount of time and budget required for complete project installation, phasing may be desirable, with the initial phases used as a demonstration section to show the final configuration and allow actual testing of the slope stability and armor material. The optimal split point if two phases were implemented would be Ryan’s Creek between Zones B and C. The historical erosion rate has been significantly higher west of Ryan’s Creek; phasing the construction with Zones A and B implemented prior to Zone C would provide the most immediate benefits.

Table 8. Total Project Cost Summary

PROJECT: Kenai River Bluff Stabilization
LOCATION: Kenai, AK
This Estimate reflects the scope and schedule in report; Kenai Bluff Feasibility Report

DISTRICT: Alaska District PREPARED: 5/8/2012
POC: CHIEF, COST ENGINEERING, xxx

WBS Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Doller Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
		Estimate Prepared: 8-May-12 Effective Price Level: 8-May-12				Program Year (Budget EC): 2013 Effective Price Level Date: 1 OCT 12								
				RISK BASED										
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($K) *C*	CNTG ($K) *D*	CNTG (%) *E*	TOTAL ($K) *F*	ESC (%) *G*	COST ($K) *H*	CNTG ($K) *I*	TOTAL ($K) *J*	Mid-Point Date *P*	INFLATED (%) *L*	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
	PHASE 1 or CONTRACT 1													
04	DAMS	$651	$130	20%	$781	0.9%	$657	$131	$788	2014Q1	1.6%	$667	$133	$801
14	RECREATION FACILITIES	$530	$106	20%	$636	0.9%	$535	$107	$642	2014Q1	1.6%	$543	$109	$652
16	BANK STABILIZATION	$23,886	$4,777	20%	$28,663	0.9%	$24,100	$4,820	$28,920	2014Q1	1.6%	$24,480	$4,896	$29,376
	CONSTRUCTION ESTIMATE TOTALS:	$25,067	$5,013	20%	**$30,080**		$25,292	$5,058	$30,350			$25,690	$5,138	$30,828
01	LANDS AND DAMAGES	$3,000	$600	20%	$3,600	0.9%	$3,027	$605	$3,632	2013Q1		$3,027	$605	$3,632
30	PLANNING, ENGINEERING & DESIGN													
1.5%	Project Management	$376	$75	20%	$451	0.7%	$379	$76	$455	2013Q1		$379	$76	$455
1.5%	Planning & Environmental Compliance	$376	$75	20%	$451	0.7%	$379	$76	$455	2013Q1		$379	$76	$455
7.0%	Engineering & Design	$1,755	$351	20%	$2,106	0.7%	$1,768	$354	$2,122	2013Q1		$1,768	$354	$2,122
1.0%	Engineering Tech Review ITR & VE	$251	$50	20%	$301	0.7%	$253	$51	$303	2013Q1		$253	$51	$303
1.0%	Contracting & Reprographics	$251	$50	20%	$301	0.7%	$253	$51	$303	2013Q1		$253	$51	$303
1.0%	Engineering During Construction	$251	$50	20%	$301	0.7%	$253	$51	$303	2013Q2	0.4%	$254	$51	$305
1.0%	Planning During Construction	$251	$50	20%	$301	0.7%	$253	$51	$303	2013Q2	0.4%	$254	$51	$305
1.0%	Project Operations	$251	$50	20%	$301	0.7%	$253	$51	$303	2013Q1		$253	$51	$303
31	CONSTRUCTION MANAGEMENT													
4.0%	Construction Management	$1,003	$201	20%	$1,204	0.7%	$1,010	$202	$1,212	2013Q2	0.4%	$1,014	$203	$1,217
2.0%	Project Operation:	$501	$100	20%	$601	0.7%	$505	$101	$606	2013Q2	0.4%	$507	$101	$608
2.0%	Project Management	$501	$100	20%	$601	0.7%	$505	$101	$606	2013Q2	0.4%	$507	$101	$608
	CONTRACT COST TOTALS:	$33,834	$6,767		**$40,600**		$34,128	$6,826	$40,954			$34,536	$6,907	**$41,443**

6.0 POTENTIAL ENVIRONMENTAL EFFECTS

The Corps previously assessed potential effects associated with the proposed bluff stabilization project in the Technical Report (USACE 2006b). The findings of the Corps report are based on the potential effects of the PND concept design (PND 2003). The tentatively selected design concept has a smaller overall footprint than the PND concept due to the elimination of the trail on the revetment, so the potential effects are assumed to apply conservatively to the current design. The total project footprint below the regulatory high water elevation of 19.1 feet MLLW is 5.8 acres. An additional 3.4 acres of the total, permanent project footprint is below the regulatory high tide elevation of 25.2 feet MLLW. A temporary staging area of 12.2 acres is included along the toe of the bluff to allow for water-based rock placement.

The proposed construction sequence is provided as Attachment F, and the proposed schedule is presented in Appendix H. The proposed construction sequencing and schedule will be further coordinated with jurisdictional agencies to determine suitable construction windows to minimize adverse effects on marine mammals (e.g., whale migration), as well as on birds and other wildlife. Adjustments to the construction schedule are anticipated in order to comply with required windows. Table 9 summarizes anticipated potential effects of the draft design on each of the components described in Chapter 2 *Existing Environment*. Figure 14 shows the jurisdictional boundaries applicable to the Kenai River area (KRC 2009).

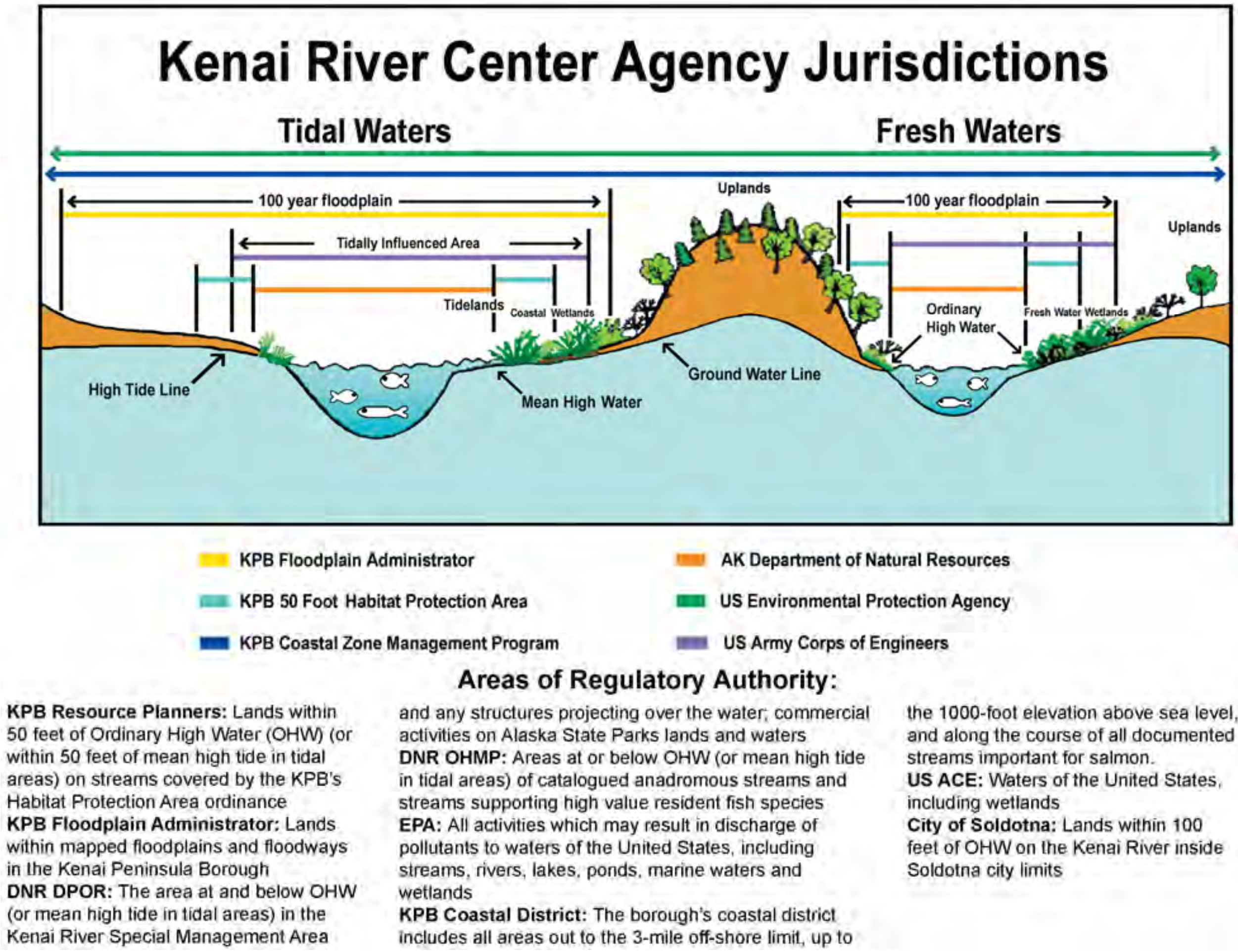

Figure 14. Agency Jurisdictions for Permitting (KRC 2009)

Table 9. Potential Effects of the Selected Alternative

Affected Environment Component	Potential Effects of Proposed Project
Climate	Negligible effect
Tides	Negligible effect
Coastal Currents	Negligible effect
Wind	Under proposed condition, the bluff area will include vegetation that, when fully established, will provide a wind buffer in the immediate vicinity of the edge of the bluff and potentially reduce wind erosion of bluff sediments. Larger-scale wind patterns are not likely to be affected.
Wave Climate	Some changes in the wave reflection patterns are anticipated due to the modified alignment of the revetment. The revetment face alignment is generally smoother than the existing bluff line, which reduces concentrated wave attacks that are caused by existing protruding points. The proposed armor gradation and revetment slope allow more wave energy dissipation (and thus less reflection) than the existing overconsolidated till layer. As a result, some reduction in wave and boat wake reflection would be anticipated as a result of the project.
Kenai River Hydrology	Negligible effect (see Overland Drainage for localized hydrological effects)
Kenai River Hydraulics	Negligible effect. The Corps Technical Report (USACE 2006b) found that the tidal backwater boundary condition masks any measurable effect of the project encroachment on Kenai River water surface elevations or river currents.
Kenai River Morphology	Bank migration to the north will be halted by the proposed design for approximately one river mile. The bluff retreat appears to be a function of localized erosion rather than large-scale bend widening or long-term adjustment of river meanders. As such, no significant effect on the river morphology is anticipated outside of the immediate project area.
Kenai River Sediment Transport	The sediment previously supplied to the Kenai River and Cook Inlet from the eroding bluff will be substantially eliminated under project conditions. The Sediment Impact Analysis in the Corps Technical Report found the effect of eliminating this sediment load to be minor relative to the overall sediment transport load in the Kenai River (USACE 2006b).
Longshore Sediment Transport	Negligible effect. The Corps Technical Report found that the dunes at the estuary mouth are primarily fed by longshore currents and wave action. Changes in longshore sediment

Affected Environment Component	Potential Effects of Proposed Project
	transport resulting from the project are not expected to be significant. Longshore sediment transport generally bypasses the inlet area, and the project would be unlikely to adversely affect the dunes at the river mouth, the intertidal zone in front of the dunes, or the water treatment plant (USACE 2006b).
Overland Drainage	Urban runoff that previously drained directly to the Kenai River over the bluff will be rerouted into the City storm drain network or concentrated and diverted into drainage swales. The rerouted flows will not significantly affect Kenai River hydrology or hydraulics.
Ice	Negligible effect
Geology/Soils	Negligible effect. Geotechnical analyses show the existing slope to be stable under normal conditions; the proposed slope will exhibit increased stability in seismic events.
Hydrogeology	No significant effect on the groundwater table elevation. The gradation of material proposed as fill against the till layer allows free drainage, preventing damming effects that would otherwise result from lower permeability material (raising the water table and pore pressures). The proposed project does not include mechanical dewatering or other features that would lower the water table. The discharge that currently seeps out of the bluff at the seepage interface in the lag gravel layer will remain subsurface along the bluff and seep through the filter under the revetment; although the flow paths will change, no significant effect is expected on the total discharge rate seeping out of the bluff.
Water Quality	Some additional groundwater filtering would occur due to the lengthened flow path under the proposed project configuration. Storm water runoff that currently drains directly to the Kenai River may receive supplemental treatment in settling basins or other BMP’s associated with the project prior to discharge into the Kenai River, potentially improving the stormwater quality. Some coordination may be required under the Clean Water Act.
Sediment Quality	No significant effect on sediment quality. Any contaminated sediments encountered during excavation activities will be removed from the site and/or treated according to specifications for sediment quality.
HTRW	BMP’s and other preventive measures will be implemented prior to, during and following construction to prevent adverse effects related to HTRW issues. Additional data collection is required to establish the baseline HTRW condition. The presence of HTRW materials would add costs to the project not currently accounted for.

Affected Environment Component	Potential Effects of Proposed Project
Aquatic Habitat and Wetlands	The Corps Technical Report assessed potential impacts to aquatic habitat and wetlands resulting from the project (USACE 2006b). Adverse impacts to the riparian zones adjacent to Ryan's Creek and Cemetery Creek are minimized with the selected project footprint; however, there will be some disturbance of these areas from construction equipment, particularly where the revetment is keyed into the toe of the existing hillside. There is also a potential for direct and indirect loss of habitat in the intertidal area from construction activities and placement of rock. A detailed wetland delineation is required to more accurately assess impacts; the Corps will be evaluating the potential effects. The analysis of impacts should account for the change in habitat use of the bluff face, particularly during establishment of vegetation, for species that currently use the bluff face or toe area. The analysis should also account for changes to aquatic habitats, including depths, velocities, and substrate types.
Fish and Wildlife	There is the potential for direct and indirect loss of habitat from stabilization of the bank. Direct habitat loss would occur by placing riprap in the intertidal area and also result in a loss of potential nesting habitat for swallows if the bank grade is altered. The Corps Technical Report assessed potential impacts to fish and wildlife resulting from the project (USACE 2006b). The report concluded that some short-term disturbance and displacement of birds is likely during certain construction phases, but that many adverse impacts could be avoided by setting construction windows with proper timing to avoid nesting or other critical periods. At low tides, gulls, eagles, shorebirds and ducks forage on the intertidal mudflats below the toe of the proposed project. Since most bird usage occurs outside the project footprint, the Corps' assessment concluded that the project is not expected to affect the dunes or opposite shoreline. The project may not negatively affect birds in the long term. Seals foraging in the river mouth may be disturbed by construction activities. Since the toe of the revetment will be above the water line except for high tides, the long-term effects to fish and aquatic species are likely to be minimal. Some spruce trees at the top of the bluff that bald eagles currently use for perching would be lost in the short term as the bank is cut back; however, in the long term, the project prevents further bluff erosion that would lead to the loss of additional trees. Because the existing slope is largely unvegetated, once vegetation has fully established under proposed conditions, an

Affected Environment Component	Potential Effects of Proposed Project
	increase in habitat value is anticipated for wildlife species in the area. Construction activities may have short-term effects on gull nesting or other uses on the opposite bank. Intertidal areas where shorebirds forage for prey to fuel their migration to breeding grounds may be affected. Eagles perching along the bank of the inside bend wetlands could also be disturbed by construction activities. Additional coordination may be required under the National Environmental Policy Act, Coastal Zone Management Act, and Fish and Wildlife Coordination Act.
Threatened and Endangered Species	Further evaluation of listed species is required to assess the affected environment and collect data that would support a Biological Assessment (BA). Additional coordination may be required under the Endangered Species Act
Cultural Resources	By stabilizing the bluff, the project preserves cultural resources that otherwise might be threatened by continued bluff erosion. The remains of two archaeological sites and four structures eligible for the National Register of Historic could be impacted by continued erosion during the project's period of analysis. Additional studies of other impacted structures (see Real Estate) may be warranted to determine historical significance. Additional data collection is required to document the existing cultural resources that fall inside the project footprint. Effects of the project on cultural resources will be minimized, but cannot be ascertained, quantified, or mitigated until further data collection is completed. The effects of the project on cultural resources in the area will be further analyzed pending additional documentation of the existing cultural resources within the project footprint, including documentation of coordination under the National Historic Preservation Act.
Economy	The project is expected to improve the economy of the area by removing an uncertainty for city planners. The stabilized slope is expected to result in increased property values for parcels along the bluff as well as additional parcels further inland that would benefit from increased stability. The Corps Technical Report (USACE 2006b) quantified economic impacts of the project. The Corps Reconnaissance Report documented groundings, collisions, delays, fish catch degradation, and other issues related to navigation. The proposed project is not expected to improve navigation.
Recreational Use	Recreational use may increase as a result of the project if recreational features are added to

Affected Environment Component	Potential Effects of Proposed Project
	the project configuration. Any increase in use must be accompanied by the appropriate infrastructure such as fencing, trash receptacles, and toilet facilities to minimize impacts of additional recreational traffic. It is difficult to predict the degree of disturbance that may arise from construction. In summer months, there is generally a large amount of boat traffic near the mouth of the Kenai from both commercial and recreational boaters. The degree of disturbance from construction is unknown. Disturbances may result from the type and duration of the noise produced from construction.
Land Use	Negligible effect. The project is not expected to affect overall land use in the area in terms of residential and commercial zoning. In coordination with the City of Kenai, zoning regulation may be developed to include an easement restricting future development within the immediate vicinity of the top of the bluff.
Real Estate	The project will involve acquisition of some parcels and condemnation, demolition, and removal of some structures. Approximately 16 structures are affected, including residential structures, sheds, detached garages, and bungalows. The configuration of the selected project seeks to minimize encroachment of the existing project on affected parcels. Though prediction of with-project condition land values is difficult, there is no doubt that the attractiveness of the land will increase dramatically resulting in additional value and added benefits to the project. The Corps Technical Report quantified the benefits to property nearby the bank. In addition to the affected structures, the projected without-project erosion rate shows approximately 30 structures susceptible to bluff erosion during the time period equivalent to the project life. The benefits from a project that stops the existing erosion problems are the increased value of land and resale ability and eliminating the elimiation of the need to relocate buildings and utility lines.

7.0 CONCLUSIONS

This report presents the design considerations for the Kenai Bluff Stabilization Project and summarizes the alternative development and selection process. The proposed design is based on the results of analyses of available information as documented in Attachment A.

7.1 Summary of Findings

The stability of the bluff was evaluated both qualitatively by field observations, and quantitatively with analytical methods. The qualitative evaluation of the slope stability was primarily based on observation of the existing areas of the bluff which are not currently subject to active toe erosion. Specifically the areas at the west end of the bluff in the vicinity of Cemetery Creek, and the slopes at the mouth of Ryan’s Creek were studied. These natural slopes appear to have stabilized and become vegetated at angles of about 1.5:1 (H:V). Based on these observations and as confirmed by additional slope stability modeling, it was concluded that the bluff regraded to 1.5:1 (H:V) or flatter will be stable with respect to global failures, absent further erosion of the toe. Surficial stability and resistance to erosion is expected to be greatly enhanced once vegetation is established on the regraded slope face. The placement of topsoil and a high performance erosion control mat/fabric is included to speed the greening process.

A layer of granular soil covering the seepage area at the base of the alluvial deposit is expected to keep the groundwater in the subsurface for most of the year, and the establishment of vegetation on the slope face will reduce the risk of erosion of the slope face during heavy rainfall, and spring breakup.

The design approach presented in this report, with armor rock at the toe, earthwork balanced and groundwater runoff collected in the alluvial fill material, was identified as the optimal project configuration in terms of balancing costs against impacts while maintaining functionality. The Kenai Bluff Stabilization Project would effectively halt further erosion of the Kenai River bluff for an approximate construction cost of $31 million and a total implementation cost of $41 million. Additional benefits of the project are not quantified in this study. Adverse environmental impacts are not anticipated to be significant in the long-term; however, there will be some limited environmental impacts during construction activities. Further environmental coordination is required as the project design proceeds.

7.2 Recommendations

Supplemental information pertaining to the existing condition, the proposed solution, or associated impacts will allow further development of the design. It is anticipated that the following information will be needed to complete the Kenai Bluff Stabilization Project Final Design and Specifications, and to support future permit applications in preparation for construction:

- *Topographic Survey*. Updated topographic survey and aerial photography of the project area was acquired in November 2007, with additional orthophotography acquired in October 2010. Cultural resources, environmental resources, and other features that fall within the project footprint may be surveyed and added to the base mapping as the project proceeds and additional baseline data become available. Project topography and datums are suitable for construction-level documents; however, the top of the bluff should be resurveyed prior to any construction work to document ongoing bluff erosion.

- *Utility Inventory*. Locations of existing infrastructure, overhead lines, pipelines, and other buried utilities were estimated but not field-verified during the Design development. These utilities can be located in the field through the Alaska Dig Line one-call service at (907) 278-3121 and subsequently incorporated into the project survey data.

- *FEMA Coordination.* The hydraulic analysis has shown that the project is unlikely to have an effect on the flood elevations due to the coastal storm backwater boundary condition. As such, coordination efforts with FEMA should be simplified; however, project implementation will result in a permanent structure that affects the spatial extent of the floodplain boundary, and some coordination with FEMA is be required to provide the conditional delineation.

- *Storm Water Analysis*. Field investigations should be conducted to delineate sources of storm water runoff, quantify the anticipated runoff, document the baseline water quality, determine existing flow paths, and assess the feasibility of routing storm water from the top of the bluff into the City storm drain network. These efforts must be coordinated with the City of Kenai and the Kenai Watershed Forum.

- *Construction Sequence and Equipment List*. Future permitting will likely require analysis of the impacts from the proposed construction equipment. A proposed construction sequence is included in Attachment F with a construction schedule and equipment list provided in Attachment H; however, any changes to the proposed construction approach, including contractor recommendations, should be coordinated with permit submittals.

- *Permitting.* Federal participation in the project requires evaluation under the Clean Water Act, National Historic Preservation Act, National Environmental Policy Act, Coastal Zone Management Act, Essential Fish Habitat, Endangered Species Act, and Fish and Wildlife Coordination Act (USACE 2006b). Additional environmental data will be required to support these permitting processes, including determination of whether the project will require an Environmental Impact Statement (EIS) or an Environmental Assessment (EA). Agency jurisdictions are presented in Chapter 6.

- *Recreational Analysis*. Coordination will be required between stakeholders to prevent site access except in designated, fenced, accessible areas. Recreational features and access should be coordinated with any relevant City of Kenai master plan features. Any proposed recreational features should be evaluated for compatibility with proposed project purposes and for potential impacts to project performance and project life.

- *Real Estate Agreements*. Prior to construction a real estate agreement should be completed with all affected parcel owners identifying all rights of way, access points, temporary construction easements, and permanent easements related to the project.

- *Operation and Maintenance Agreement*. Prior to construction, agreement on responsibilities for monitoring and operation, maintenance, repair, replacement, and rehabilitation (OMRRR) activities should be reached between all stakeholders.

- *Archeological Survey*. Prior to construction, historical buildings and areas with archeological value should be identified. The effects of the project on these sites and the relocation potential of historical buildings and resources should be assessed.

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ATTACHMENTS

ATTACHMENT A: PREVIOUS STUDIES

Narrative Summary of Relevant Previous Studies

A number of studies and other efforts have been undertaken to investigate and assess the bluff erosion problem at Kenai, develop measures to protect the bluff from continuing erosion, and evaluate potential environmental effects from proposed protection measures. These previous studies span over 25 years and were conducted by the Corps of Engineers, the City of Kenai, the University of Alaska, and others. Results and recommendations are summarized below for relevant documents pertaining to studies in the Kenai area spanning the period from 1982 through 2007.

Estimated Bluff Erosion Rate and Effects

In a 2001 study, the University of Alaska Anchorage (UAA 2001) documented that between 50 and 100 feet of lateral erosion had occurred during the period 1976 to 1999, yielding an average annual bank retreat rate of approximately 3 feet per year. In a Corps study released in 2006 (USACE 2006b), the Corps concluded that the UAA estimate was conservative, and suggested that a more realistic estimate of the historical rate would be 1.2 feet per year. The Corps report reasoned that during the period of time analyzed in the UAA report, the study area experienced higher than normal erosion. An extrapolation of either rate into the future shows the top of bluff reaching several structures and utilities within the City of Kenai over the next decade.

- The 2001 UAA study reported that the bluffs contribute approximately 51,000 tons of sediment to the Kenai River each year, representing approximately 7% of the sediment load in the river.
- A Sediment Impact Assessment conducted by ERDC in 2004, as reported by the Corps, found that a total of approximately 21,000 tons of sediment was eroding from the bluff annually, representing approximately 5% of the total sediment load in the Kenai River (USACE 2006b).
- The Corps (2006b) also estimated that the average annual capital loss due to the bluff erosion was about $150,000.

Factors Contributing to the Bluff Erosion

All previous studies concurred that the factors contributing to the bluff erosion include: (a) wave action undermining the bluff toe; (b) groundwater from the surrounding area flowing through the bluff face; (c) overland or surface flow; (d) wind action eroding the face of the bluff; and (e) tidal and river currents carrying away sloughed and eroded material. There is no concurrence among previous studies, however, as to the relative importance of each of these factors. For example, the 2001 UAA study found the bluff erosion to be primarily associated with extreme high tides and wave action, and that the influence of river currents was less, and indirect (UAA 2001). The 2006 Corps study (USACE 2006b) pointed to additional findings by Scott (1982), Barrick (1984), Inghram (1985), Reckendorf (1989), and Reckendorf and Saele (1993) that documented anthropogenic (human) factors such as loss of bank vegetation, streamside use, boat wakes, and improperly designed erosion control practices as important contributing factors.

Several mechanisms of bank loss were noted in the Corps' Sediment Impact Assessment. Bank failure in the stiff clay in the lower layer was characterized by wave erosion retreat at the toe, freeze/thaw action, and block failures associated with poor internal drainage. The till soils in the upper layer are subject to dry soil fall, aeolian transport, freeze/thaw, rilling, and piping, which results in shallow translational failures and soil fall when the lower layer fails (USACE 2006b).

The 2002 PND concept report reported that the historical Kenai River thalweg appeared to remain relatively constant over time, and that a shifting river thalweg was, therefore, not a significant contributor to the bluff erosion.

Previously Proposed Solutions

A number of potential solutions to the bluff erosion at Kenai have been proposed in previous studies, as discussed below.

Tippetts, Abbett, McCarthy, Stratton (TAMS), 1982. A 1982 bluff erosion study by TAMS presented a range of alternative concept designs and preliminary cost estimates for addressing the bluff erosion. One proposed design involved installing a cutoff wall with wells and pumps, and excavating the slope to a 1.25H:1V vegetated slope with a collector pipe at the sand/silt interface. An alternative design involved constructing a vertical sheet pile bulkhead and layered rock armoring at a 1H:2V slope. Constructing a 24’ roadway with a 10’ walkway was also considered in the alternatives.

Peratrovich, Nottingham, & Drage (PN&D), 2002. PN&D proposed a design solution in their February 2002 report that involved cutting the upper slope of the bluff back to a 1.5H:1V vegetated slope, and constructing a layered armoring system at a 1.5H:1V slope along the lower portion of the bluff face, and constructing a 200’ span bridge across Cemetery Creek at the Kenai Dunes Park. The proposed design also included constructing a bench across the bluff face for seepage control that included a 12’ wide paved recreation trail.

In addition to the above two concept design solutions, other previous studies have proposed regulatory solutions such as limiting public access to the dunes, regulating land use in the vicinity of the top of the bluff, promoting vegetation for erosion control, and controlling surface water flows (USACE 2006b and UAA 2001).

Potential Effects of Previously Proposed Solutions

Local stakeholders and agencies commented on the PN&D concept design (City of Kenai 2002). In general, the stakeholders expressed the need to have further analysis of potential effects on the Kenai Flats area located across from the eroding bluff. Another major concern was the environmental effect associated with bringing a large number of people onto the proposed recreation trail along the bluff face.

The 2001 UAA erosion study evaluated longshore, river, tidal, and wave-induced sediment transport forces under existing conditions and conditions based on the 2000 PN&D draft concept design. The report found that the predicted effects on future erosion trends would likely be relatively minor. However, the trampling of dune vegetation by human visitors encouraged by the trail and bridge was likely to present a serious threat to the Kenai Dunes.

The Corps Technical Report (2006b) concluded that although stabilization of the Kenai Bluffs would affect the sediment dynamics in the estuary, the overall impact of the reduction in sediment load would likely be minor. A key finding of the report was that changes in the morphology of the tidal flats and dunes were not expected to result from bluff stabilization given the net surplus of sediment in the reach.

Table A-1: Summary of Previous Study Contents and Results

Title	Agency/author	Date	Contents/summary of results
City of Kenai Comprehensive Plan, Public Review Draft	City of Kenai (Kevin Waring Associates, Benson Planning Associates, Bechtol Planning and Development)	February 2003	Summary of existing city infrastructure and plans for future development, downloaded from City website http://www.ci.kenai.ak.us/. Includes GIS plates for existing land use, land ownership, wetlands, floodplains, zoning, roads, water, sewer, and aerial photography.
Draft Bluff Erosion Study, Kenai River Sedimentation Study	City of Kenai (TAMS Engineers)	November 1982	Preliminary costs and quantities for addressing erosion control problems. Includes site photos, topography, and typical sections. According to 905(b) this report identified groundwater seepage from the bluff face as the primary mechanism of bluff erosion and recommended control of this seepage as the first order of work towards bluff stabilization.
Erosion and Sedimentation in the Kenai River, Alaska. Geological Survey Professional Paper 1235	U.S. Geological Survey (Kevin Scott)	1982	Assessment of erosion and sedimentation of the entire Kenai River. Includes an overall assessment of the underlying regional geology and geological processes.
Erosion at the Mouth of the Kenai River, Alaska. Analysis of Sediment Budget with regard to the proposed Kenai Coastal Trail and Erosion Control Project	University of Alaska Anchorage (Orson Smith, William Lee, and Heike Merkel)	April 2001	Evaluation of PND design, including wind speed analysis, longshore transport capacity, streamflow statistics, and river sediment transport data. Report contains a sediment budget analysis with regard to the proposed “Kenai Coastal Trail and Erosion Control Project”, PND January 2000 Draft.
Groundwater Monitoring Report. Kenai River Bluff Erosion	R&M Consultants	January 2008	Results of one year of monthly groundwater monitoring well readings.
Geotechnical Investigation and Site Conditions Report. Kenai River Bluff Erosion	R&M Consultants	February 2007	Laboratory results and summary geotechnical data from November 2006 site investigations and borings along the Kenai Bluff.
Kenai Agency Concerns and Technical Report Responses	USACE, Alaska District, Project Formulation Section	November 2007	Summarizes agency comments received on Draft Technical Report. Outlines responses to concerns based on additional studies.
Kenai Bluff Erosion Project Benthic Invertebrate Sampling Memorandum	USACE Alaska District (Christopher Hoffman)	July 3, 2003	Invertebrate sampling methods and results, includes sampling location map

Title	Agency/author	Date	Contents/summary of results
Kenai Bluff Erosion Project Bird and Marine Mammal Survey Memorandum	USACE Alaska District (Christopher Hoffman)	July 3, 2003	Bird and mammal survey methods and results, including maps of monthly survey results
Kenai Bluff Erosion Project Phase 2 Work Plan Report	Tetra Tech, Inc.	September 5, 2006	Presents recommendations for additional data collection and analyses in preparation for initiating design work.
Kenai Coastal Trail and Erosion Control Project Design Concept Report and Plan Set	City of Kenai (Peratrovich, Nottingham, and Drage, Inc.)	February 2002	This report provides a design concept of bluff stabilization and a pedestrian trail along the bluff. Report includes schematic design, preliminary costs and quantities, preliminary design assumptions for armor sizing, sand budget, slope stabilization, and drainage. Separate attachment includes 12-sheet plan set with plan/profiles, typical sections, typical bridge details, and right of way property plan. Plan set attachment obtained is from January 2000 draft (not obtained for February 2002 final)
Kenai Coastal Trail Memorandum, Summary of Agency Comments	City of Kenai (Keith Kornelis)	October 16 2001	Compilation of agency comments on 2000 PND concept design Includes comments from Corps (regulatory), EPA, DEC, USF&W, State DF&G, NOAA, KBP, State DOT/PF, State DGC, Central Peninsula Counseling
Kenai Coastal Trail Permitting Process, Letter to Keith Kornelis	PND (Dennis Nottingham)	November 15, 2001	Recommended tasks for project permitting process
Kenai River Bank Erosion Technical Report	USACE Alaska District	July 2006	According to 905(b) analysis, "this report assessed environmental resources at the lower Kenai River, identified the mechanisms for bluff erosion, and assessed environmental and hydrogeomorphic consequences of bluff stabilization." Includes project summary, economic evaluation, and maps of affected parcels and utilities. Includes the following technical appendices: Appendix A: Environmental Studies - Invertebrate sampling - Bird and marine mammal survey - Cultural resources - ADF&G baseline fisheries assessment Appendix B: Hydraulics and Hydrology - Tidal datums - Mean daily discharge summary (Kenai River at Soldotna)

Title	Agency/author	Date	Contents/summary of results
			- Estimated design wave - Wind measurements - Estimated volume of eroded material - Estimated groundwater seepage - HEC-RAS results - Groundwater readings from October 2003 and April 2004 Appendix C: Sediment Impact Assessment - Erosion assessment - Sediment analysis Appendix D: Geotechnical Investigation - Laboratory results/gradation and water levels for four boreholes drilled Sep 2003
Kenai River Bluff Erosion Section 905(b) (WRDA 86) Analysis	USACE Alaska District (Colonel Timothy Gallagher)	July 28, 2005	Project summary, funding details, location maps, typical conceptual cross section
Kenai River Bluff Erosion Study Meeting Notes	USACE Alaska District (Patrick Fitzgerald)	July 29, 2002	Agency concerns and information requested
Kenai River Cultural Resources Memorandum	USACE Alaska District	unknown	Includes two maps from 1996 Kenai Townsite Historic District Survey Report. Shows 25 potential sites in project area.
Kenai River Estuary Baseline Fisheries Assessment Regional Information Report No. 2A04-13	Alaska Dept of Fish and Game (T. M. Willette, J. M. Edmundson, R. D. DeCino)	March 2004	Baseline fisheries assessment focused on documenting the fish assemblage and some predator-prey interactions occurring in the Kenai River estuary.
Kenai River Sedimentation Study	City of Kenai (TAMS Engineers)	September 1983	Primarily to support a study of for a proposed harbor upstream of the project site. Pebble counts, grain size distribution
Letter to Keith Kornelis, City Engineer, City of Kenai	Alaska Dept. Fish and Game (Gary Liepitz)	January 31, 2000	Referenced in 2001 Smith report (not obtained)
Reconnaissance Report for Navigation Improvements and Erosion Control, Lower Kenai River	USACE, Alaska District	1997	Discusses findings relative to dredging for navigation improvements and the use of dredge spoils behind a revetment for erosion control. Referenced in 2001 Smith report.

Title	Agency/author	Date	Contents/summary of results
Summary Trip Report	Tetra Tech, Inc.	March 24, 2006	Trip report, including meeting notes, site photos, and newspaper articles for March 2006 site visit and City Council meeting

ATTACHMENT B

HYDROLOGY AND HYDRAULICS

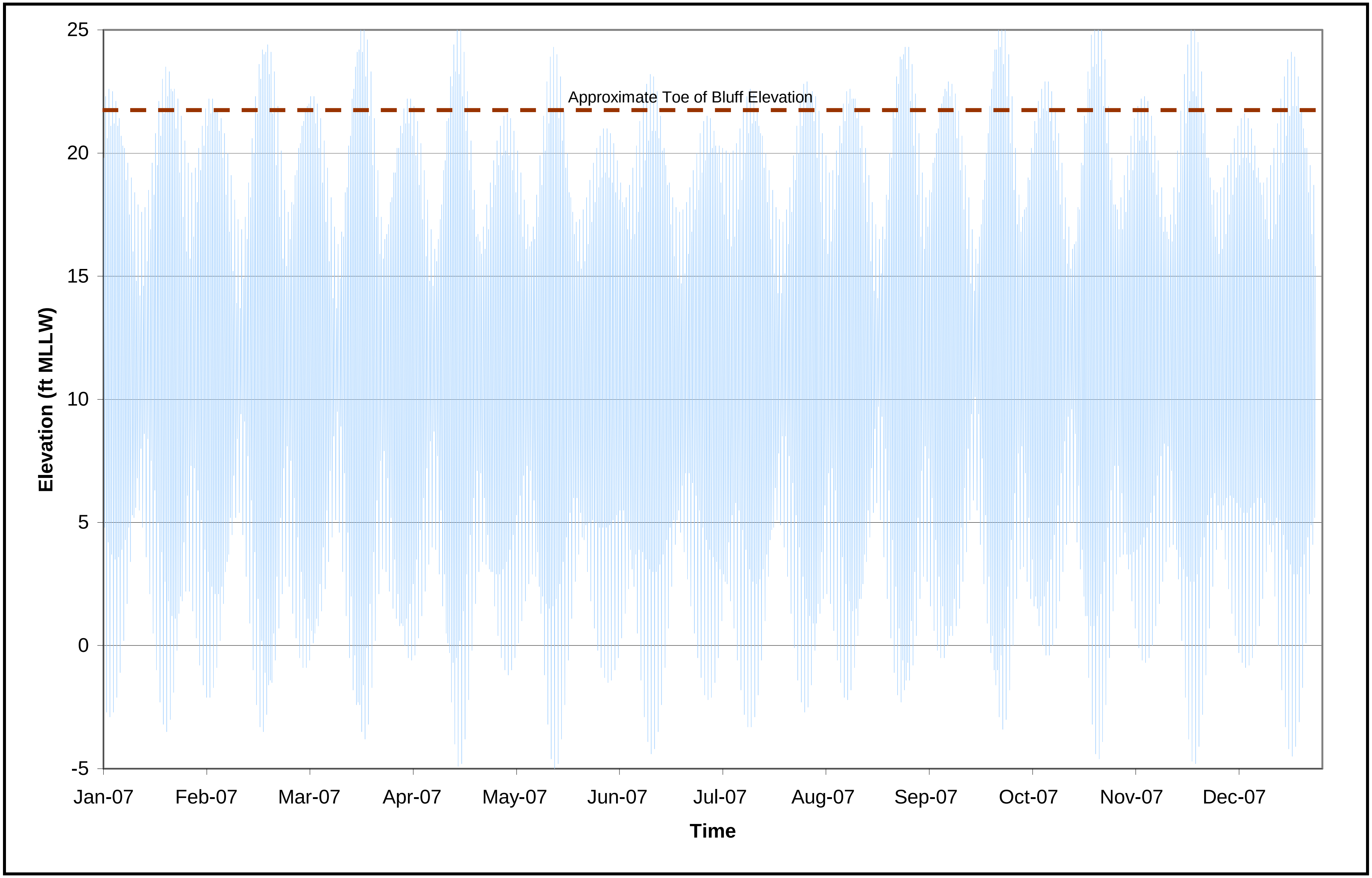


Figure B-1. 2007 Tide Predictions for Kenai River Entrance

Table B-1: Station Metadata for Tidal Data

Station	Lat	Long	Mean Range (ft)	Spring Range (ft)	Mean Tide (ft)	Reference Station	Time Correction	Height Correction
Kenai City Pier	60° 33'	151° 14'	17.5	19.8	10.4	Seldovia	High +1 hr 54 min Low +2 hr 55 min	High +1.9 Low +-0.1
http://tidesandcurrents.noaa.gov/get_predictions.shtml?year=2007&stn=1815+Seldovia&secstn=Kenai+City+Pier&thh=%2B1&thm=54&tlh=%2B2&tlm=55&hh=%2B1.9&hl=-0.1&footnote=								
Kenai River Entrance	60° 33'	151° 17'	17.7	20.7	11.0	Seldovia	High +1 hr 52 min Low +2 hr 18 min	High +2.7, Low +0.5
http://tidesandcurrents.noaa.gov/get_predictions.shtml?year=2007&stn=1815+Seldovia&secstn=Kenai+River+entrance&thh=%2b1&thm=52&tlh=%2b2&tlm=18&hh=%2b2.7&hl=%2b0.5&footnote=								

Table B-2: Tidal Datums for Nikiski (Station 9455760)

Tidal Datum	Elevation (ft MLLW)
Highest Observed Water Level (12/26/1976)	29.02
Mean Higher High Water	20.42
Mean High Water	19.68
Mean Sea Level	11.18
Mean Tide Level	10.86
NAVD 1988	6.76
Mean Low Water	2.05
Mean Lower Low Water	0.00
Lowest Observed Water Level (12/25/1999)	-6.37

Tidal Datum Notes: Nikiski data are based on 1983-2001 Tidal Epoch, with no NGVD29 orthometric height for AB7146. Kenai MLLW datum is based on 2003 data with US C&GS Kenai Cook Inlet Tidal Bench Mark 3 (1966) at Elevation 31.44 feet. The available datum information from NOAA is presented for the two Kenai tidal stations below. Additional corrections were applied to reference the tidal bench mark to the Nikiski Tidal Bench Mark in March 2008, resulting in a net correction factor of -0.26 feet. Project vertical datum is referenced to Mean Lower Low Water (MLLW) based on NOAA Tidal Station Nikiski, Station ID No. 945 5760, publication date 10/30/2003. Station Nikiski is referenced by BM No. 8, et al., which was held for all project elevations (BM No. 8 elevation was verified by measurements to BM Nos. 7 & 9). The official station designation for BM No. 8 is "945 5760 TIDAL 8" (see PID No. AB7150). NOAA MLLW elevation for BM No. 8 = 109.659 U.S. Survey Feet (33.424 meters).

NOS ID	1983	Name	Kenai River entrance, Cook Inlet, Alaska
SEQ	0	Common Name	

Latitude	60	33.00	North	T. M. 135.00	T. M. Corr.	0.00 Hrs.
Longitude	151	17.00	West	T. Z. 9.00	Reference ID	9455500

Greenwich Int.

HWI	1307
LWI	712
HHWI	
LLWI	
MRI	1010
LI	1026

Time Diff.

HW	152
LW	218
HHW	
LLW	
Mean	205
DR	555

Height Diff.

HW	2.70
LW	0.50
HHW	
LLW	

Ratios

HW	0.00	Sp/Mn	0.00
LW	0.00	Np/Mn	0.00

Levels (ft.)

HAT	
TcHHW	
HHW	20.70
HWS	
HW	19.90
HWN	
MTL	11.00
MSL	
DTL	10.30
LWN	
LW	2.20
LWS	
LLW	0.00
TcLLW	
LAT	

Local Int.

HWI	241
LWI	911
HHWI	
LLWI	

Ranges

Mean	17.70	Neap	
Spring		Gc	-100
Gt	20.70	DATUM	MLLW
DHQ	0.80	DLQ	2.20

Source: Acc. values for Chinulna Pt. near Kenai R. entr. 159 H-158 L, 1910.

Benchmark Date		Source Year	1910
NGVD	(MLLW)	Source Length	0 Yr(s). 0 Month(s)
Estimated Low	-6 ft. below MLLW	Tide Table	WCTT

Remarks: Name, Lat, long. changed in 1938. T.M. changed 10-30-83.

Epoch -

Ratio of Ranges		First used in T.T.		By: WBZ	6/8/1936 00:00:00
Mn.	0.00	Last used in T.T.		Entered: ML	2/22/1993 00:00:00
Gt.	0.00	Lastr revised in T.T.	1985	Verified:	

Table B-3: Station Metadata for Rainfall, Streamflow, and Climatological Data

Parameter	**Source**	**Metadata**
Tides		
Precipitation	http://www.wrci.dri.edu	NCDC Station Historical Listing for NWS Coop #504550-5 KENAI 9 N, ALASKA Lat 60 deg 40 min, Long 115 deg 19 min Elev. 130 ft Period of record 6/83 to present. NCDC Station Historical Listing for NWS Coop #504546-5 KENAI FAA AIRPORT, ALASKA Lat 60 deg 34 min, Long 115 deg 15 min Elev. 90 ft Period of record 9/49 to present
Runoff	http://waterdata.usgs.gov	USGS Gage 15266300 Kenai River at Soldotna. Hydrologic Unit 19020302 NAD27 Latitude 60°28'39" Longitude 151°04'46" Period of record 5/1/65 – present. Drainage area: 1,951 square miles Datum of gage: 35.34 feet above sea level NGVD29.
Temperature	http://www.wrci.dri.edu	NCDC Station Historical Listing for NWS Coop #504550-5 KENAI 9 N, ALASKA Lat 60 deg 40 min, Long 115 deg 19 min Elev. 130 ft Period of record 6/83 to present. NCDC Station Historical Listing for NWS Coop #504546-5 KENAI FAA AIRPORT, ALASKA Lat 60 deg 34 min, Long 115 deg 15 min Elev. 90 ft Period of record 9/49 to present
Wind Speed	http://weather.noaa.gov	ICAO Station ID PAEN. Latitude 60°34'23" N Longitude 151°14'42" W Elev. 99 ft ASOS Tower, Height 25 ft NCDC Data Set 702590

Note: Project measurements are based on Nikiski benchmark NO 8 1973 (NOAA designation 945 5760 TIDAL 8). Corrections were made was to Kenai BM No. 3 and any data that was based on Kenai BM No. 3.

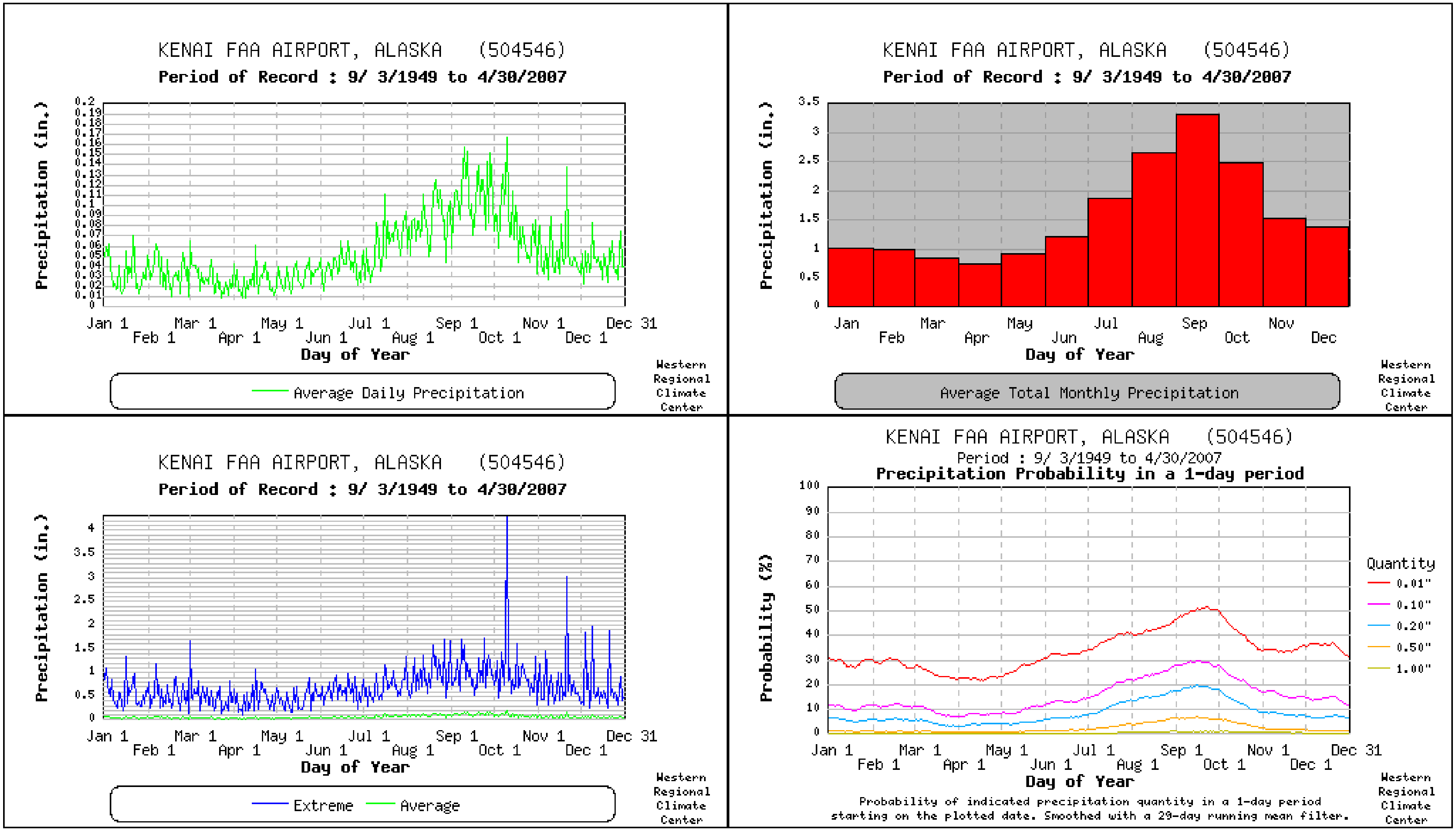


Figure B-2. Historical Precipitation Records and Statistics for Kenai Airport (WRCC 2007)

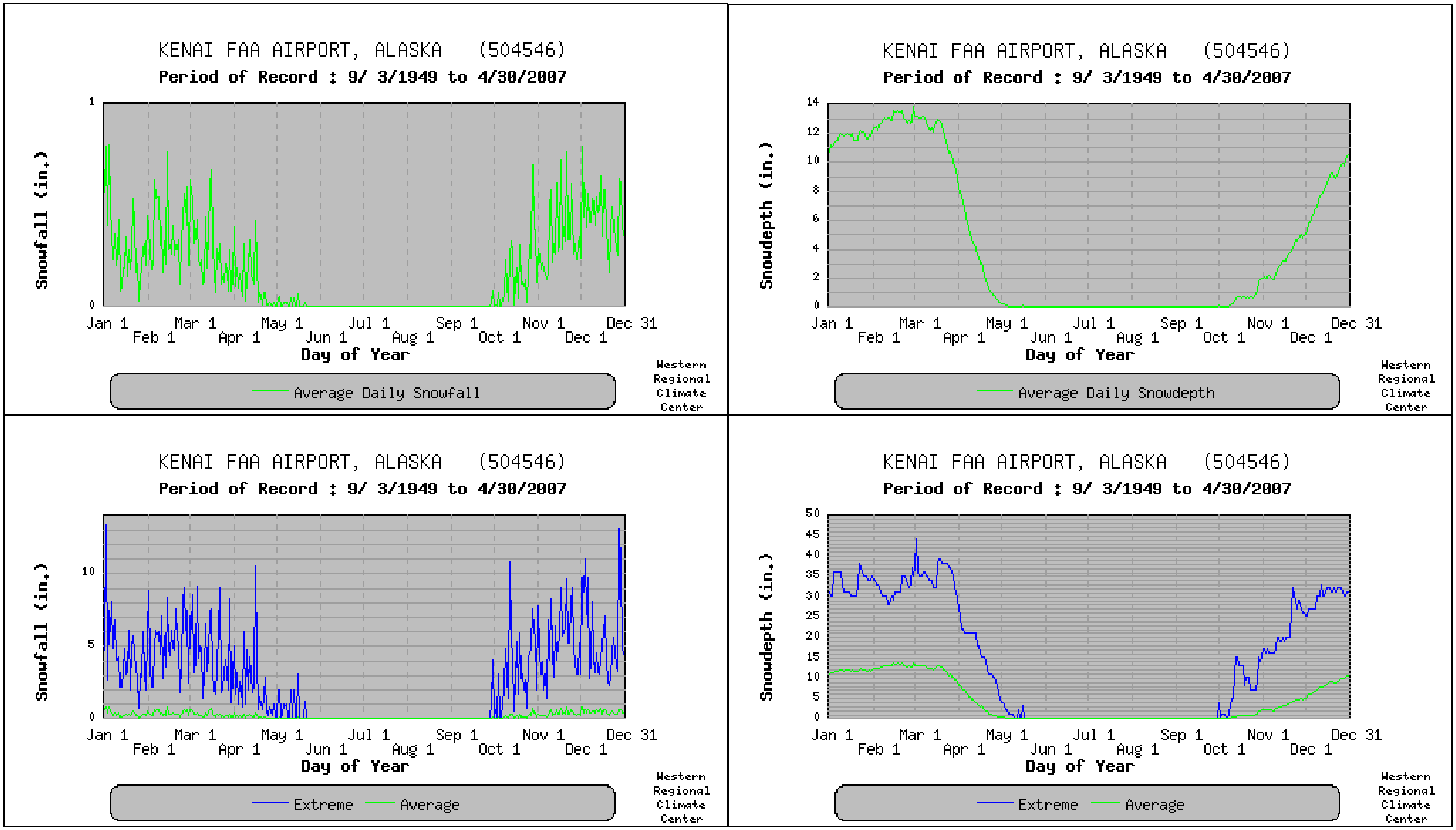
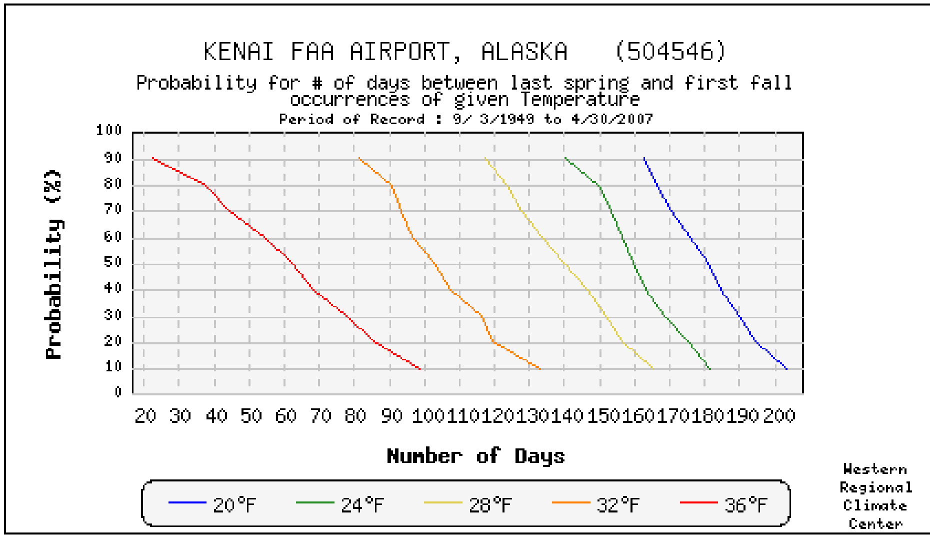


Figure B-3. Historical Snowfall Records and Statistics for Kenai Airport (WRCC 2007)



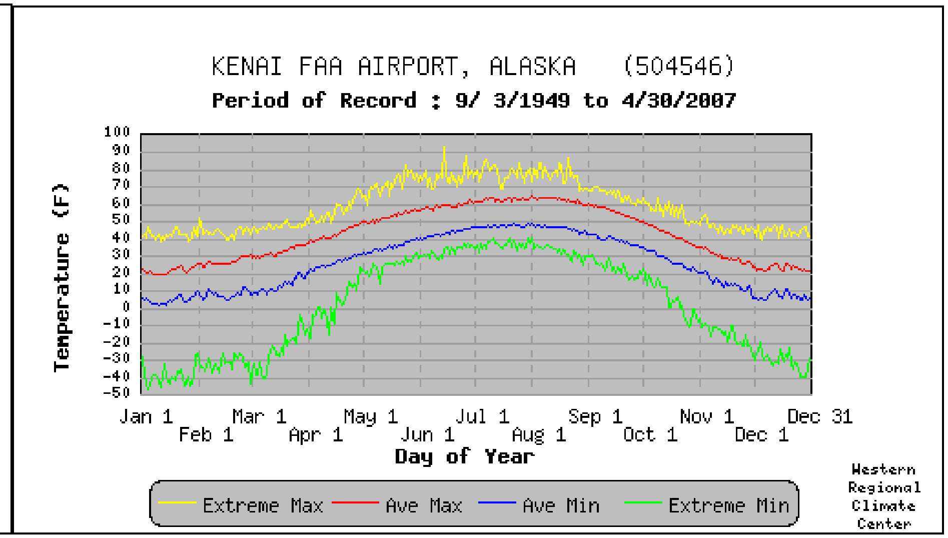


Figure B-4. Historical Temperature Records and Statistics for Kenai Airport (WRCC 2007)

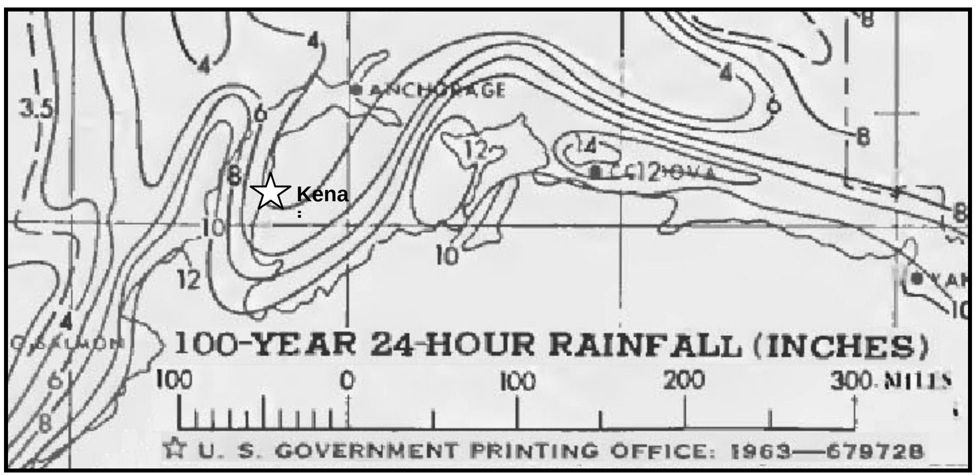


Figure B-5. Isopluvial Map (USGS 2003)

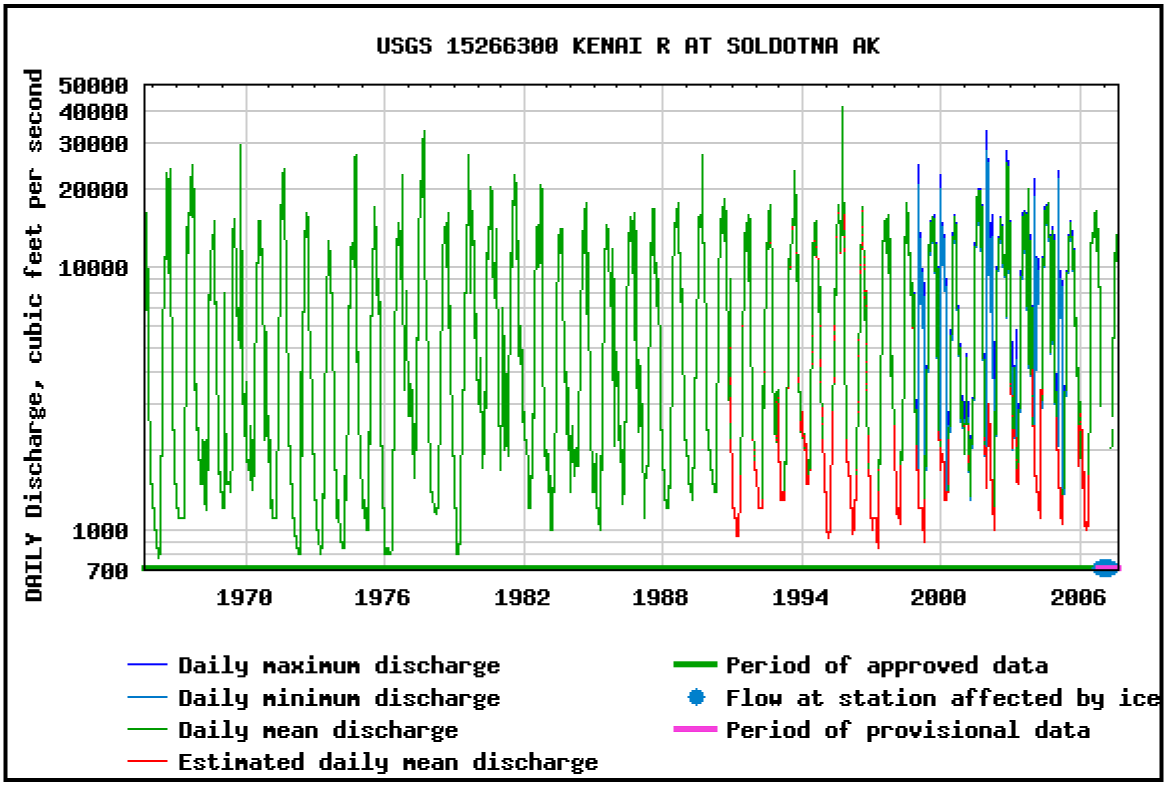


Figure B-6. Kenai River Historical Flow Records (USGS 2007)

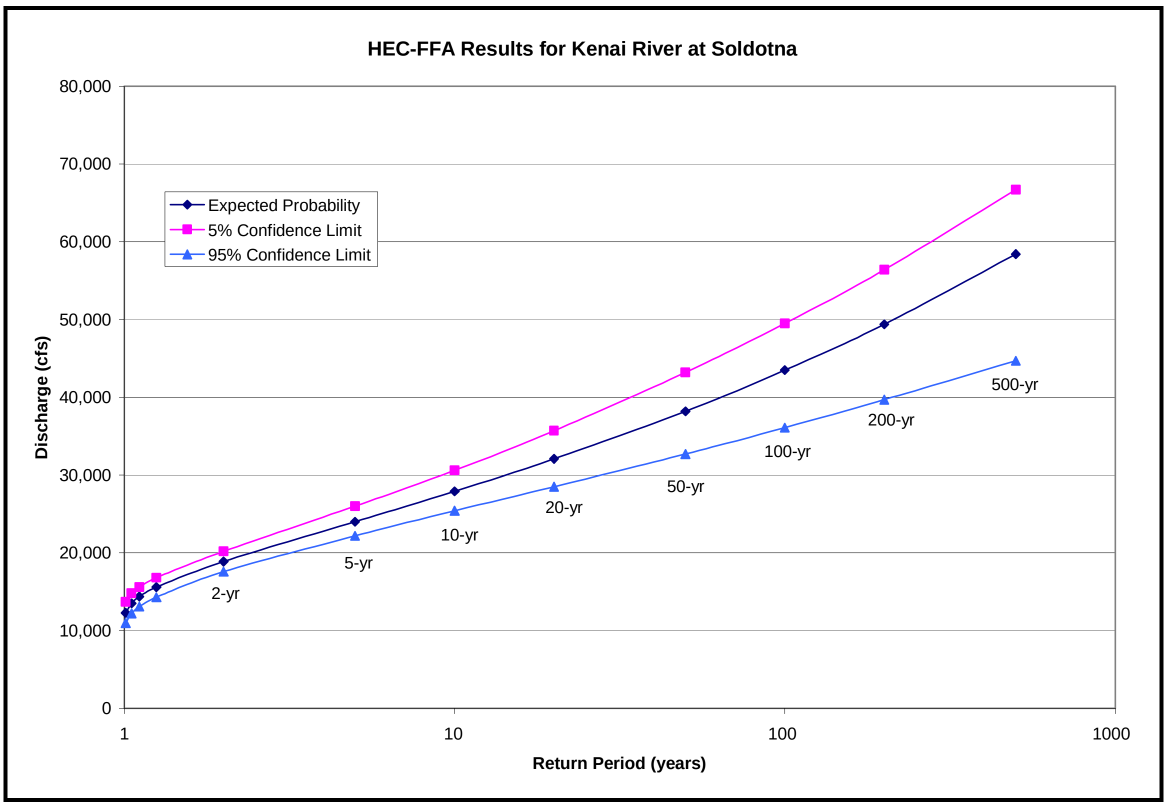


Figure B-7. Kenai River Flood Frequency Analysis (USGS 2007)

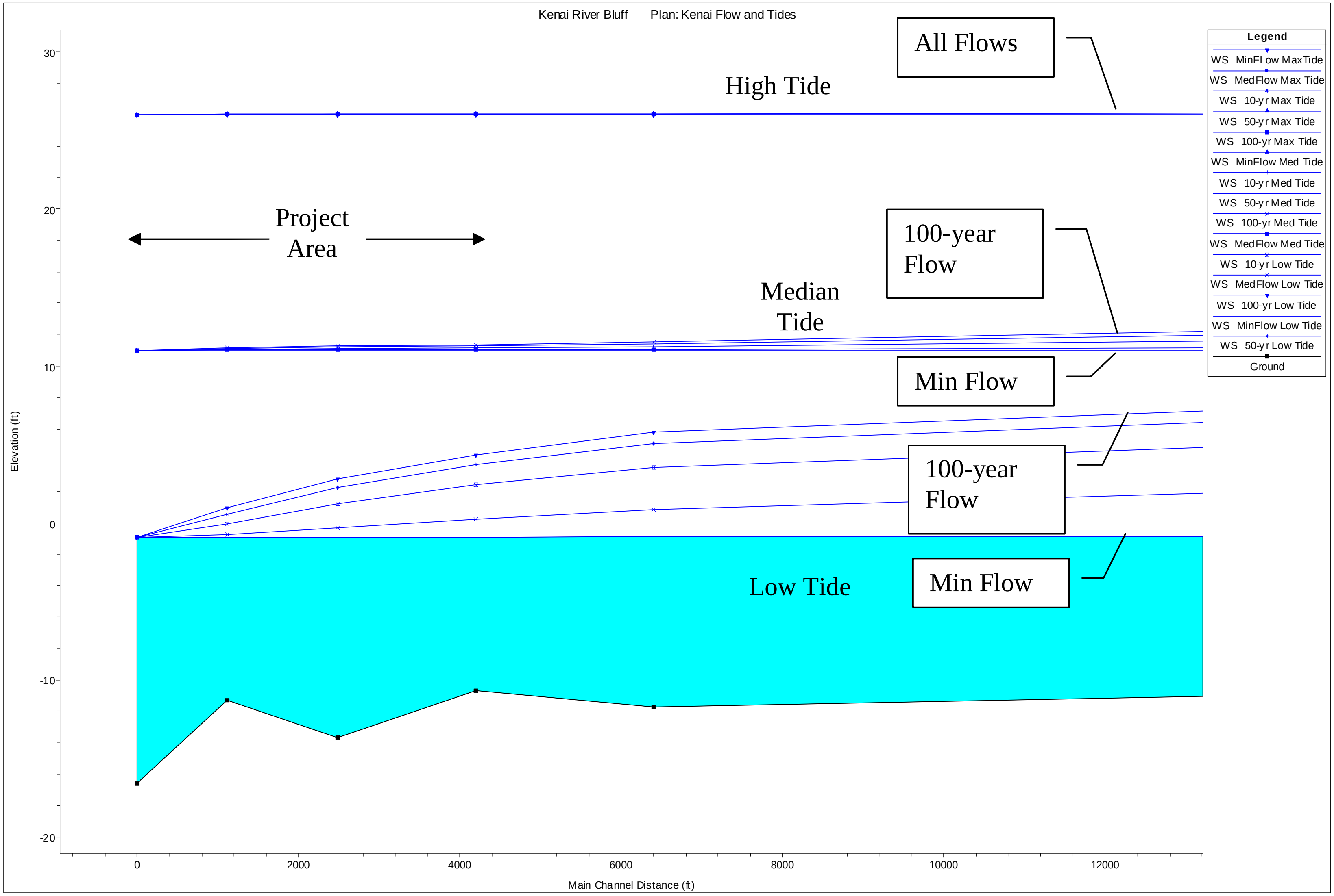


Figure B-8. HEC-RAS Profiles

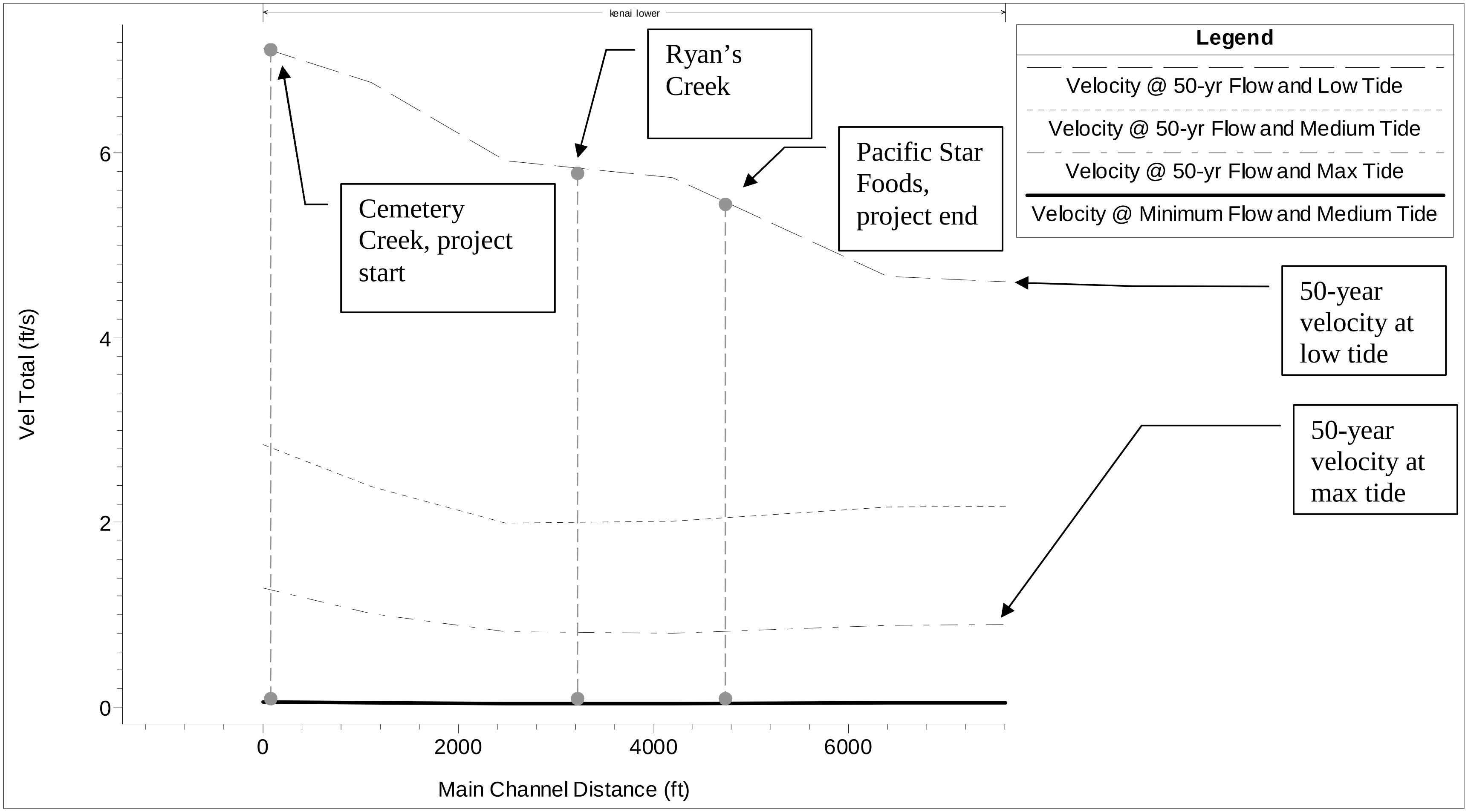


Figure B-9. Kenai River Velocity Profile

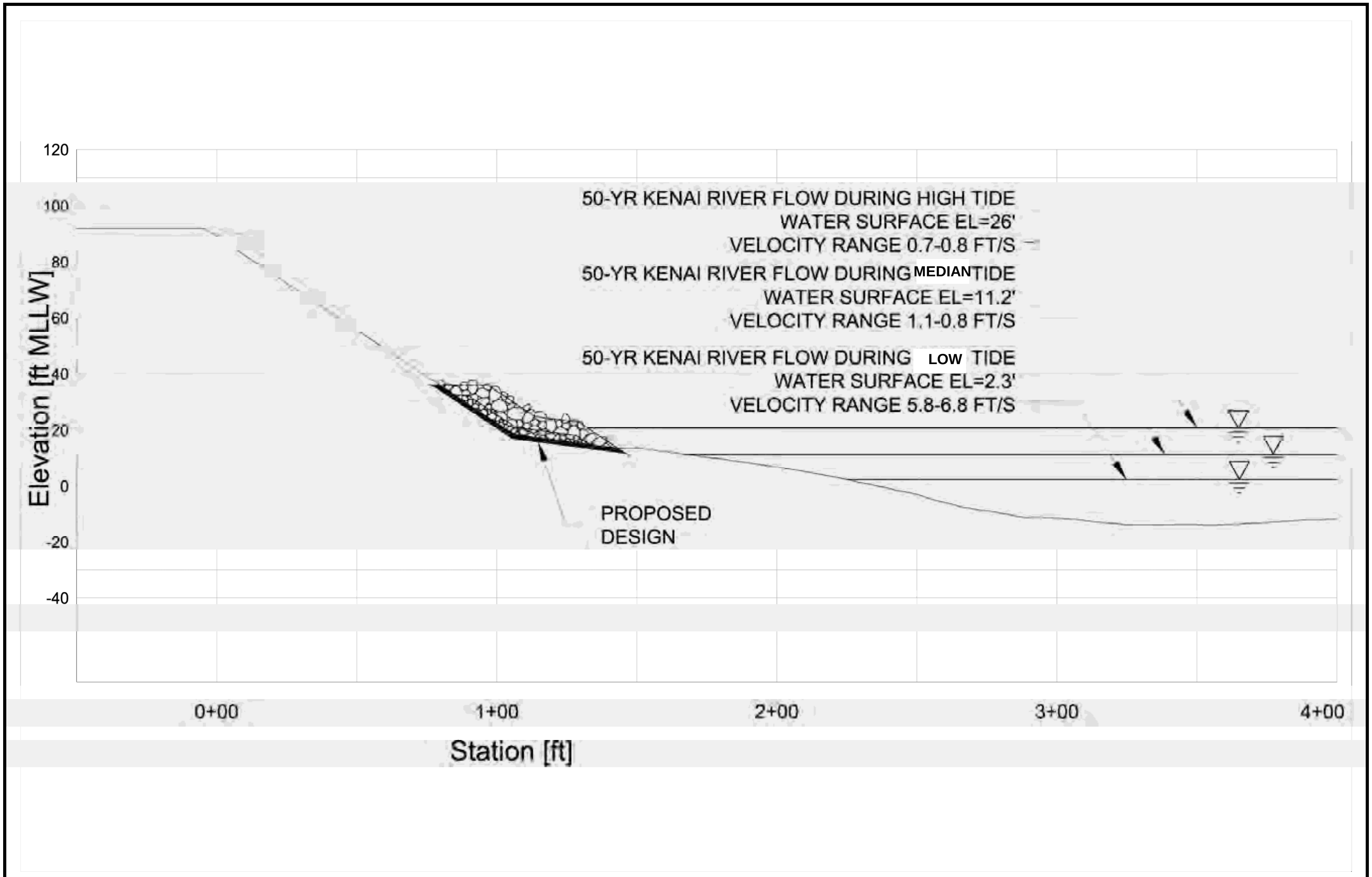


Figure B-10. Typical Kenai River Cross Section with Velocity Range by Tide Level

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NGVD)	WITH FLOODWAY (FEET NGVD)	INCREASE
Kenai River								
A	0	1,223[2]	26,200	1.5	13.5	9.0[3]	9.0[3]	0.0
B	3,380	1,901[2]	38,750	1.0	13.5	9.1[3]	9.1[3]	0.0
C	6,440	1,701[2]	34,746	1.1	13.5	9.1[3]	9.1[3]	0.0
D	9,840	1,821[2]	29,073	1.3	13.5	9.1[3]	9.1[3]	0.0
E PROJECT	13,030	1,343[2]	28,620	1.3	13.5	9.1[3]	9.1[3]	0.0
F	16,270	1,216[2]	24,083	1.6	13.5	9.2[3]	9.2[3]	0.0
G	19,460	1,248[2]	18,531	2.1	13.5	9.3[3]	9.3[3]	0.0
H	22,700	1,012[2]	21,076	1.8	13.5	9.4[3]	9.4[3]	0.0
I	25,460	873[2]	15,249	2.5	13.5	9.4[3]	9.4[3]	0.0
J	25,880	790[2]	15,604	2.5	13.5	9.5[3]	10.5[3]	1.0
K	29,430	751[2]	13,168	2.9	13.5	9.7[3]	10.7[3]	1.0
L	31,430	630[2]	10,073	3.8	13.5	9.8[3]	10.7[3]	0.9
M	33,370	603[2]	9,895	3.9	13.5	10.1[3]	11.0[3]	0.9
N	36,000	747[2]	12,739	3.0	13.5	10.6[3]	11.4[3]	0.8
O	38,765	758[2]	13,024	2.9	13.5	10.8[3]	11.6[3]	0.8
P	41,495	564[2]	10,559	3.6	13.5	11.0[3]	11.8[3]	0.8
Q	44,215	481[2]	8,959	4.3	13.5	11.3[3]	12.0[3]	0.7
R	46,980	770[2]	10,869	3.5	13.5	11.9[3]	12.6[3]	0.7
S	49,975	1,120[2]	20,287	1.9	13.5	12.3[3]	12.9[3]	0.6
T	52,835	440[2]	6,994	5.5	13.5	12.3[3]	12.9[3]	0.6
U	54,435	880[2]	13,379	2.8	13.5	12.8[3]	13.4[3]	0.6
V	55,915	450[2]	6,202	6.1	13.5	12.8[3]	13.4[3]	0.6
W	58,000	1,049	12,437	3.0	13.7	13.7	14.2	0.5
X	59,705	2,250	14,922	2.5	13.9	13.9	14.4	0.5
Y	62,640	1,210	6,842	5.5	14.6	14.6	15.0	0.4
Z	65,485	850	8,840	4.3	16.0	16.0	16.5	0.5

[1]Feet Above Cross Section A [2]Width Affected by Tidal Influences [3]Elevations Computed Without Consideration of Backwater Effects From Cook Inlet

TABLE 4

FEDERAL EMERGENCY MANAGEMENT AGENCY
Federal Insurance Administration

KENAI PENINSULA BOROUGH, AK

FLOODWAY DATA

KENAI RIVER

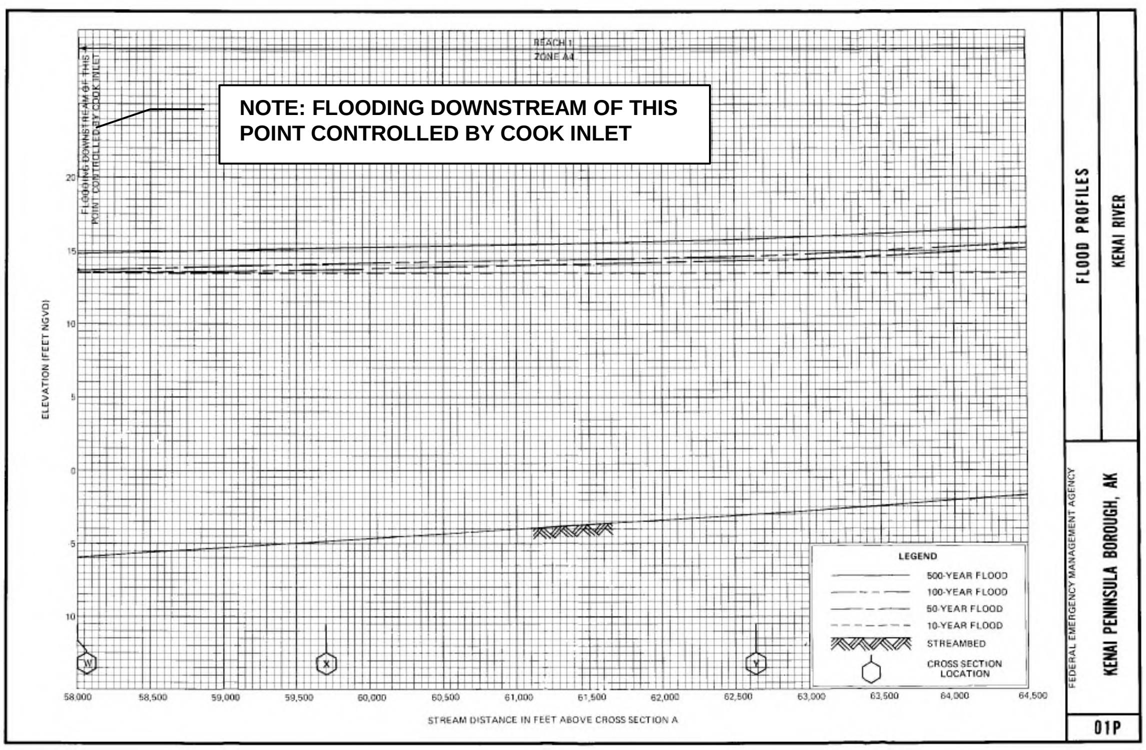


Figure B-11. Kenai River Flood Profile (FEMA 1981)

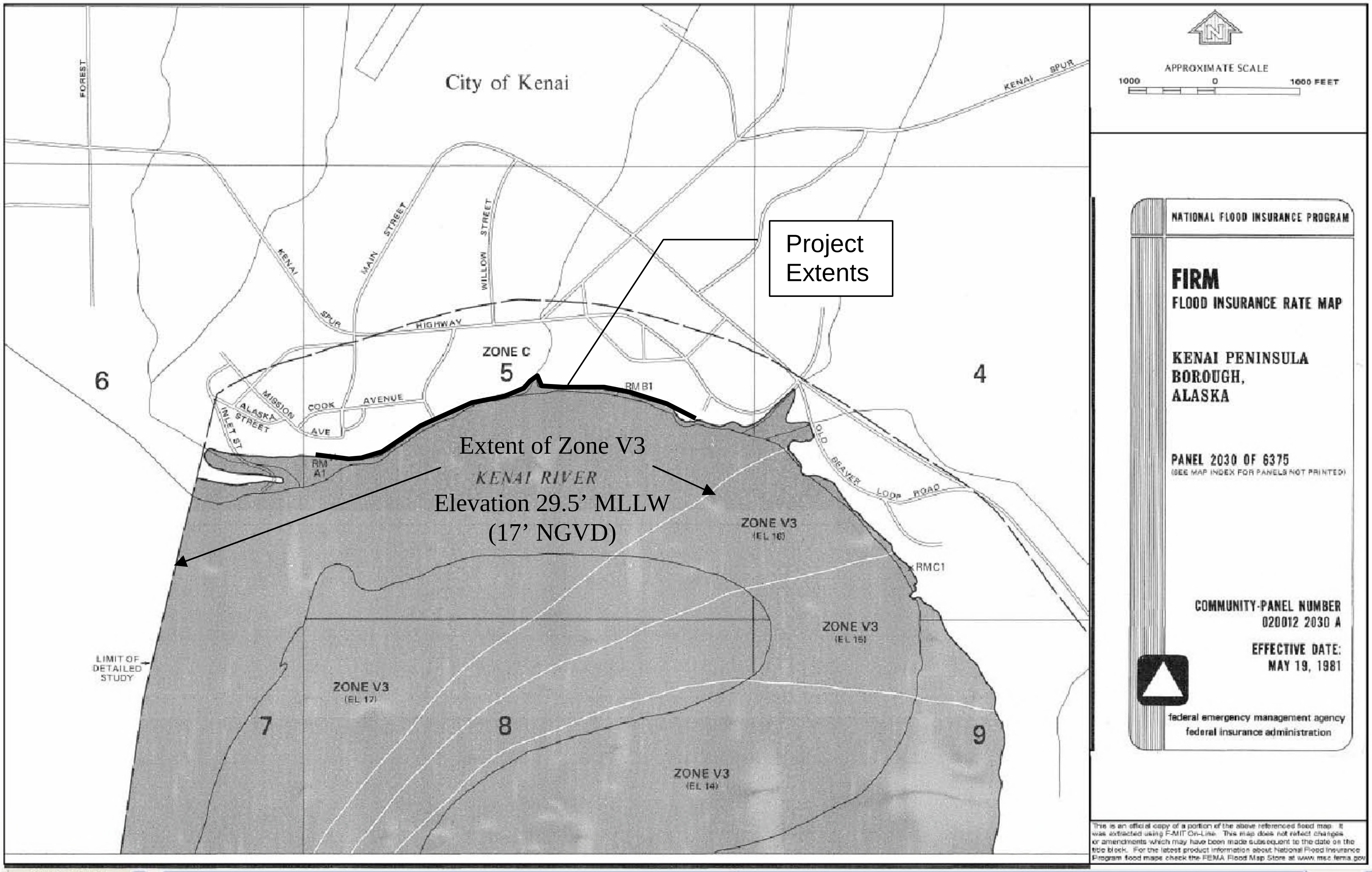


Figure B-12. FEMA FIRM Panel 2030 with V-Zone Designation

ATTACHMENT C

HISTORICAL BLUFF EROSION

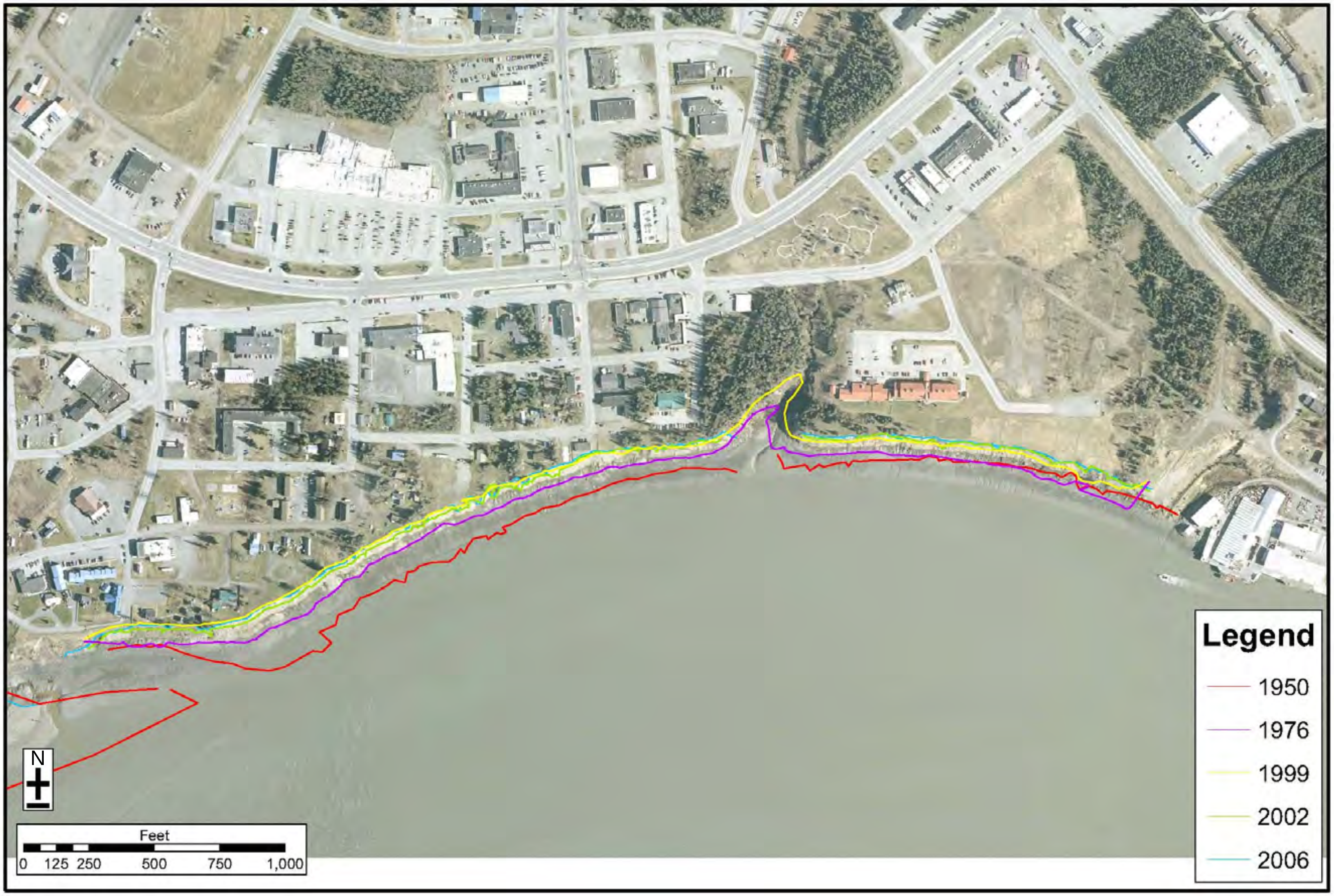


Figure C-1. Historical Bluff Retreat, 1950-2006

Figure C-2. Historical River Morphology, 1950-2006 (with 1950 aerial background)

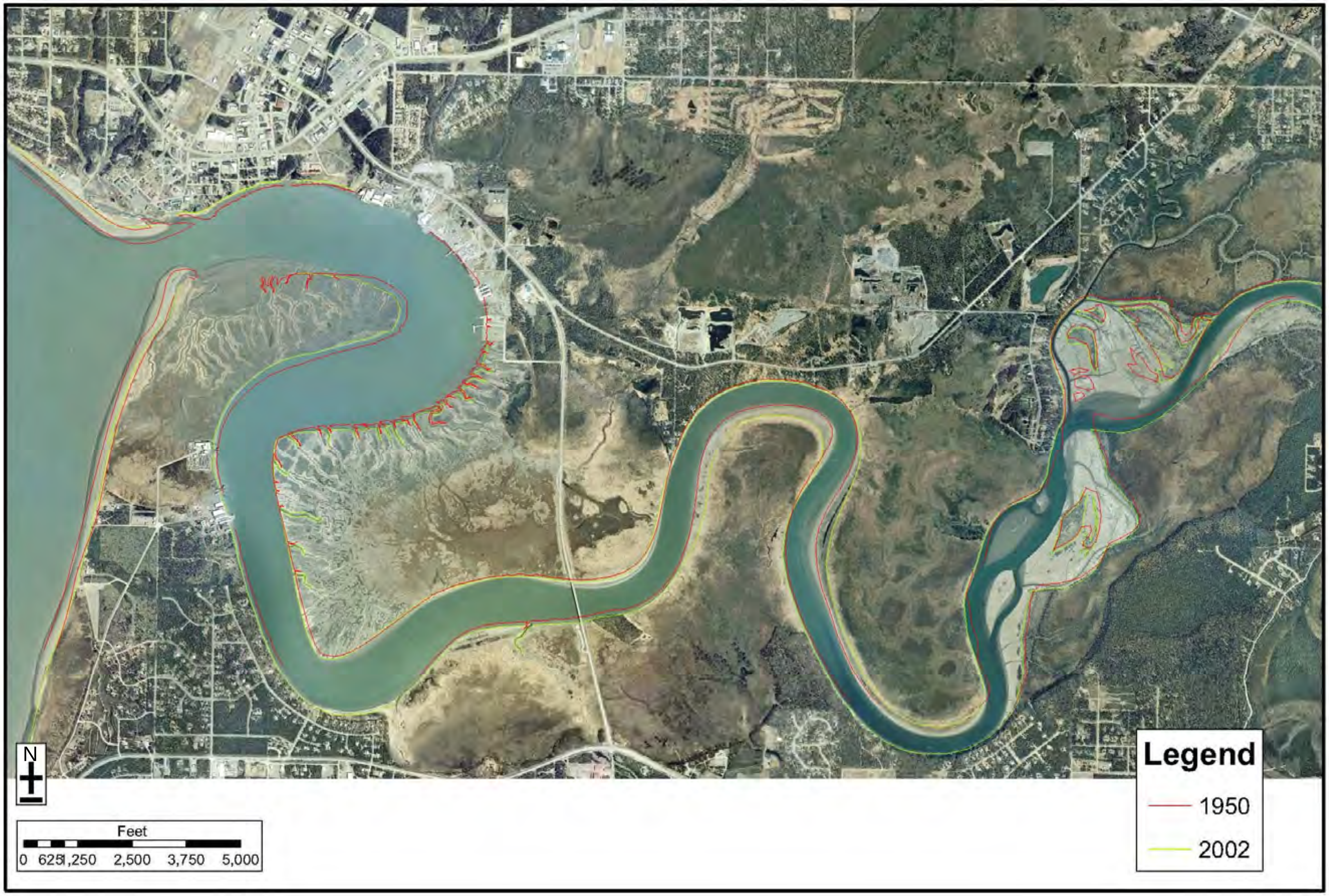


Figure C-3. Historical River Morphology, 1950-2006 (with 2002 aerial background)

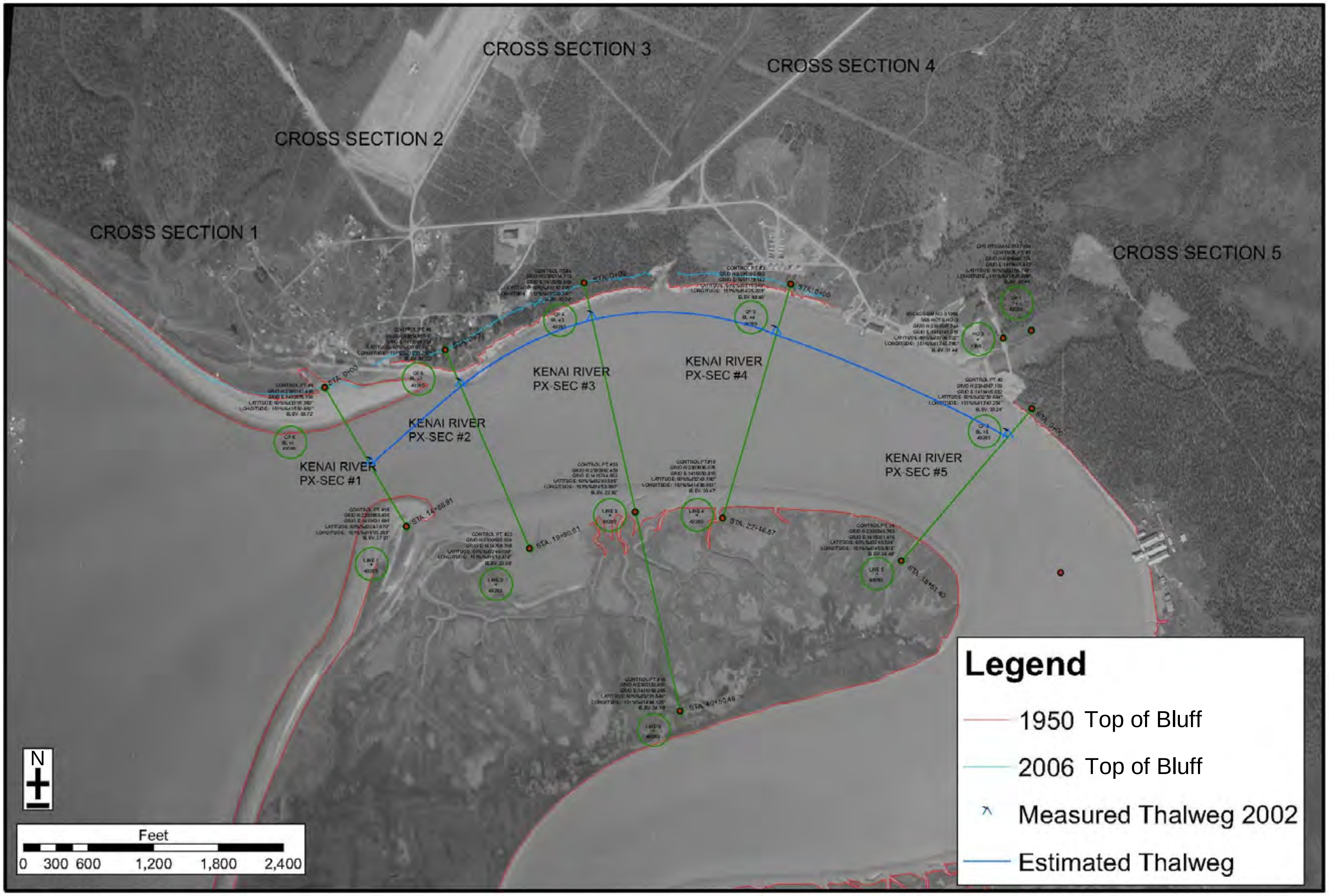


Figure C-4. 1950 Aerial Image with 2002 Thalweg and Bathymetric Section Locations

Figure C-5. 2002 Aerial Image and Thalweg with 1950 Top of Bluff Overlay

Table C-1: Aerial Photo Sources

Agency / Company	**Website**	**Metadata**			
		Acquisition Date	Image Type	Scale	Product
USGS	earthexplorer.usgs.gov	8/2/1950	BW	40000	Scanned
		6/25/1951	BW	40000	Medium Res/Scanned
		7/22/1972	BW / CIR	42893	Scanned
		6/23/1974	BW	444000	Scanned
		7/16/1977	CIR	124002	Scanned
		8/20/1980	BW	32000	Medium Res/Scanned
		8/3/1982	BW	119333	Scanned
		8/12/1984	CIR	61428	Scanned
		8/27/1996	BW	24000	Scanned
Aero-metric	www.aero-metric.com	1963, 1967, 1973, 1979, 1984, 1986, 1990, 1995, 1998, 2001, 2006, 2007, 2010. Additional details available from Aero-metric.			

Table C-2. Historical Bluff Retreat, 1950-2006

River Station from Corps XS #1	Bluff Retreat (ft)	Avg Annual (ft/yr)	Location
0	0	0.0	Cross Section #1
250	0	0.0	Coastal shore, no bluff discernible in historical aerials
500	0	0.0	Banks match in historical aerials
750	83	1.5	
1000	75	1.3	
1250	212	3.8	Cross Section #2
1500	245	4.4	Area demonstrating maximum historical bluff retreat
1750	150	2.7	
2000	163	2.9	
2250	134	2.4	
2500	136	2.4	
2750	140	2.5	Cross Section #3
3000	110	2.0	
3250	122	2.2	
3500	0	0.0	Ryan's Creek - no bluff
3750	100	1.8	
4000	84	1.5	
4250	79	1.4	
4500	65	1.2	
4750	67	1.2	Cross Section #4
5000	50	0.9	
5250	0	0.0	Developed shoreline, no retreat discernible
5500	0	0.0	Developed shoreline, no retreat discernible
5750	0	0.0	Developed shoreline, no retreat discernible
6000	0	0.0	Developed shoreline, no retreat discernible
6250	0	0.0	Developed shoreline, no retreat discernible
6500	0	0.0	Developed shoreline, no retreat discernible
6750	0	0.0	Developed shoreline, no retreat discernible
7000	0	0.0	Cross Section #5

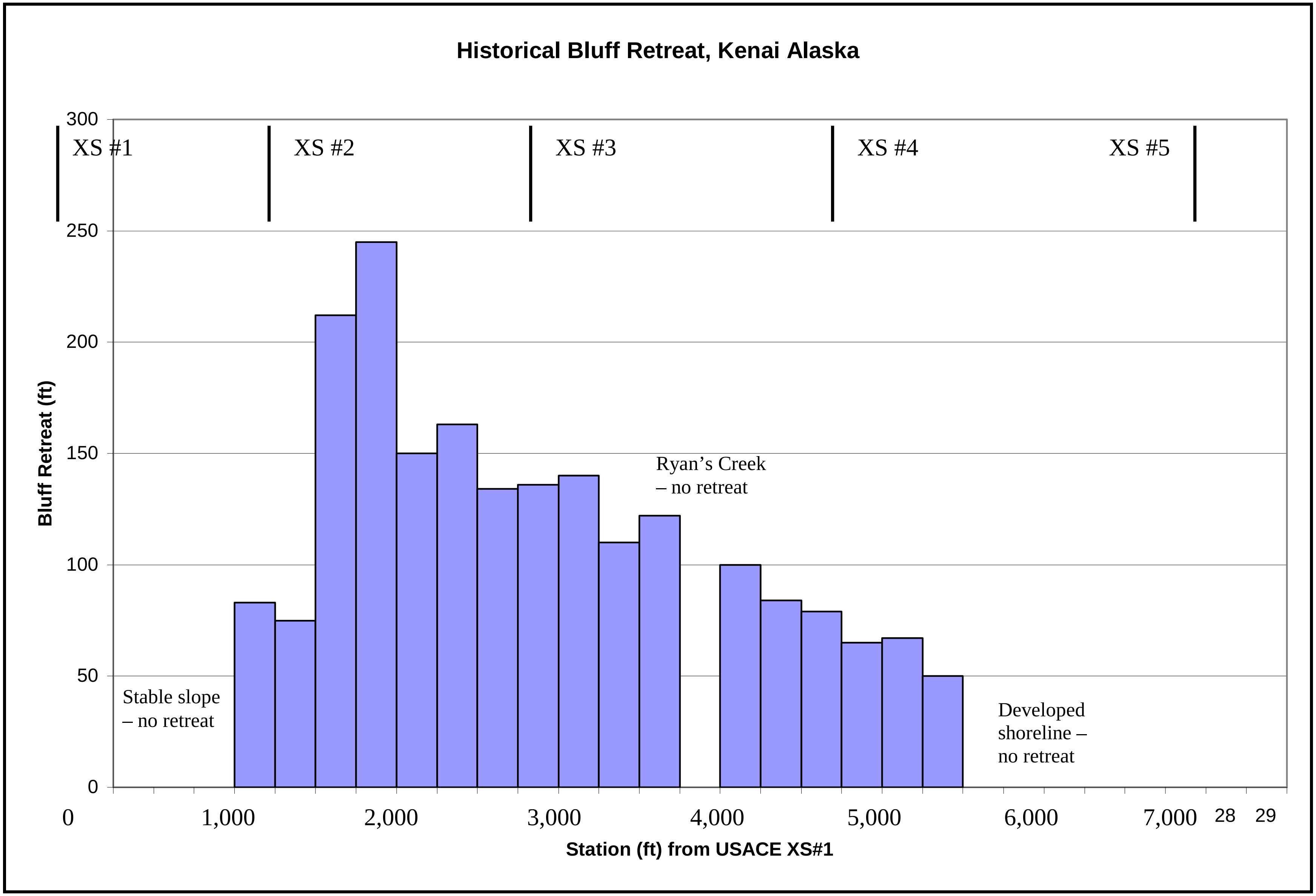


Figure C-6. Historical Bluff Retreat, 1950-2006

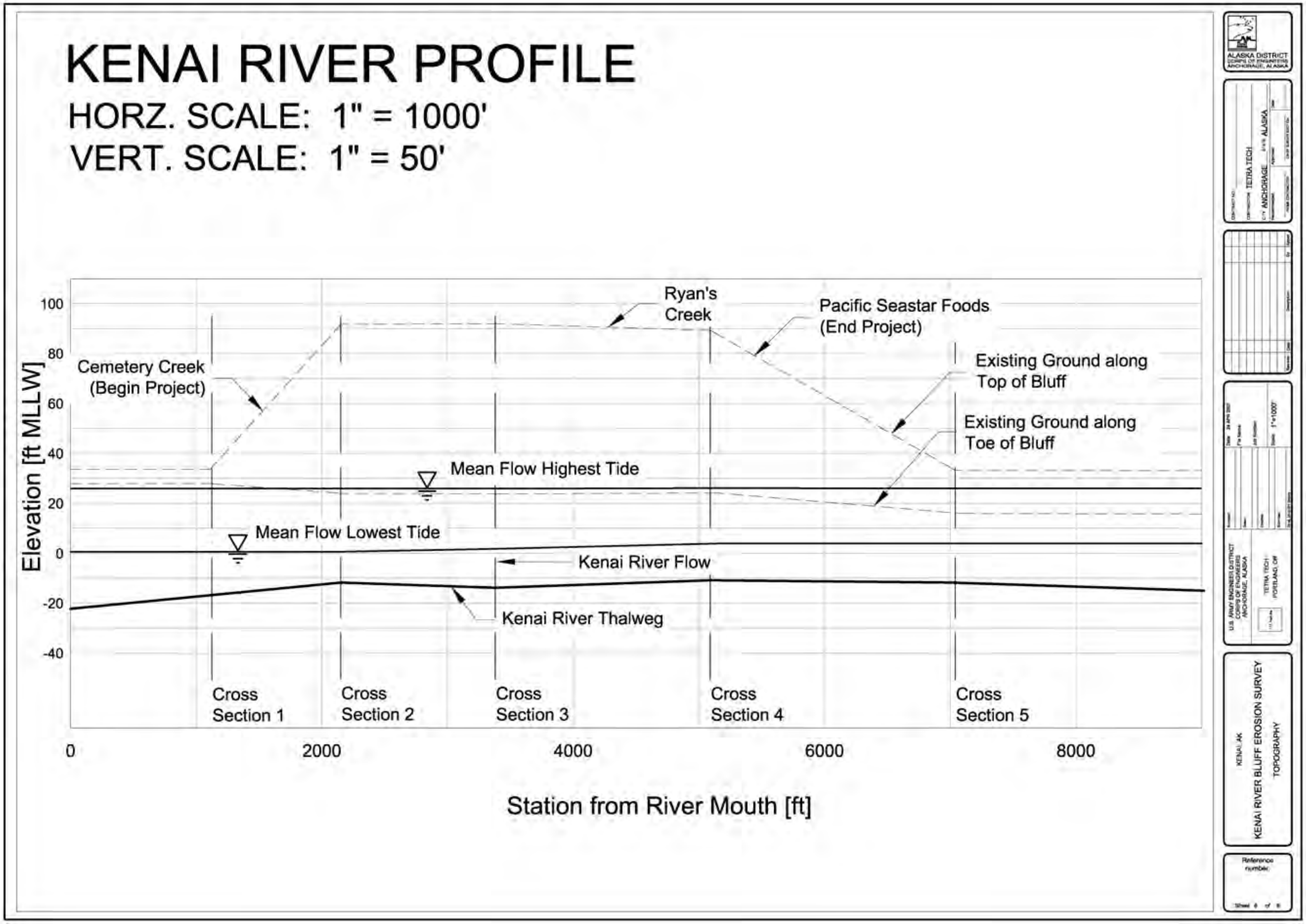


Figure C-7. Kenai River Profile, 2003

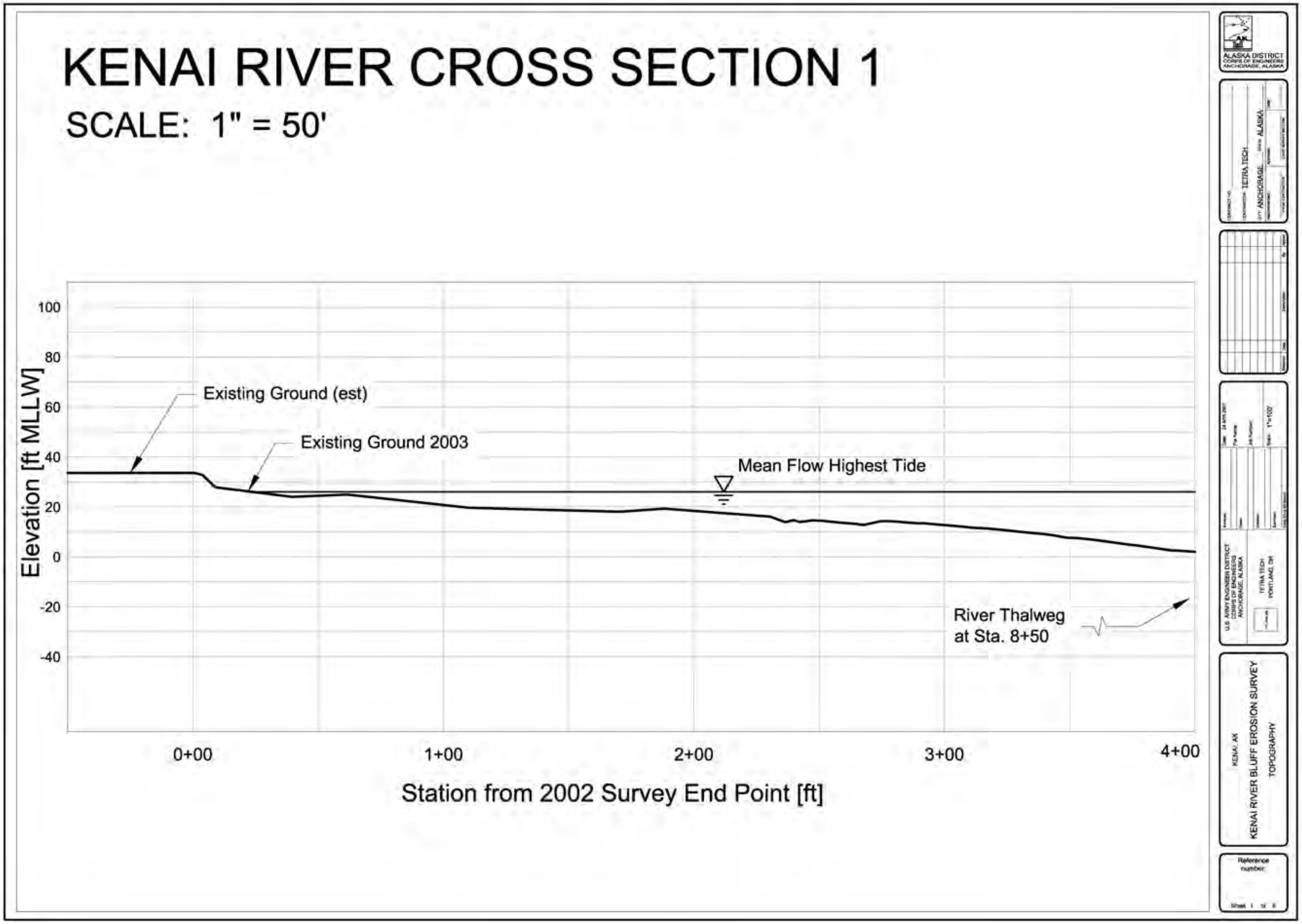


Figure C-8. USACE 2003 Hydrographic Cross Section #1

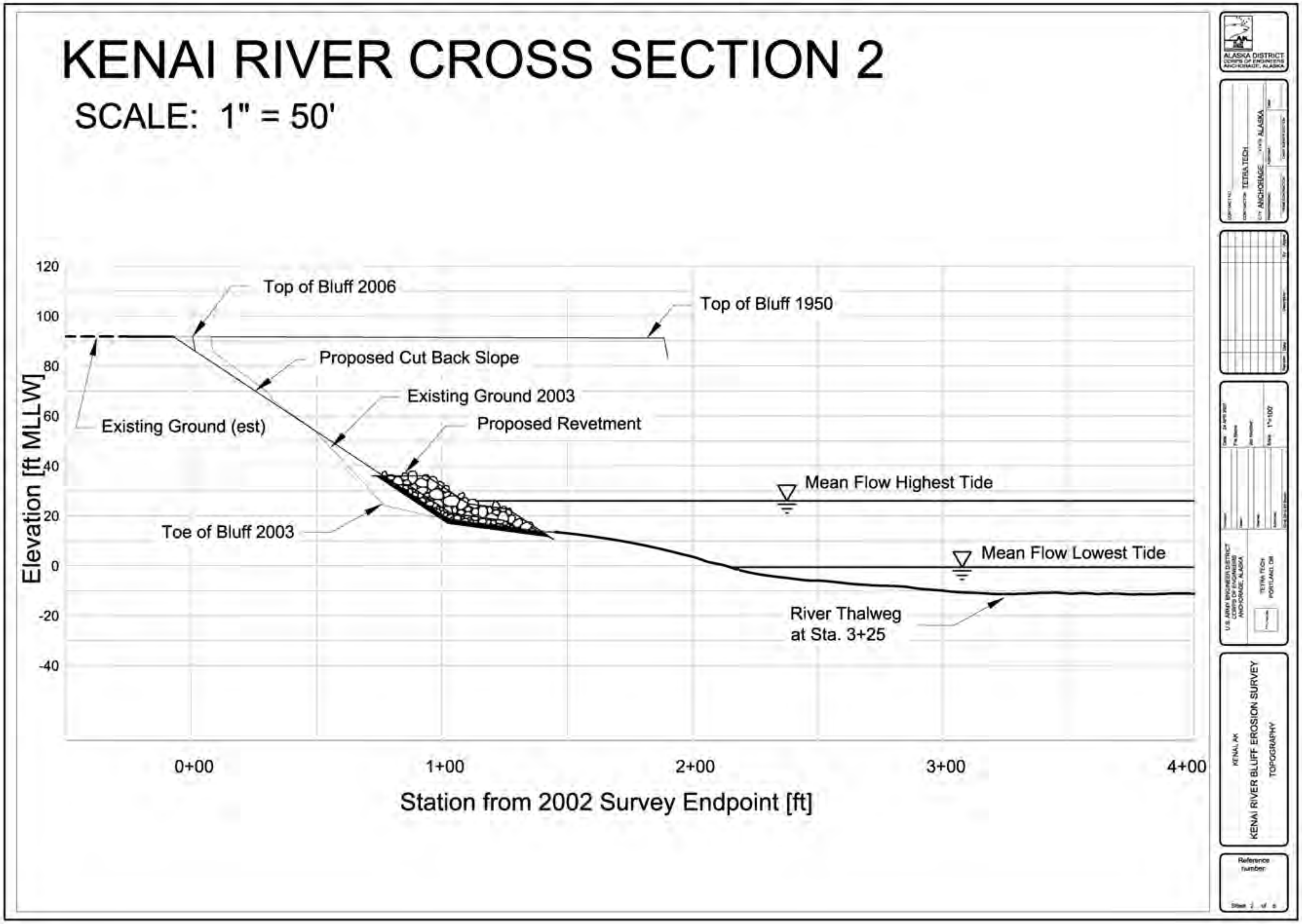


Figure C-9. USACE 2003 Hydrographic Cross Section #2 with Historical Top of Bluff

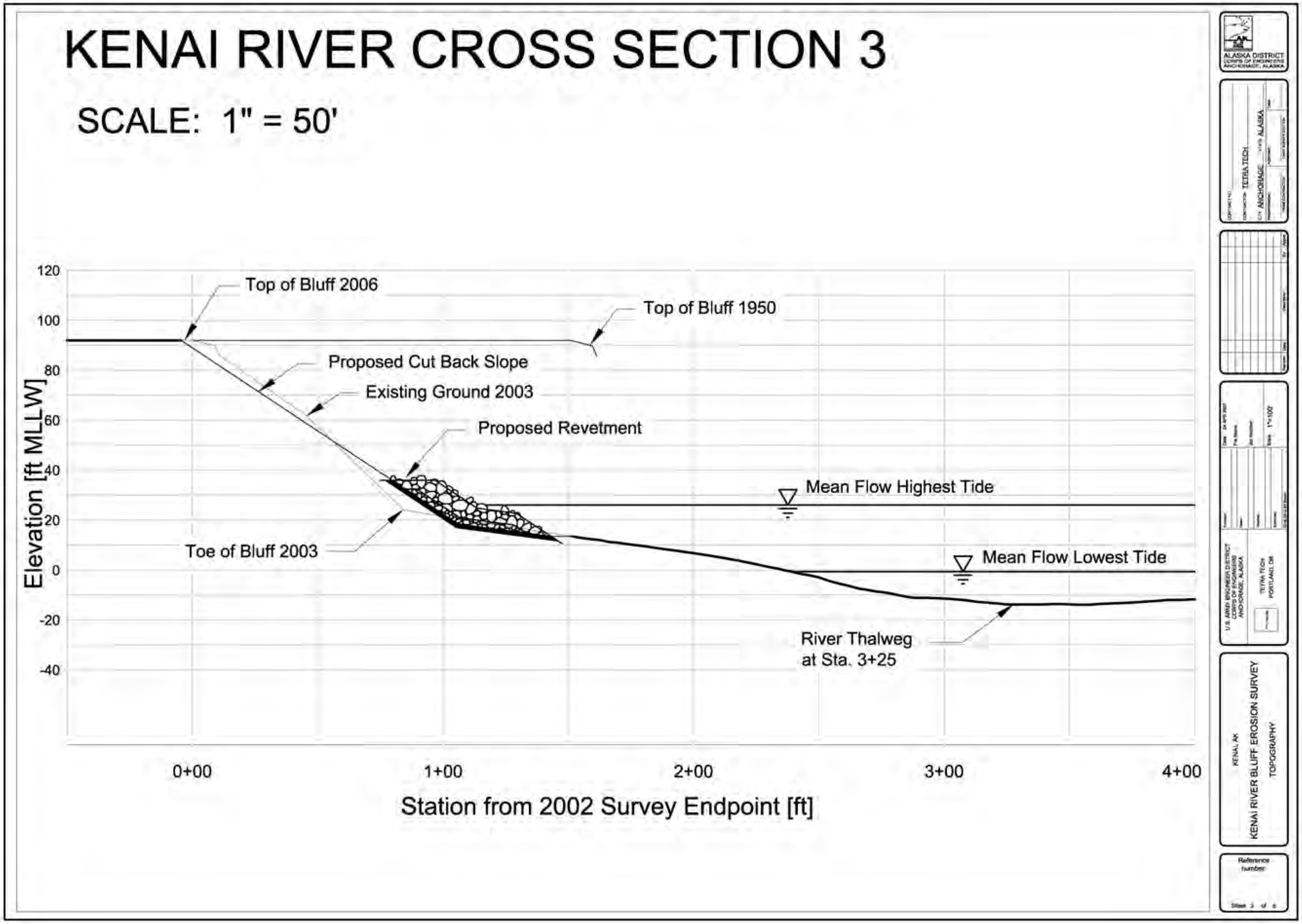


Figure C-10. USACE 2003 Hydrographic Cross Section #3 with Historical Top of Bluff

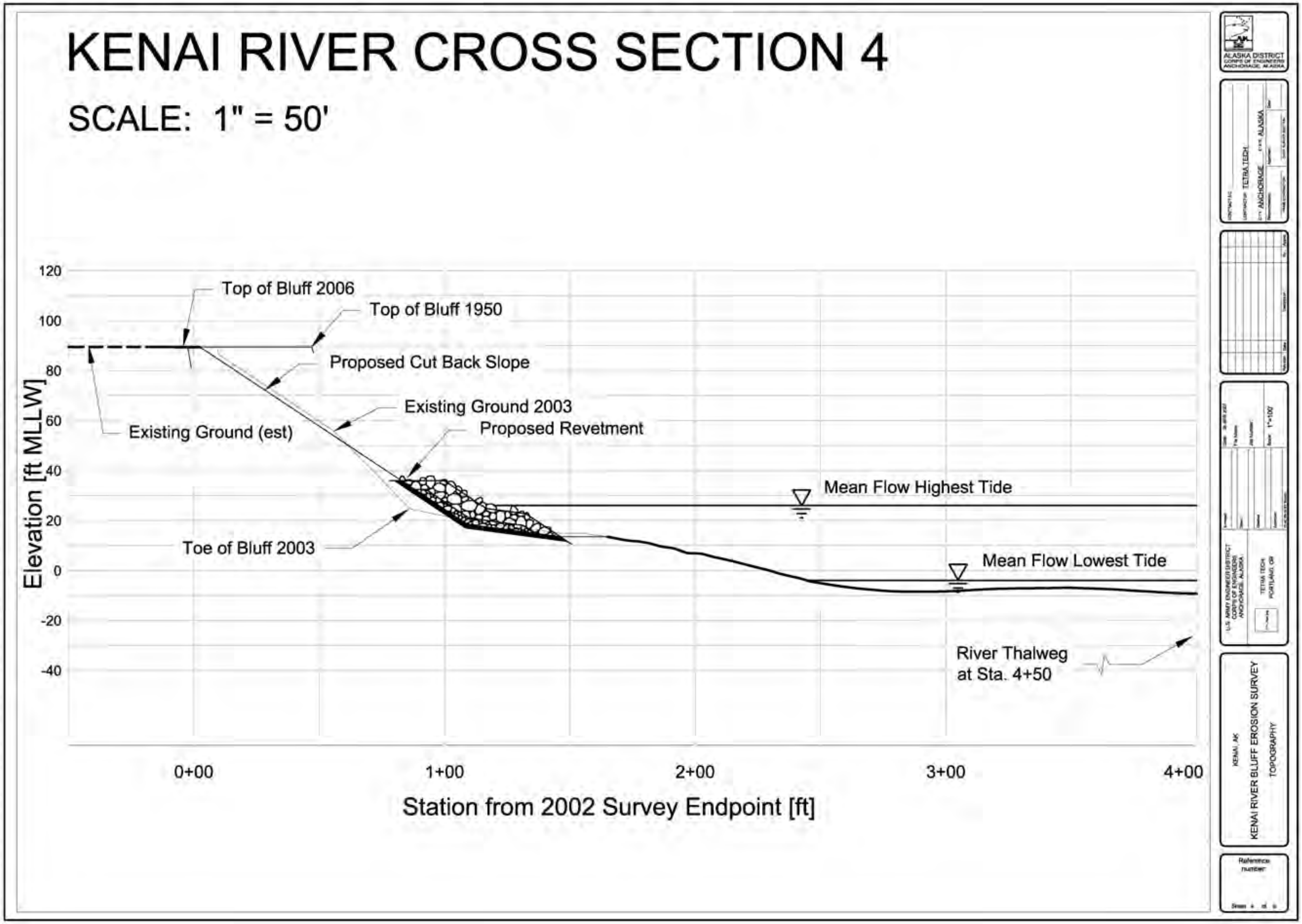


Figure C-11. USACE 2003 Hydrographic Cross Section #4 with Historical Top of Bluff

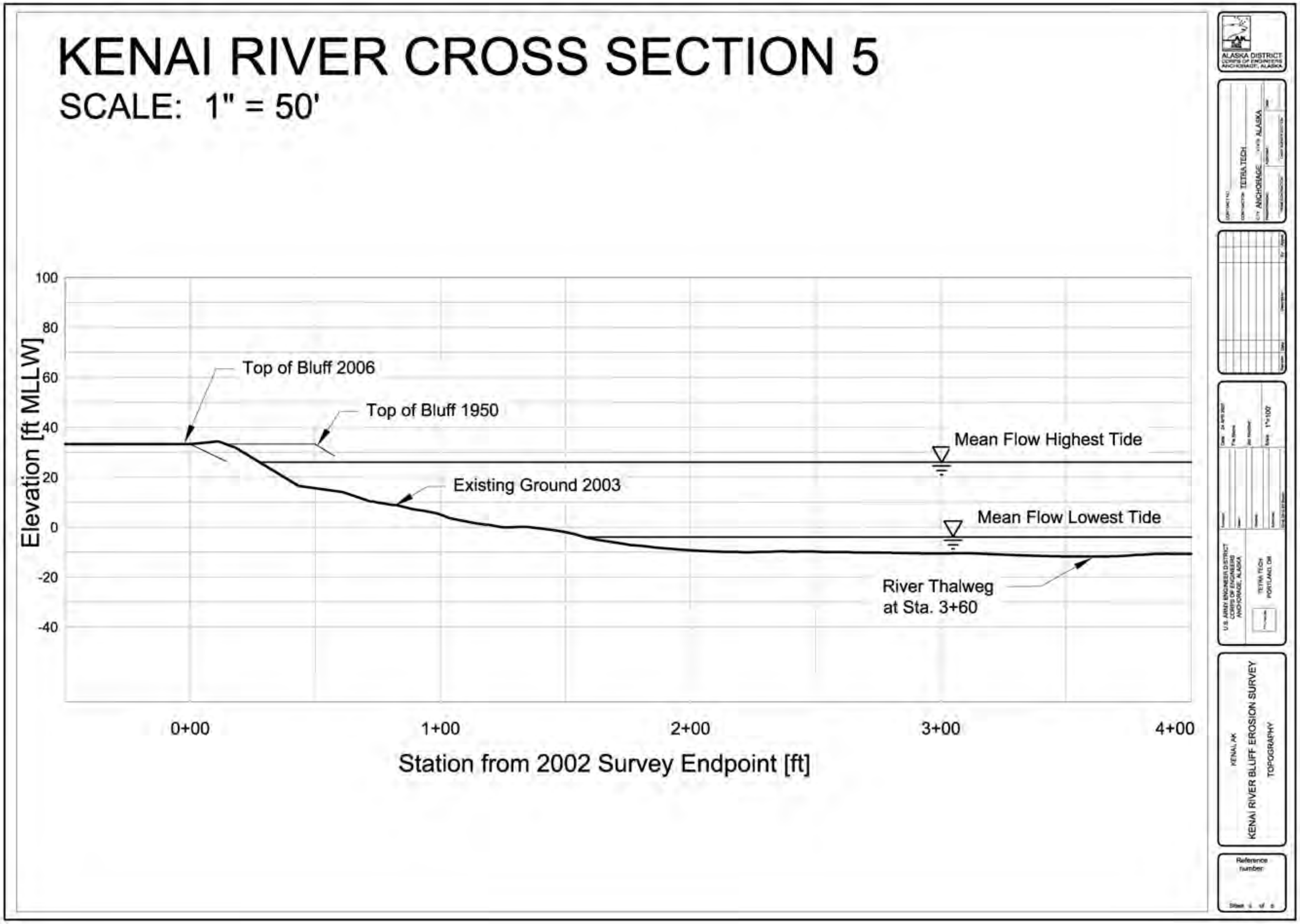


Figure C-12. USACE 2003 Hydrographic Cross Section #5 with Historical Top of Bluff

ATTACHMENT D

REAL ESTATE AND GEOSPATION DATA SOURCES

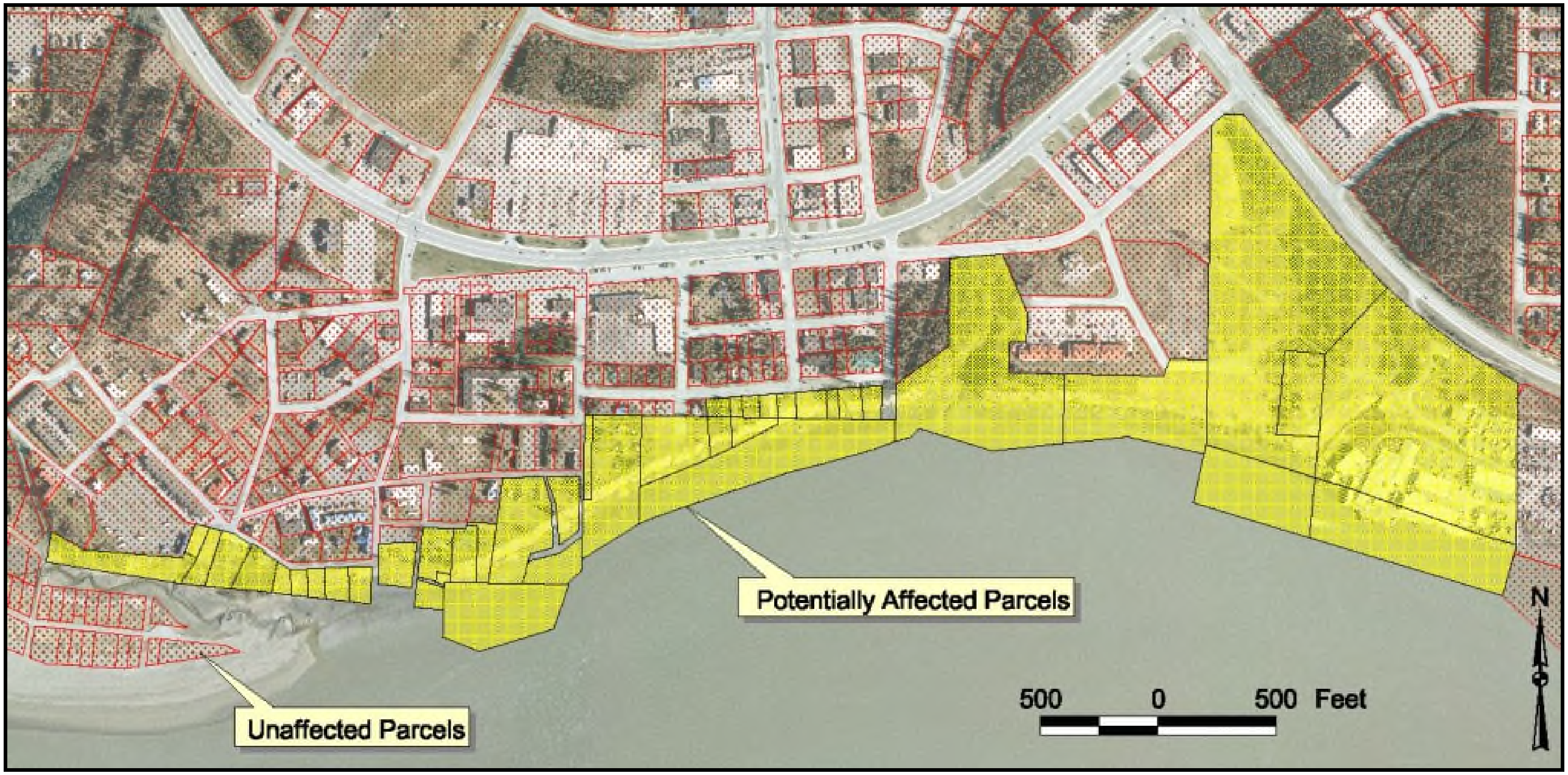


Figure D-1. Parcels Intersecting Top or Toe of Bluff

Table D-1: Potentially Affected Parcels

Note: Assessed values and ownership are from Kenai Peninsula Borough GIS. Some values in the GIS records are placeholders only. Updated information may be available. This information is presented for planning and informational purposes only.

Parcel ID	Ownership Type	Usage	Required Easement (Acres)	Total Lot Size (Acres)	Required Easement (% of Lot)	Affected Structures (square feet)	Total Assessed Value	Owner
4709308	PRV	VA	0.41	0.41	100%	0	$400	OCONNELL ROBERT D ET AL, SWARNER LINDA
4709307	PUB	VA	0.64	0.64	100%	0	$100	CITY OF KENAI
4709306	PRV	RS	0.44	0.58	76%	0	$119,900	SHOWALTER JENNIFER F
4709305	PUB	VA	0.19	0.19	100%	0	$100	KENAI CITY OF
4709304	PRV	VA	0.19	0.19	100%	0	$100	WEBBER CHARLES R
4709303	PRV	VA	0.21	0.21	100%	0	$100	KNIGHT KEITH K
4709302	PUB	VA	0.32	0.32	100%	0	$100	KENAI CITY OF
4709301	PRV	VA	0.33	0.33	100%	0	$100	KENAI BIBLE CHURCH
4709109	PRV	RS	0.00	0.37	1%	0	$172,000	ANDERSON HARRY K & NELLIE MAE
4709110	PRV	CH	0.02	0.35	7%	0	$434,300	KENAI BIBLE CHURCH
4710315	PRV	RS	0.63	0.63	100%	1314	$131,900	LOFSTEDT DIANA
4710308	PRV	VA	0.17	0.30	56%	0	$400	STERLING GLENDA A ET AL, MCCANN BILLY ESTATE
4710306	PRV	CM	0.63	0.63	100%	1938	$136,200	LOFSTEDT DIANA
4710307	PRV	VA	0.06	0.06	100%	0	$100	ERREA JULIAN & HILDERBRAND DAN L
4710311	PRV	VA	0.10	2.77	4%	0	$2,300	CLARK RUSSELL S
4710312	PRV	RS	0.43	0.57	76%	3137	$184,900	FOSTER GARY L & KATHLEEN
4710316	PRV	VA	0.30	0.33	91%	0	$5,300	SEELINGER DONALD P
4710219	PRV	RS	0.66	1.40	47%	0	$59,400	SEELINGER DONALD P
4710301	PUB	VA	0.03	0.69	4%	0	$100	KENAI CITY OF
4710201	PRV	VA	0.47	0.62	75%	0	$23,500	PETERKIN ROBERT T & BONNIE
4711907	PUB	VA	0.08	0.29	27%	0	$100	CITY OF KENAI
4711906	PRV	RS	1.13	2.67	42%	637	$126,400	KARAFFA PAUL P & CONSIEL ROGER D
4711904	PRV	VA	1.08	1.60	67%	0	$36,100	VANN RICKY L & CONNIE L TRUSTEES
4711901	PRV	VA	2.98	4.31	69%	0	$3,100	JOHNSON JAMES E, JOHNSON LANCET ANN ET AL

Parcel ID	Ownership Type	Usage	Required Easement (Acres)	Total Lot Size (Acres)	Required Easement (% of Lot)	Affected Structures (square feet)	Total Assessed Value	Owner
4711903	PRV	VA	0.35	0.35	100%	0	$1,400	COOPER DOROTHY M
4711902	PRV	VA	0.36	0.36	100%	0	$1,100	SANDS PATRICIA R TRUSTEE B B SANDS
4711603	PRV	AB	0.02	0.10	20%	0	$4,100	FREITAG HERBERT & JUDITH
4711602	PUB	VA	0.18	0.18	100%	0	$5,800	KENAI CITY OF
4711607	PRV	RS	0.07	0.16	42%	2369	$52,600	VANHORNE ALAN K & MARIAN F
4711606	PRV	VA	0.11	0.17	65%	0	$10,500	HANNAH TONEY A & LINDA M
4711605	PRV	CM	0.17	0.19	86%	2040	$35,400	HUTCHINGS STEPHEN PAUL SR CUST
4711501	PRV	VA	0.35	0.35	100%	0	$2,000	ALASKA LABORERS BUILDING CORP
4711502	PRV	VA	0.14	0.14	100%	0	$1,100	YOUNG WILLIAM C TRUSTEE
4711503	PRV	VA	0.30	0.30	100%	0	$2,100	CENTRAL PENINSULA MENTAL HEALTH
4711504	PRV	VA	0.27	0.27	100%	0	$2,000	LEDOUX CLARENCE E SR ESTATE OF
4705506	PUB	VA	3.14	8.22	38%	0	$281,500	CITY OF KENAI
4205502	PUB	VA	0.22	1.11	20%	0	243000	CITY OF KENAI
4705501	PRV	CH	0.02	1.14	2%	0	$109,800	SHELDON DENTON SHILLING
4705510	PUB	VA	0.14	3.43	4%	0	5508100	CITY OF KENAI
4705806	PUB	VA	3.13	3.37	93%	0	$193,700	CITY OF KENAI
4705602	PUB	VA	3.24	14.98	22%	0	$104,800	PACIFIC STAR SEAFOODS INC
4705601	PRV	CH	1.24	1.43	87%	0	$82,800	DIOCESE OF SITKA & ALASKA ORTHODOX
4705703	PRV	ID	0.32	14.50	2%	0	$1,351,800	PACIFIC STAR SEAFOODS INC

A total value of existing real estate of $2.75 million is assumed based on 11,400 square feet of existing structures and 1.09 million square feet of platted land within the project footprint. Structures are assigned a uniform value of $50 per square foot, with land valued at $2 per square foot. Most of the existing parcel land within the project footprint is not suitable for development and is thus assigned a relatively low unit price.

Table D-1: GIS Metadata for Parcel and Utility Layers

Parameter	**Value**
Projected Coordinate System	NAD 1927 State Plane Alaska 4 FIPS 5004
Projection	Transverse Mercator
Central_Meridian	-150.00000000
Scale_Factor	0.99990000
Latitude_Of_Origin	54.00000000
Linear Unit	U.S. Foot
Geographic Coordinate System	GCS North American 1927
Datum	D North American 1927
Prime Meridian	0
Angular Unit	Degree

Table D-2: GIS Data Layers Obtained for Kenai Bluff Erosion Study

Layer	**Source**	**Comments**
Aerial Photo	Peninsula Borough	Proprietary 2005 data – do not distribute
Sewers	City of Kenai	Includes relocated sewer near bluff
Storm Drains	City of Kenai	None near site
Street Lights	City of Kenai	Lights present within potential project footprint
Water Supply	City of Kenai	Pipes present within potential project footprint
Linked As-builts	City of Kenai	Raster scans of previous public works projects
Parcels	Peninsula Borough	Includes ownership data as of 2005

Table D-3: Metadata and Survey Notes for Aerial Photography and Topographic Mapping

- Mapping compiled to meet horizontal accuracy in accordance with ASPRS Class II Accuracy Standards.
- Mapping compiled to meet vertical accuracy in accordance with ASPRS Class II Accuracy Standards.
- Areas denoting vegetation cover on the ground should be considered less accurate and not used for engineering purposes until field checked in accordance with ASPRS Accuracy Standards.
- Projection is Alaska State Plane, Zone 4, NAD83 as expressed in U.S. Survey feet.
- Vertical data is referenced to MLLW based on NOAA Tidal Station "Nikiski".
- Mapping based on photography acquired 09-27-2007 at a nominal scale of 1"=300'.
- Mapping produced for output at a scale of 1"=100' with a contour interval of 1 foot.
- Information provided is based on Aerial Mapping produced by Aerometric and controlled by field surveys performed by R&M Consultants. The aerial photography was acquired September 27, 2007. R&M Control Surveys took place in 2007 and 2008.
- Primary horizontal control and aerial photo control was established using Static GPS techniques with Trimble duel frequency receivers. GPS vectors were adjusted using simultaneous least-squares methods.

- Project coordinates are referenced to the Alaska Coordinate System of 1983 (ACS83), Zone 4 values, reported in U.S. Survey Feet and are based on Survey Control Station "McLane CP 1" as shown on the DOWL Engineers drawing "Kenai River Bluff Erosion Survey Topography" dated July 16, 2003.
- McLane CP 1 zone 4 coordinates = N 2,395,666.774, E 1,419,401.413. Project bearings are NAD83 Zone 4 state plane grid bearings based on GPS adjusted measurements constrained at McLane CP 1.
- Primary vertical control was established with a combination of Trimble dual frequency GPS measurements and differential leveling. GPS measurements incorporated Geoid06. Differential levels were performed with a Leica DNA10 digital level and barcode rod.
- Project vertical datum is referenced to Mean Lower Low Water (MLLW) based on NOAA Tidal Station Nikiski, Station ID No. 945 5760, publication date 10/30/2003. Station Nikiski is referenced by BM No. 8, et al., which was held for all project elevations (BM No. 8 elevation was verified by measurements to BM Nos. 7 & 9). The official station designation for BM No. 8 is "945 5760 TIDAL 8" (see PID No. AB7150). NOAA MLLW elevation for BM No. 8 = 109.659 U.S. Survey Feet (33.424 meters). Elevations were transferred from BM No. 8 roughly 10 miles south to the project site using the following sequence:

BM No. 8 to nearby set point CP 51	Differential levels.
CP 51 to McLane CP 1	GPS & Geoid06
CP 1 to nearby Kenai BM No. 3	Differential levels.

- Note that CP 1 is vertically unstable and that Kenai BM No. 3 has been used to control and adjust the elevation of CP 1 at each visit for GPS observations. The most recent visit found CP 1 with aluminum cap lying nearby. The cap was reset and the elevation reestablished from Kenai BM No. 3. The elevation for Kenai BM No. 3, established from Nikiski, is 31.18 feet.
- Elevations of tidal datums referred to station Nikiski MLLW in feet:
- Aerial Mapping contours were ground-truthed using RTK GPS broadcasted from station McLane CP 1. Elevations fit well in areas without foliage and less well where trees and brush existed. No extreme discrepancies were discovered.
- Geotechnical borehole positions were located using RTK GPS together with differential levels.
- The contour interval shown is one foot.

Property lines, street rights-of-way, street names, etc. were taken from the Kenai Peninsula Borough (KPB) Geographical Information Systems (GIS) website. The KPB GIS was inserted and fit to physical features within the aerial mapping (street intersections, etc).

Originator: Aero-Metric, Anchorage
Title: Kenai 2006
Geospatial_Data_Presentation_Form: remote-sensing image
Publication_Place: Anchorage, Alaska, USA
Publisher: Aero-Metric, Anchorage
Online_Linkage: \\AM068\E$\6070103_Kenai\2client\kenai.tif
Abstract:
Digital Orthomosaic of Kenai based on 22 May 2006 aerial photography with a pixel ground resolution of 1.0 foot
Purpose: Provide visual backdrop for vector data
Calendar_Date: 20060522
Currentness_Reference: ground condition
Bounding_Coordinates:
West_Bounding_Coordinate: -151.275428
East_Bounding_Coordinate: -151.223419
North_Bounding_Coordinate: 60.557871
South_Bounding_Coordinate: 60.548427
Source_Currentness_Reference: ground condition
Source_Citation_Abbreviation: Automated DEM
Source_Contribution:
The DEM was used in the construction of the orthomosaic to correct for terrain distortion.

Process_Description:
Aerial Photography Capture: A twin-engine aircraft with an on-board 6 (six) inch focal length film camera was used to capture 3 (three) exposures along 1 (one) flight line.

Scanning Process: The photographic negatives were scanned on a photogrammetric scanner at a resolution 16 microns to produce pixels with a nominal ground distance of about 0.9449 feet

Aerotriangulation Process: The aerotriangulation was performed using GPS/IMU data and was refined using conventional photogrammetric methods.

Orthorectification Process: The scanned images, aerotriangulation information, and DEM were processed using orthoimagery software to remove systematic and geographic distortions while georeferencing the scanned imagery. The resulting orthorectified images were then mosaicked and color balanced into a single image with a ground resolution of 1.0 foot

Raster_Object_Type: Pixel
Row_Count: 3276
Column_Count: 9301
Horizontal_Coordinate_System_Definition: Planar
Map_Projection_Name: Transverse Mercator

Scale_Factor_at_Central_Meridian: 0.999900
Longitude_of_Central_Meridian: -150.000000
Latitude_of_Projection_Origin: 54.000000
False_Easting: 1640416.666667
False_Northing: 0.000000
Planar_Coordinate_Encoding_Method: row and column
Abscissa_Resolution: 1.000000
Ordinate_Resolution: 1.000000
Planar_Distance_Units: survey feet
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222
Entity_and_Attribute_Overview:
The orthomosaic is a natural color image

ATTACHMENT E

DESIGN CALCULATIONS AND SPECIFICATIONS

Hydraulic Design and Armor Sizing

The design wave heights are derived from hindcasting efforts published in the Oceanweather report Cook Inlet Wave Extreme Storm Study (2009) and additional refinements made in coordination with the Alaska District Corps of Engineers. Figure E-1 shows the adopted design wave zones applied to the revetment design.

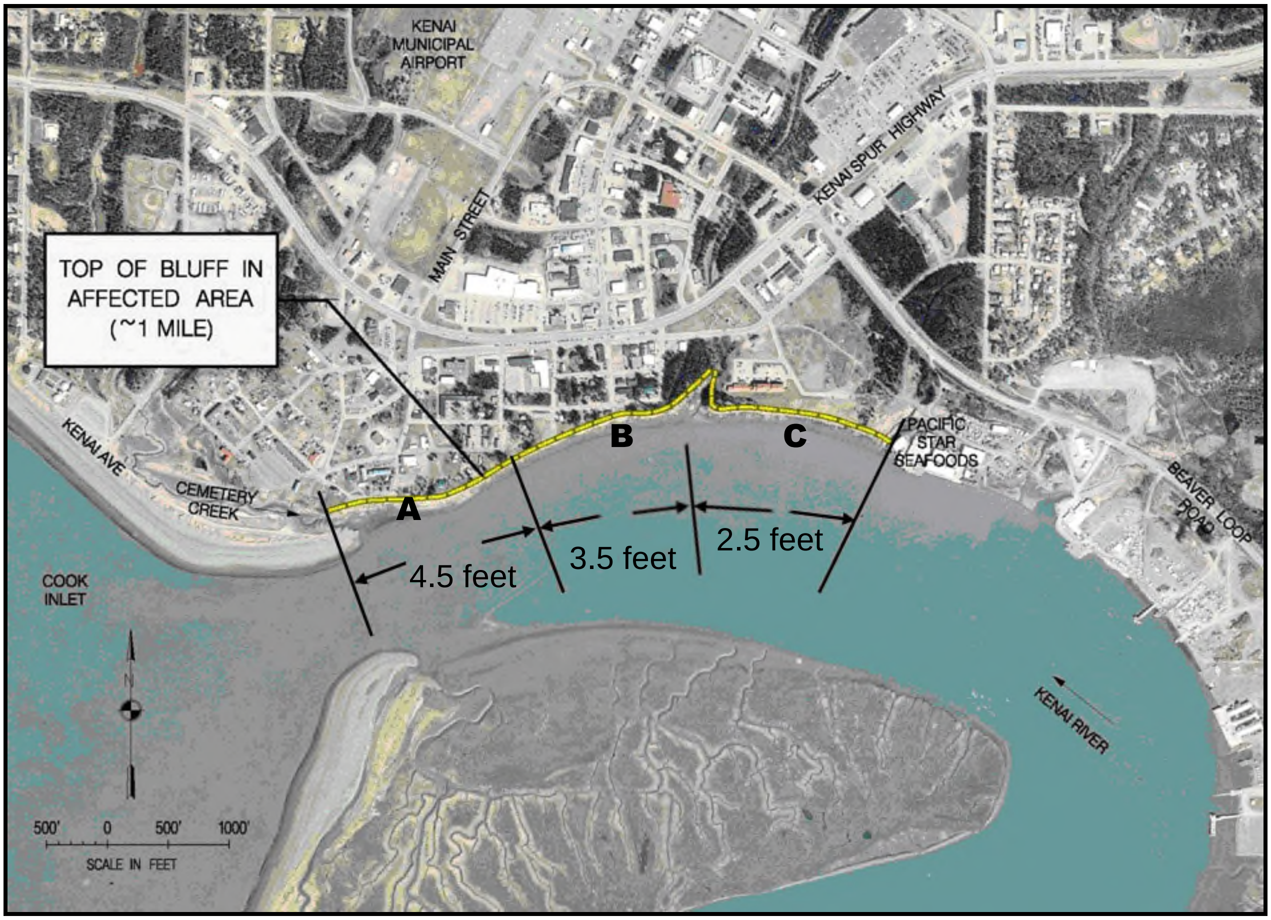


Figure E-1. Design Wave (USACE 2010)

The design wave height in Zone C utilizes a minimum median armor stone weight of 600 lbs to resist ice forces; the equivalent design wave matches that of Zone B. The top of revetment height is based on the design wave superimposed on the highest observed tide. The actual design wave for each zone is applied in determining the top of revetment with no adjustment for ice forces. A K_{rr} value of 2.0 is applied. An additional factor of safety may be attained by ensuring longitudinal placement in accordance with Shore Protection Manual guidelines; however, because this project may be constructed by other agencies rather than the Corps, the K_{rr} value for random placement is assumed. Additional design criteria for the top of revetment and the toe depth are included in Table E-1.

Table E-1. Revetment Height and Toe Protection Depth

Parameter	**Zone A (Sta. 0+00 to 15+00)**	**Zone B (Sta. 15+00 to 45+00)**	**Zone C (Sta 45+00 to 70+00)**
MHHW	20.7 feet MLLW	20.7 feet MLLW	20.7 feet MLLW
Extreme Tide	26.0 feet MLLW	26.0 feet MLLW	26 feet.0 MLLW
Highest Observed	27.7 (6/14/95)	27.7 (6/14/95)	27.7 (6/14/95)
Design Wave	4.5 feet	3.5 feet	2.5 feet
Computed Armor Stone W_{50}	1280 lbs	600 lbs	220 lbs
Applied Armor Stone W_{50}	1280 lbs	600 lbs	600 lbs
Applied Armor Stone D_{50}	2.5 feet	1.9 feet	1.9 feet
Applied Armor Layer Thickness (2 x D_{50})	5.0 feet	3.8 feet	3.8 feet
Computed B Layer W_{50}	128 lbs	60 lbs	22 lbs
Applied B Stone W_{50}	128 lbs	60 lbs	60 lbs
Aplied B Layer D_{50}	1.1 feet	0.9 feet	0.9 feet
Applied B Layer Thickness (1.5 x D_{50})	1.7 feet	1.4 feet	1.4 feet
Wave Runup	6.8 feet	5.3 feet	3.8 feet
Storm Surge / Barometric Pressure	1.5 feet	1.5 feet	1.5 feet
Nominal Wave Height	3.0 feet	2.0 feet	1.5 feet
Nominal Wave Runup	4.5 feet	3.0 feet	2.3 feet
Top of Revetment for Condition 1 (MHHW + design wave runup +	29.0 feet MLLW	27.5 feet MLLW	26.0 feet MLLW

Parameter	Zone A (Sta. 0+00 to 15+00)	Zone B (Sta. 15+00 to 45+00)	Zone C (Sta 45+00 to 70+00)
storm surge)			
Top of Revetment for Condition 2 (extreme tide + nominal wave runup + storm surge)	32.0 feet MLLW	30.5 feet MLLW	29.8 feet MLLW
Top of Revetment for Condition 3 (highest observed tide + nominal wave runup)	32.2 feet MLLW	30.7 feet MLLW	30.0 feet MLLW
Top of Revetment for Condition 4 (highest observed tide + design wave runup)	**34.5 feet MLLW**	**33.0 feet MLLW**	**31.5 feet MLLW**
Effective Toe Depth (Greater of 2/3 wave height or 1 armor stone + B layer thickness)	4.2 feet	3.3 feet	3.3 feet

A multilayer armor section is recommended for the revetment at the toe of the slope along the Kenai Bluff. The U.S. Army Engineer Waterways Experiment Station (WES) developed a formula to determine the stability of armor units on rubble structures. The stability formula is based on modeled test results. The formula for the weight of an individual armor unit in the primary layer is:

$$W = \frac{w_r H^3}{K_{RR}(s_r - 1)^3 \cot\theta}$$ (Equation 7-117, USACE, 1984)

Table E-2 lists the components of the equation along with values used in this study to verify the stability of the armor stone.

Table E-2: Design Assumptions and Armor Stone Weight Calculations

Variable (units)	Definition	Design Value
W (lbs)	Weight of individual armor unit (primary layer)	Calculated
w_r (lb/ft^3)	Unit weight of armor unit	165 lb/ft^3
H_1 (ft)	Design wave height, Zone A	4.5 feet
H_2 (ft)	Design wave height, Zones B and C	3.5 feet
S_r (unitless)	Specific gravity, computed as w_r/w_w	2.6
w_w (lb/ft^3)	Unit weight of water	64 lb/ft^3

Variable (units)	Definition	Design Value
theta (degrees)	Structure slope angle (from horizontal)	33.7 degrees
K_{RR} (unitless)	Angular graded riprap stability coefficient	2.0

The unit weight of the stone material is assumed to be 165 lb/ft^3, corresponding to a specific gravity of 2.6 relative to the unit weight of seawater. Although the salinity varies along the bluff with Kenai River flows, the effect on the unit weight of water is minimal relative to the armor sizing. The design wave heights provided by the Corps (4.5 feet for Zone A, 3.5 feet for Zone B, and 2.5 feet for Zone C) are used for this analysis. The angle of the revetment is derived from an armor face at a 1.5H:1V slope. As recommended in Table E-3 below, the assumed stability coefficient of 2.0 accounts for graded angular quarrystone subjected to a breaking wave. As recommended for use of the 2.0 stability factor, the armor layer is sized to approximately twice the diameter of the median rock with random placement. Special placement with the long axis of the stone placed perpendicular to the revetment face will increase the factor of safety.

Applying these assumptions to the stability equations gives a calculated W_{50} values presented in Table E-1. The SPM recommends a maximum individual stone weight of four times the W_{50} and a minimum of one-eighth of the W_{50} (USACE 1984). Placing armor stones in the maximum size range would be impractical, particularly for the near-mouth area (Zone A). According to the SPM, uniform-size armor units are generally more economical. The resulting cross sections are attached for review.

Placing armor stones in the maximum size range would be impractical, particularly for the near-mouth area (Zone A). According to the SPM, for waves higher than 5 feet, uniform-size armor units are generally more economical. Bedding layer gradations are designed according to Terzaghi's Equations and other design standards to prevent piping and accommodate the bearing loads. The armor rock and B rock sublayer gradations are tabulated in Table E-4, with layer dimensions shown on Plate C-12 in Attachment G.

Table E-3. Suggested K_D Values for use in determining Armor Unit Weight (Table 7-8, USACE, 1984)

No-Damage Criteria and Minor Overtopping							
Armor Units	n^3	Placement	Structure Trunk $K_D{}^2$ Breaking Wave	Structure Trunk $K_D{}^2$ Nonbreaking Wave	Structure Head K_D Breaking Wave	Structure Head K_D Nonbreaking Wave	Structure Head Slope Cot θ
Quarrystone							
Smooth rounded	2	Random	*1.2*	2.4	*1.1*	1.9	1.5 to 3.0
Smooth rounded	>3	Random	*1.6*	*3.2*	*1.4*	*2.3*	5
Rough angular	1	Random 4	4	*2.9*	4	*2.3*	5
Rough angular	2	Random	2.0	4.0	*1.9*	3.2	1.5
					1.6	2.8	2.0
					1.3	2.3	3.0
Rough angular	>3	Random	*2.2*	*4.5*	*2.1*	*4.2*	5
Rough angular	2	Special 6	5.8	7.0	*5.3*	6.4	5
Parallelepiped 7	2	Special 1	7.0 – 20.0	*8.5 – 24.0*	--	--	
Tetrapod and Quadripod	2	Random	7.0	8.0	*5.0*	6.0	1.5
					4.5	5.5	2.0
					3.5	4.0	3.0
Tribar	2	Random	*9.0*	10.0	*8.3*	9.0	1.5
					7.8	8.5	2.0
					6.0	6.5	3.0
Dolos	2	Random	15.8[8]	31.8[8]	*8.0*	*16.0*	2.0[9]
					7.0	*14.0*	3.0
Modified cube	2	Random	*6.5*	7.5	-----	*5.0*	5
Hexapod	2	Random	*8.0*	9.5	*5.0*	*7.0*	5
Toskane	2	Random	*11.0*	22.0	--	--	5
Tribar	1	Uniform	12.0	15.0	*7.5*	*9.5*	5
Quarrystone (K_{RR}) Graded angular	–	Random	2.2	2.5	--	--	

[1] CAUTION: Those K_D values shown in *italics* are unsupported by test results and are only provided for preliminary design purposes.

[2] Applicable to slopes ranging from 1 on 1.5 to 1 on 5.

[3] n is the number of units comprising the thickness of the armor layer.

[4] The use of single layer of quarrystone armor units is not recommended for structures subject to breaking waves, and only under special conditions for structures subject to nonbreaking waves. When it is used, the stone should be carefully placed.

[5] Until more information is available on the variation of K_D value with slope, the use of K_D should be limited to slopes ranging from 1 on 1.5 to 1 on 3. Some armor units tested on a structure head indicate a K_D-slope dependence.

[6] Special placement with long axis of stone placed perpendicular to structure face.

[7] Parallelepiped-shaped stone: long slab-like stone with the long dimension about 3 times the shortest dimension (Markle and Davidson, 1979).

[8] Refers to no-damage criteria (<5 percent displacement, rocking, etc.); if no rocking (<2 percent) is desired, reduce K_D 50 percent (Zwamborn and Van Niekerk, 1982).

[9] Stability of dolosse on slopes steeper than 1 on 2 should be substantiated by site-specific model tests.

Table E-4. Idealized Multilayer Gradation

Kenai Armor Stone Gradation Calculations

Variable (units)	Definition	Design Value	
W (lbs)	Weight of individual armor unit (primary layer)	Calculated	
w_r (lb/ft^3)	Unit weight of armor unit	165	lb/ft^3
H_1 (ft)	Design wave height, near-mouth area	4.5	feet
$H_{2,3}$ (ft)	Design wave height, remaining area	3.5	feet
s_r (unitless)	Specific gravity, computed as w_r/w_w	2.58	
w_w (lb/ft^3)	Unit weight of water	64	lb/ft^3
θ (degrees)	Structure slope angle (from horizontal)	33.7	deg
K_{rr} (unitless)	Angular graded riprap stability coefficient	2.0	

$s_r=w_r/w_w$

$W=(w_rH^3)/(K_{rr}(s_r-1)^3\cot\theta)$

W (for H_1): **1276** lbs

W (for H_2): **600** lbs

Diameter=((W*6)/(π*w_r))^(1/3)

Rock Size Gradation

Rock Size	Layer	Denominator	Gradation		Gradation for H_1 (lbs)					
			from	to	W_0	D_0	W_{50}	D_{50}	W_{100}	D_{100}
W	Primary Cover Layer	1	75%	125%	957	2.2	1276	2.5	1595	2.6
W/10	First Underlayer	10	30%	130%	38	0.8	128	1.1	166	1.2
W/15	Secondary Cover Layer Toe	15	75%	125%	64	0.9	85	1.0	106	1.1
W/200	Second Underlayer	200	50%	150%	3.2	0.3	6	0.4	10	0.5
W/6000	Core and Bedding Layer	6000	30%	170%	0.1	0.1	0.2	0.1	0.4	0.2

Rock Size	Layer	Denominator	Gradation		Gradation for H_2 (lbs)					
			from	to	W_0	D_0	W_{50}	D_{50}	W_{100}	D_{100}
W	Primary Cover Layer	1	75%	125%	450	1.7	600	1.9	750	2.1
W/10	First Underlayer	10	30%	130%	18	0.6	60	0.9	78	1.0
W/15	Secondary Cover Layer Toe	15	75%	125%	30	0.7	40	0.8	50	0.8
W/200	Second Underlayer	200	50%	150%	1.5	0.3	3.0	0.3	4.5	0.4
W/6000	Core and Bedding Layer	6000	30%	170%	0.0	0.1	0.1	0.1	0.2	0.1

Filter Layer Gradation

In the design provided in Attachment G, groundwater that currently emerges from the bluff face continues to flow along the seepage plane but remains subsurface within a layer of alluvial fill material. The alluvial material placed at the toe acts as a filter layer to prevent piping of soil, and the groundwater emerges through geotechnical fabric underlying the rock revetment. The fabric allows groundwater seepage while preventing piping of the granular material. Benching into the bluff face is recommended to expose undisturbed material. Control of the seepage water will also be important during construction. The fill should not be allowed to become excessively wet prior to compaction. An open-graded gravel material against the bluff face is recommended to aide in drainage as necessary.

Contacts at various Alaska agencies have provided examples of successes as well as slope failures, vegetation desiccation, or other issues encountered on projects with slopes of similar scale and/or materials, including some with similarities in climate zone, soil types and other parameters. The applicability of reference sites or other details may be revisited upon receipt of additional monitoring data.

Table E-5 presents a recommended filter layer gradation. The recommended gradation is held relatively loose with overlapping bounds to prevent the exclusion of most of the alluvial borrow material. A coarser material would potentially preclude the use of existing alluvial deposits and potentially drain the soils below the establishing roots of the vegetation on the bluff face. To help facilitate drainage, a layer of coarser gravel in areas where the seepage is greatest may be beneficial. Placement of localized gravel lenses would require import or sorting, and the coarse material would require an intermediate filter layer as bedding to prevent piping. The soil used as granular fill material should contain no muck, frozen material, roots, sod, or other delirious matter. The plasticity shall not exceed 6. In some locations, the existing bluff sediments include fines exceeding the maximum allowable percentage specified in Table E-5. Some sieving of these materials from the stockpile may be required.

Table E-5. Filter Layer Gradation

Sieve	% Passing
3”	100%
#4	20-100%
#60	0-50%
#200	0-6%

Slope Drain or V-Ditch for Stormwater Management

The schematic illustration in Figure E-2 shows a typical solution for routing flows from a collection basin to the toe of the bluff in a slope drain configuration. Slope drains are commonly used on roadway fills. The berm in the illustration can be constructed of earthen fill, concrete, asphalt, or other materials. The inlet can be horizontal or vertical, with or without grating, or apply other configurations. The drain itself can be open channel (earthen, geotextile, rock, asphalt, or concrete V-ditch) piped (anchored surface pipe or buried pipe), or a combination (French drain, half-round corrugated metal). Dissipation at the outlet is typically provided with rock, concrete baffles, or other solution.

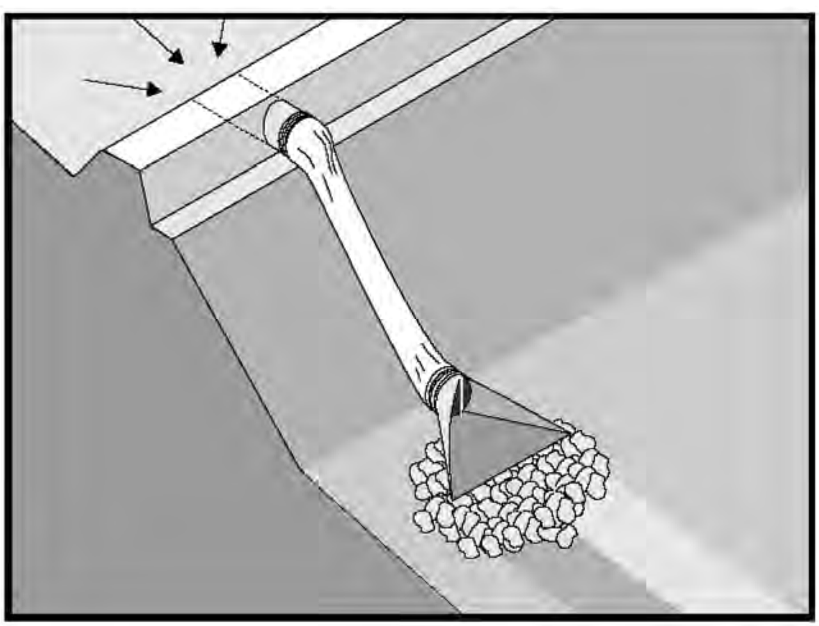


Figure E-2. Typical Slope Drain (Source: CASQA)

For a pipe solution in Kenai, freezing conditions would cause concerns. Local building codes utilize a design frostline depth of 42 inches, with pipes commonly placed 1 foot below the frostline. Blockage of the outlet by ice could present a safety hazard because of the substantial head that could build up behind the ice. Maintenance of the pipe could also present concerns. Alternatives including geotextile liners, rock, asphalt, concrete, and vegetated swales, anchored surface pipes, a grid or hardened trenches, french drains, and other solutions were presented to the Corps in a meeting held 4/30/2008. In light of potential maintenance, safety, aesthetic, and other concerns, all parties were in favor of infiltration basins and bioswales at the top of the bluff, rerouting flows to the City's storm drain network, and handling excess flows through an open channel, rip rap V-ditch rather than a buried pipe or other solution.

Additional details on the City's storm drain network are not expected to become available during the current study period; a combination of these alternatives is therefore proposed as an interim solution in the draft design. The vegetated swales and basins serve to attentuate peak flows. Connection to the City's storm drain network is supplemented by a flashboard riser which feeds into a culvert across the maintenance road and a rip rap V-ditch 10 feet wide and 1 foot deep. Applying the rational method and HEC-RAS to the infiltration basin, culvert and ditch under a conservative 100-year rainfall intensity of 2 inches per hour yields the following results:

Table E-5 Stormwater Parameters

Zone	Drainage Area (ac)	Impervious Area (%)	Rational Coefficient	Peak Discharge (cfs)	Channel Velocity (fps)	Channel Shear (psf)
A	18	40	0.6	22	12	11
B	25	30	0.5	25	13	12
C	5	0	0.2	2	7	5

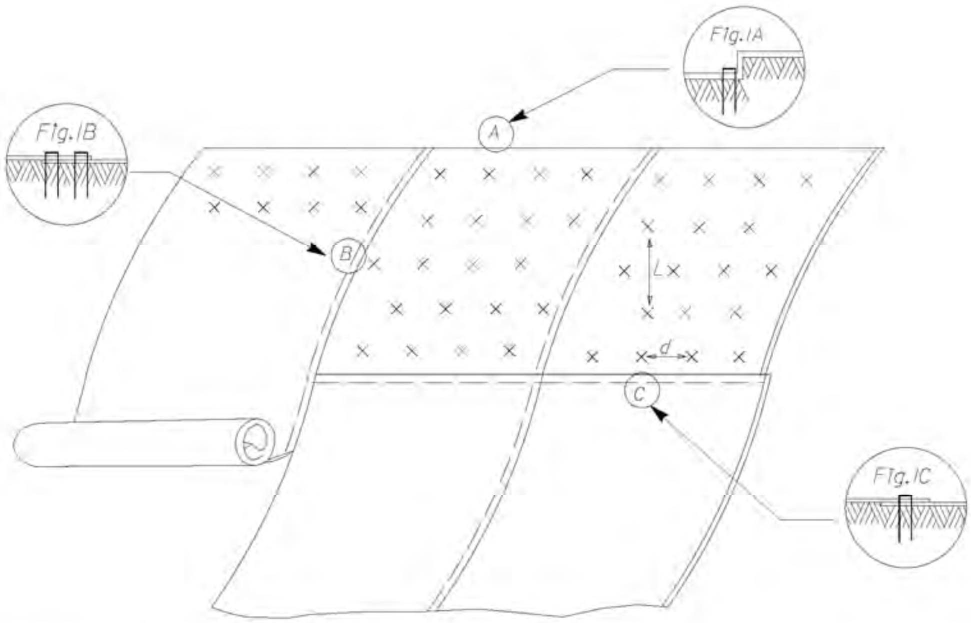
The proposed rip rap thickness is 2.5 feet, with a D_{50} of 12 inches and a D_{100} of 18 inches. The rip rap should be well-graded and compacted with void spaces filled. The larger rock should project from the surface, generating enough turbulence to prevent sustained supercritical flows. A rip rap geotextile should underlie the V-ditch. The V-ditch is intended for emergency overflows only. Rock and other debris may be mobilized down the slope during freeze-thaw cycles. Localized maintenance activities may be required after severe events. As more detailed stormwater discharge details become available, design parameters should be verified using rock chute design programs such as those available through NRCS (ASAE 1998), USBR, or in Corps Engineering Manuals such as EM 1110-2-1601.

Filter Fabric Recommendations

Filter Fabric recommendations:

- Filter fabric with an Apparent Opening Size (AOS) <0.3mm
- Permittivity >0.1 sec-1
- Strong and stiff fabric
- Grab strength >700 N
- Elongation 15%
- Burst Strength >1300 kPa
- Trapezoidal Tear >250 N.
- Examples include Mirafi FW500 and FW700.

http://www.usfabricsinc.com/



General Installation Instructions for TRM and Blanket in Slopes

1. Prepare soil, including grading, application of lime, fertilizer, and seeds. The surface of the soil should be smooth and free of rocks, roots and other obstructions.
2. Start at the top of the slope by anchoring blankets in a 6" deep and 6" wide anchor trench, place blankets, staple (8" staples recommended), backfill and compact. (Fig. 1A)
3. Roll the blankets down the slope (recommended for steep slopes) or across the slope. Staple the open blanket edge using one row of staples at 1.5 – 2 feet intervals. The middle of the blankets should be stapled using a preferred staple pattern (Table 1). Be sure to lay blankets loosely on the ground allowing a good contact between soil and blankets.
4. When blanket splicing is necessary, use an 8 inch overlap. Use two rows of staples to anchor blankets. A twelve inch staple spacing with a staggered pattern is recommended. Overlap sides of blankets at least 6" and use staples along the overlap at 12" spacing (Fig. 1C).
5. Provide a 6" deep and 6" wide anchor trench at the toe of the slope or streambank or shoreline. This anchor trench in streambanks and shorelines may be replaced with BioD-Roll coir rolls.
6. Use wire staples of gauge 11 or lower and a minimum length of 8". If wooden pegs are used, the minimum length is 12 inches. Anchors should be long enough to provide a strong bond between the blanket and the ground. Require anchor length may vary depending on the soil conditions.
7. This procedure could be altered at the discretion of the site engineer / architect.

TABLE 1

STAPLE PATTERN		
SLOPE	L	D
> 1:1 Slopes	3.0'	2.0'
2:1 Slopes	4.0'	2.0'
3:1 Slopes	6.0'	3.0'
4:1 Slopes	8.0'	3.0'

Figure E-3. Typical Erosion Control Installation Details (Source: www.rolanka.com)

Table E-6 General Specifications for Erosion Control Fabric

Following are minimum design criteria for erosion control fabric. Equivalent products shall meet the properties shown. The blankets shall be woven from coir twines. Coir twines shall be made of bristle coir obtained from freshwater cured coconut husks which shall be machine spun to a uniform diameter. The blanket shall also conform to the following properties.

Property	Test Method	BioD-Mat 90
Weight	ASTM D 3776	29 oz/SY
		(980 g / m^2)
Tensile Strength **Dry**	ASTM D 4595	
Machine direction		2024 lbs/ft
		(29.6 kN/m)
Cross direction		1160 lbs/ft
		(17.0 kN/m)
Tensile Strength **Wet**	ASTM D 4595	
Machine direction		1776 lbs/ft
		(26 kN/m)
Cross direction		936 lbs/ft
		(13.7 kN/m)
Open area	Calculated	38%
Thickness	ASTM D1777	0.35 inch
		(9 mm)
Number of twines in the mat		
Machine direction		117 / yard (128 / m)
Cross direction		55 / yard (60 / m)
Recommended slope		>1:1
Recommended flow		16 fps
		(4.9 m/s)
Recommended shear stress		5 lbs /ft^2
		(240 N/m^2)
"C" factor		0.002

(Source of specifications www.rolanka.com)

Table E-7 Equivalent Geogrid Products

Manufacturer	Product	LTDS
Huesker Inc	Fortrac 20/13-20	780
Strata Systems	Stratagrid 150	1008
Mirafi	Miragrid 2XT	1082
Synteen Technical Fabrics	SF 20	1099
Huesker Inc	Fortrac 35	1322
Tensar Earth Technologies	UX1100HS	1450*
Tensar Earth Technologies	UX1400HS	1760*
Synteen Technical Fabrics	SF 35	1787
Mirafi	Miragrid 3XT	1705
Strata Systems	Stratagrid 200	1918
Huesker Inc	Fortrac 55	2027
Mirafi	Miragrid 5XT	2327
Synteen Technical Fabrics	SF 55	2361
Strata Systems	Stratagrid 350	2685
Tensar Earth Technologies	UX1500HS	2860*
Mirafi	Miragrid 7XT	3084
Huesker Inc	Fortrac 80	3117
Strata Systems	Stratagrid 500	3507
Tensar Earth Technologies	UX1600HS	3620*
Mirafi	Miragrid 8XT	3788
Huesker Inc	Fortrac 110	4130
Synteen Technical Fabrics	SF 80	4133
Tensar Earth Technologies	UX1700HS	4390*
Strata Systems	Stratagrid 550	4466
Synteen Technical Fabrics	SF 90	4747
Strata Systems	Stratagrid 600	4987
Tensar Earth Technologies	UX1800HS	5080*
Mirafi	Miragrid 10XT	5141
Huesker Inc	Fortrac 150	5535
Synteen	SF 110	5700
Mirafi	Miragrid 20XT	6252
Strata Systems	Stratagrid 700	6411

Source: www.usfabrics.com

Table E-8 General Specifications for Geogrid

Ultimate and Creep Limited Strengths

			Microgrid[1,3]	SG 150[1]	SG 200	SG 350	SG 500	SG 550	SG 600	SG 700
Ultimate Strength[2,3]	ASTM D-6637 METHOD A	lbs/ft (kN/m)	2000 (29.2)	1875 (27.4)	3500 (51.1)	4900 (71.5)	6400 (93.4)	8150 (118.9)	9100 (132.8)	11700 (170.7)
Creep Limited Strength	ASTM D-5262	lbs/ft (kN/m)	1266 (18.5)	1165 (17.0)	2215 (32.3)	3101 (45.3)	4051 (59.1)	5158 (75.3)	5759 (84.1)	7405 (108.1)

	Microgrid	SG 150	SG 200	SG 350	SG 500	SG 550	SG 600	SG 700
$RF_{installation\ damage}$ (Sand, Silt & Clay, D_{50} < 0.6mm)	1.20	1.05	1.05	1.05	1.05	1.05	1.05	1.05
$RF_{installation\ damage}$ (3/4" minus angular aggregate, D_{50} < 6mm)	1.30	1.10	1.10	1.10	1.10	1.10	1.10	1.10
$RF_{installation\ damage}$ (1.5" minus angular aggregate, D_{50} < 20mm)	1.40	1.20	1.20	1.20	1.20	1.20	1.20	1.20
$RF_{durability}$	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10

Long-Term Design Strength (LTDS or T_{al})[4]

		Microgrid[1]	SG 150[1]	SG 200	SG 350	SG 500	SG 550	SG 600	SG 700
For Sand, Silt & Clay	lbs/ft (kN/m)	959 (14.0)	1008 (14.7)	1918 (28.0)	2685 (39.2)	3507 (51.2)	4466 (65.2)	4987 (72.8)	6411 (93.6)
For ¾" minus angular aggregate	lbs/ft (kN/m)	885 (12.9)	962 (14.0)	1813 (26.7)	2563 (37.4)	3348 (48.9)	4263 (62.2)	4760 (69.5)	6120 (89.3)
For 1.5" minus angular aggregate	lbs/ft (kN/m)	822 (12.0)	882 (12.9)	1678 (24.5)	2349 (34.3)	3069 (44.8)	3908 (57.0)	4363 (63.7)	5610 (81.9)

Soil Interaction Coefficients for Pullout (C_i) and Direct Sliding (C_{ds})

Sand/Clay (ML, CL)	0.6 - 0.7
Sandy Silts & Clay (SC, GC)	0.7 - 0.8
Uniformly-Graded Sands, Silty Sand (SP, SM)	0.8 – 0.9
Gravel, Sand Gravel Mix, Well-Graded Sand (SW, GP, GW)	0.9 – 1.0

Molecular Properties

Item	Unit	Spec
Molecular Weight (min.)	g/mol	25000
Carboxyl End Group (CEG) Count (max.)	Meq/kg	60

Physical Properties

			Microgrid	SG 150	SG 200	SG 350	SG 500	SG 550	SG 600	SG 700
Roll Dimensions	Width x Length	feet (m)	10 x 225 (3.05 x 68.6)	6 x 150 (1.83 x 45.7)	6 x 300 (1.83 x 91.4)	6 x 300 (1.83 x 91.4)	6 x 300 (1.83 x 91.4)	6 x 300 (1.83 x 91.4)	6 x 300 (1.83 x 91.4)	6 x 300 (1.83 x 91.4)
Area		Sq. Yds Sq. m	250 (209)	100 (83.6)	200 (167.2)	200 (167.2)	200 (167.2)	200 (167.2)	200 (167.2)	200 (167.2)
Weight Per Roll		lbs (kg)	105 (47.6)	45 (20.4)	110 (49.9)	130 (59.0)	155 (70.3)	170 (77.1)	180 (81.6)	210 (95.3)

[1]Bi-Axial (strength in both directions) / [2]Microgrid Ultimate Tensile per ASTM D-4595 / [3]Values shown are Minimum Average Roll Values

[4]LTDS or T_{al} = Tult (RFcreep x RFinstallation damage x RFdurability) as per FHWA NHI-00-043

Source: www.usfabrics.com
Additional info: http://www.gxgeogrids.com/

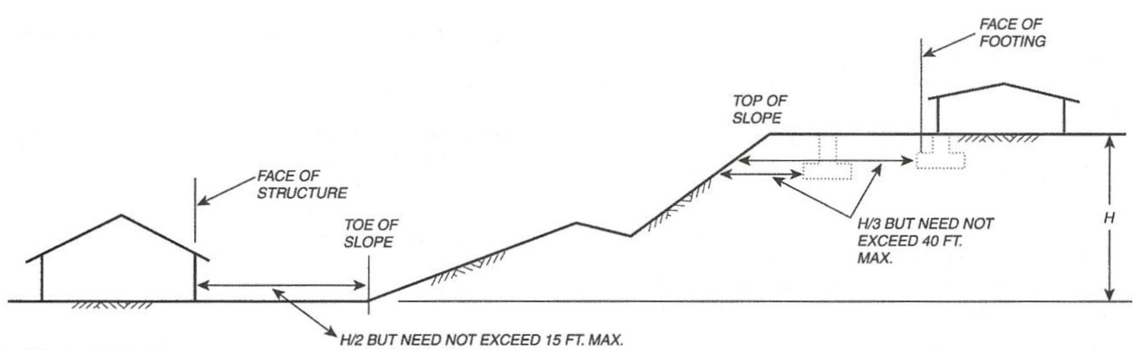
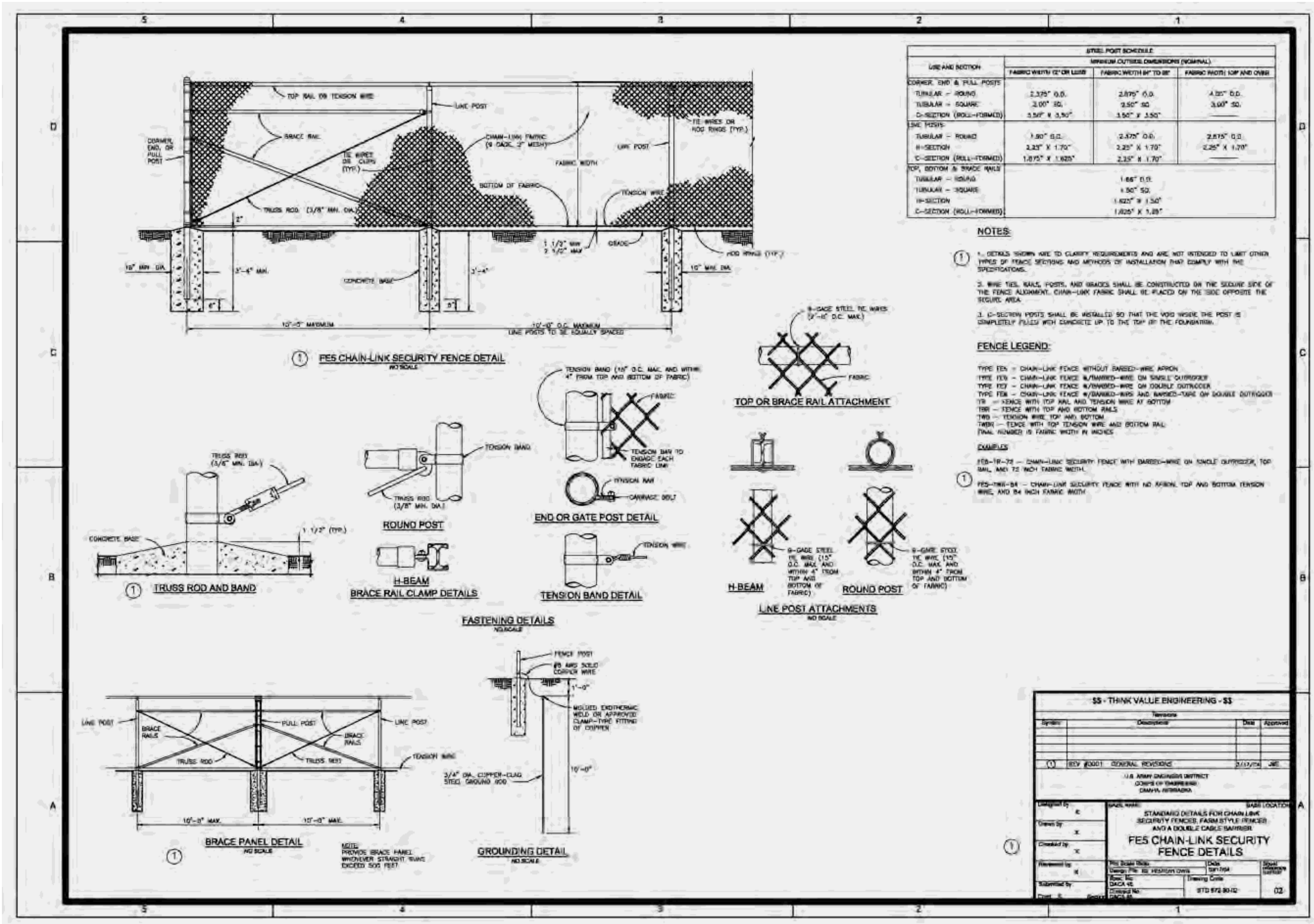
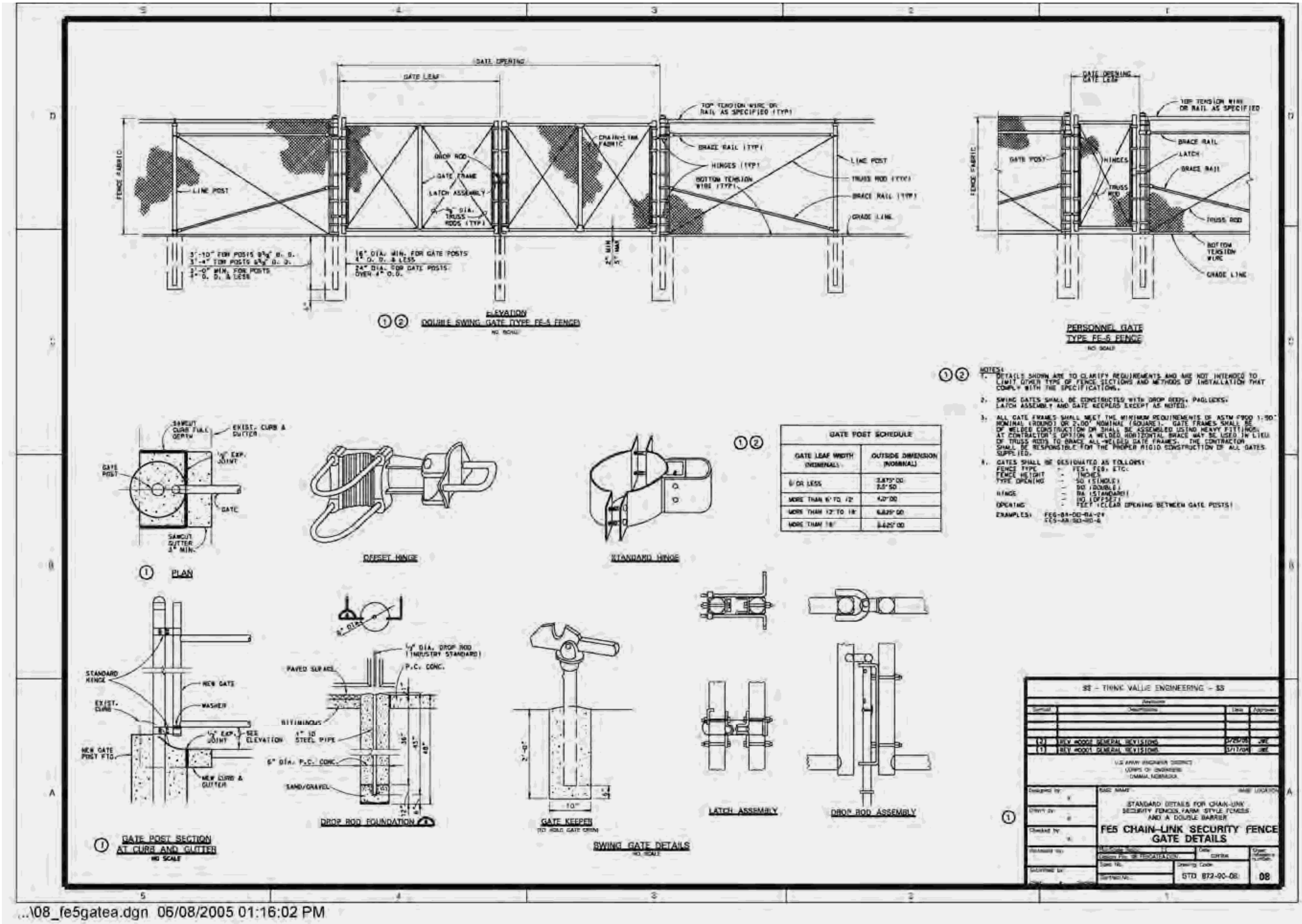


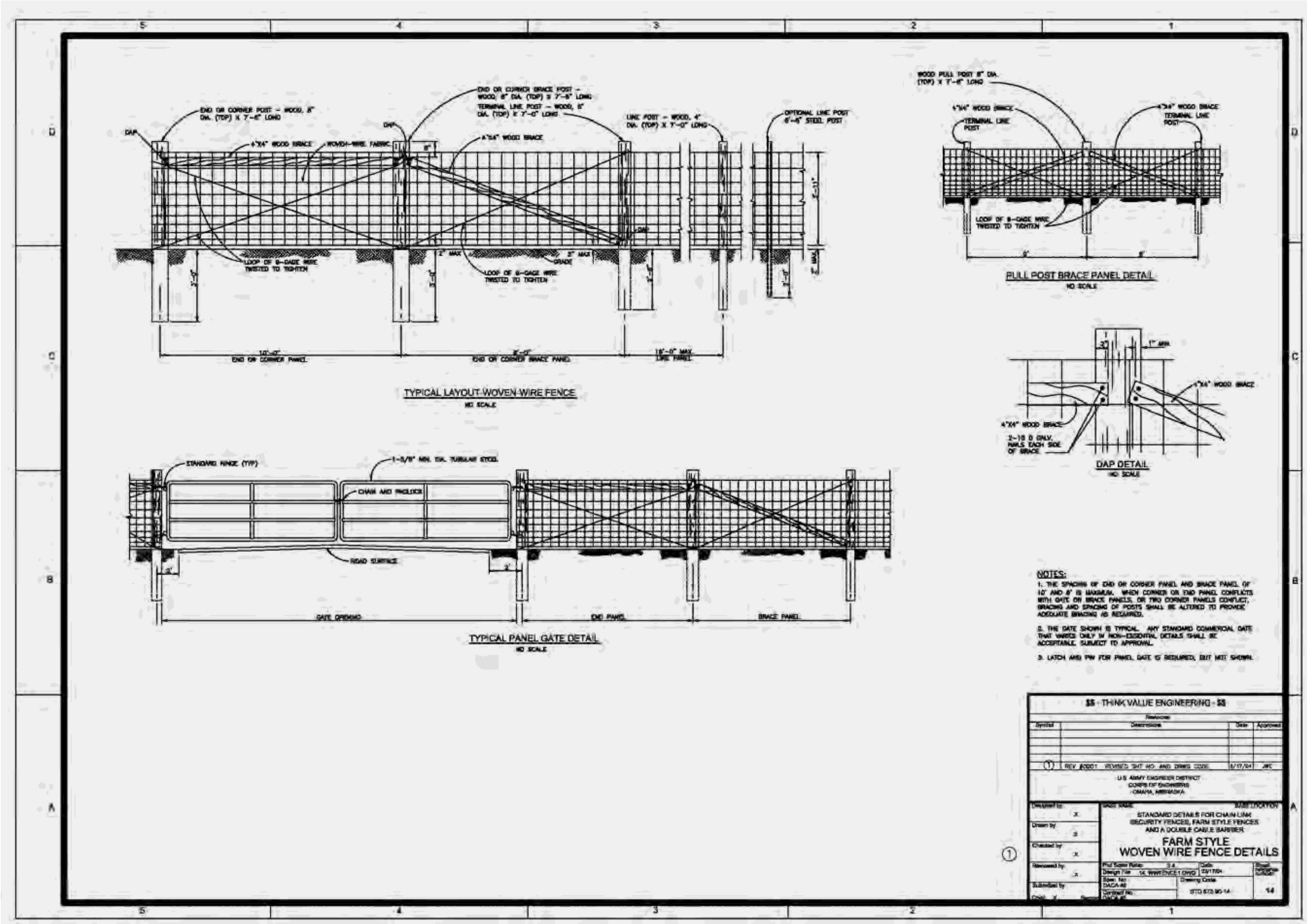
Figure E-4. Typical Setback Recommendations (ICC 2006)

Security Fencing

The Draft Design Plans in Attachment I show a wood plank fence along the project boundary. Wood plank fencing generally provides preferable aesthetics to chain link fencing; however, it also may present obstruction of views for parcels along the top of the bluff. The following figures show Corps standard plans for chain link and woven wire fencing and access gates that may be preferred by residents.


STEEL POST SCHEDULE
NOTES:
FENCE LEGEND:
EXAMPLES
FES CHAIN-LINK SECURITY FENCE DETAIL
NO SCALE
TOP OR BRACE RAIL ATTACHMENT
END OR GATE POST DETAIL
ROUND POST
TRUSS ROD AND BAND
H-BEAM
BRACE RAIL CLAMP DETAILS
TENSION BAND DETAIL
FASTENING DETAILS
LINE POST ATTACHMENTS
BRACE PANEL DETAIL
GROUNDING DETAIL
$$ - THINK VALUE ENGINEERING - $$
FES CHAIN-LINK SECURITY
FENCE DETAILS


GATE OPENING
GATE LEAF
ELEVATION
DOUBLE SWING GATE (TYPE FE-5 FENCE)
NO SCALE
PERSONNEL GATE
TYPE FE-5 FENCE
NO SCALE
GATE POST SCHEDULE
GATE LEAF WIDTH (NOMINAL)
OUTSIDE DIMENSION (NOMINAL)
MORE THAN 6' TO 12'
MORE THAN 12' TO 18'
MORE THAN 18'
PLAN
OFFSET HINGE
STANDARD HINGE
GATE POST SECTION AT CURB AND GUTTER
NO SCALE
DROP ROD FOUNDATION
GATE KEEPER
LATCH ASSEMBLY
DROP ROD ASSEMBLY
SWING GATE DETAILS
NO SCALE
$$ - THINK VALUE ENGINEERING - $$
STANDARD DETAILS FOR CHAIN-LINK SECURITY FENCES, FARM STYLE FENCES AND A DOUBLE BARRIER
FE5 CHAIN-LINK SECURITY FENCE GATE DETAILS
STD 872-90-08
08
...\08_fe5gatea.dgn 06/08/2005 01:16:02 PM


TYPICAL LAYOUT WOVEN WIRE FENCE
NO SCALE
PULL POST BRACE PANEL DETAIL
NO SCALE
DAP DETAIL
NO SCALE
TYPICAL PANEL GATE DETAIL
NO SCALE
NOTES:
$$ - THINK VALUE ENGINEERING - $$
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
OMAHA, NEBRASKA
STANDARD DETAILS FOR CHAIN LINK SECURITY FENCES, FARM STYLE FENCES AND A DOUBLE CABLE BARRIER
FARM STYLE
WOVEN WIRE FENCE DETAILS

ATTACHMENT F

PROPOSED CONSTRUCTION SEQUENCE

The following sequence is proposed for constructing the Kenai Bluff Stabilization Project:

1. Mobilize equipment and prepare site

The temporary staging areas and permanent construction zones along the top of the bluff would initially be cleared and grubbed of vegetation and debris, with the materials stockpiled on site or removed for off-site disposal. The trees lining the top of the bluff within the project footprint would also be removed. Affected utilities located within the construction area would be rerouted as needed. Some small structures would be demolished and resulting debris would be hauled off-site. In addition, all abandoned concrete and timber foundations located within the construction area would be removed and hauled to the selected disposal area. Temporary stormwater and erosion control measures would be implemented according to the adopted SWPPP. Temporary security fencing would be installed along the bluff above the construction area according to the fencing details in the plans.

2. Construct four access ramps from top of bluff to toe of bluff
    a. Cemetery Creek
    b. Ryan’s Creek (west)
    c. Ryan’s Creek (east)
    d. Pacific Seastar

Figure F-1. Ramps and Stockpile/Staging Areas

The ramps would follow the alignment of the control line in the design plans from the top of bluff to the proposed bench elevation and would then proceed to the toe of the bluff along the same alignment. Materials excavated for the construction of the access ramps would need to be sorted and temporarily stored. Four temporary stockpile or staging areas are shown in Figure F-1. A partial ramp already exists near ramp *d*. While small amounts of material could be stored in the two westernmost staging areas, due to space limitations, the bulk of the material would need to be stored in the outlined areas near the senior center, requiring road transport for the materials excavated for ramps *a* and *b*. Organics and topsoil would need to be separated and stored separately for later disposal or reuse.

3. Construct temporary haul road from ramp *d* to *c*

Granular material suitable for construction of a haul road would be sorted from the stockpile near the senior center. After some preliminary grading of the haul road alignment, this material would be placed from *d* to *c* to construct a temporary haul road. Due to the nature of the tide flat, the preliminary grading, material placement and compaction would be done with equipment from each constructed reach of the haul road itself. Where possible, the elevation and alignment of the haul road would match the proposed top of the alluvium/till mix (“CF” zone) shown in the individual cross sections (10 vertical feet below the top of revetment). The haul road fill could then be used as backing for the geotextile underlying the rock. An example is shown as the cross-hatched pattern in Figure F-2 for Section 12+00. This section is used as a representative cross section throughout this document. Other cross sections vary in their balance of cuts and fills and the zones outlined in the figures would be reduced or increased accordingly; the proposed grading plan attempts to balance the cuts and fills with the reuse of suitable material for the overall project. 6-wheel drive articulated trucks with a 30 cy capacity are assumed for hauling.

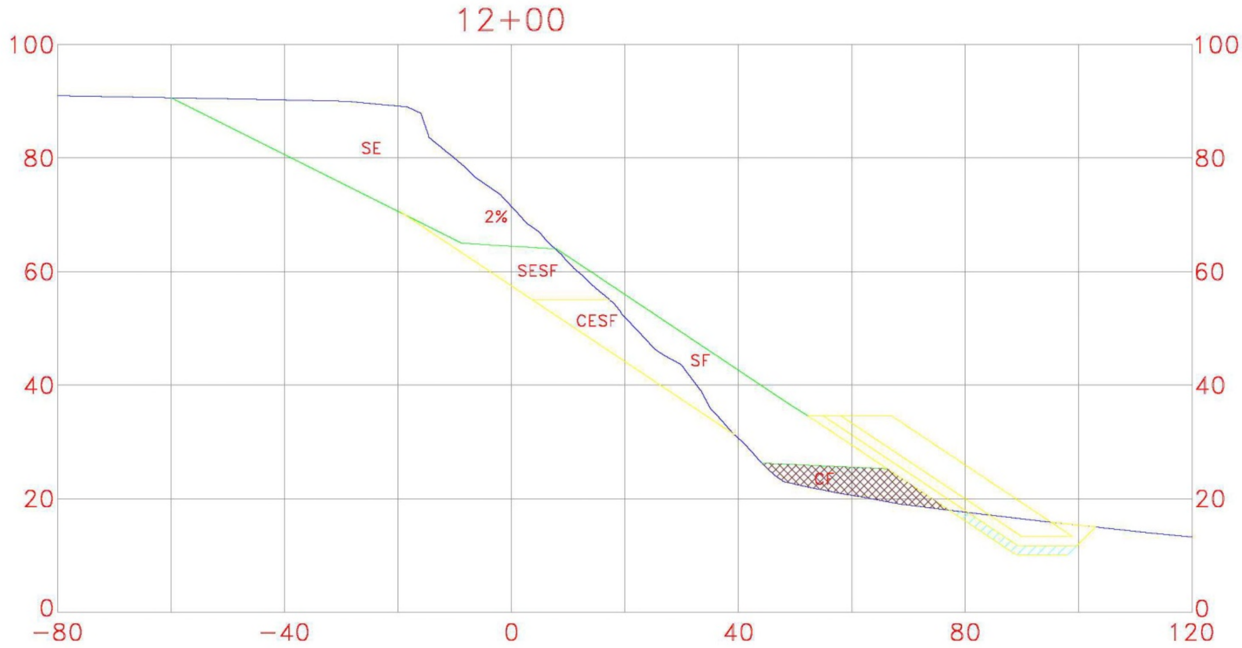


Figure F-2. Haul Road Location in Section View

4. Construct temporary bridge over Ryan's Creek

As shown in Figure F-3, a temporary bridge would need to be constructed over Ryan's Creek to connect the construction zones between ramps *c* and *b*. Placement of culverts with rock cover would allow for scour protection and vehicle access; however, a wider opening may be desirable. The bridge could be a set of flatbed trailers or could utilize a similar approach. The bridge would be placed at the haul road elevation or above. During limited time periods in extreme high tide conditions, the haul road would become submerged, and placement of the bridge at a higher elevation may be warranted to prevent submersion. The Ryan's Creek area is a highly sensitive environment, and the proposed bridge would need to be coordinated with the relevant jurisdictional authorities to avoid adverse impacts.

5. Construct temporary haul road from ramp *b* to *a*

The sorted material would be hauled from the senior center stockpile along ramp *d* and then over the temporary bridge to be used to construct a haul road from ramp *b* to *a*. The haul road would need to be extended past each ramp to facilitate the placement of rock to the tie-in point with the hillside. Because the project footprint does not extend through these areas (particularly due to the sensitive habitat at Cemetery Creek and Ryan's Creek) trucks and other construction equipment would need to back in or out of these areas rather than operating in a loop. A second bridge over Ryan's Creek was considered to connect the endpoints of the haul road; however the radius would limit the equipment capable of making the turn. Construction of a turnaround with sufficient radius does not appear to be feasible along the toe of the bluff. Some efficiency may be lost in having to back vehicles to the nearest access ramp during construction of the haul road, and this has been accounted for in the cost estimate.

Figure F-3. Haul Road Location in Plan View

6. Excavate material from top of bluff

Several passes with a scraper would be needed to remove organics and the upper silt layer. The excavation equipment would need to be located a sufficient distance from the edge of bluff to avoid the risk of bank failure caused by the equipment. As shown in Figures F-4 and F-5, the initial passes would extend along the proposed bluff face, leaving sufficient distance to the bluff edge. Material close to the edge of the bluff could be excavated with excavators, draglines, or other equipment once the scraper passes have reached their maximum extent. The excavated material between ramps *a* and *b* would be transported along city streets to the stockpile area while excavated material between ramps *c* and *d* could be transported directly to the stockpile without on-road vehicle limitations. The granular material that meets the specification for use as the filter layer would be separated and stockpiled for placement. The proposed haul routes and initial excavation passes are shown as dashed lines below. The cross section below shows in the hatched pattern where excavation could commence with scrapers and other heavy equipment. Some material may be collected from the haul road at the toe of the bluff, either by equipment pushing it down from above or pulling it down from below, particularly where the excavation depth along the bluff would not allow for a sufficiently wide bench on which to locate excavation equipment. In some areas, such as along Mission Avenue, only minimal excavation would occur as most of the cross section is in fill. The exposed bluff face would be notched or scarified to prepare for the placement of the filter layer or topsoil backfill.

Figure F-4. Schematic Excavation and Haul Routes

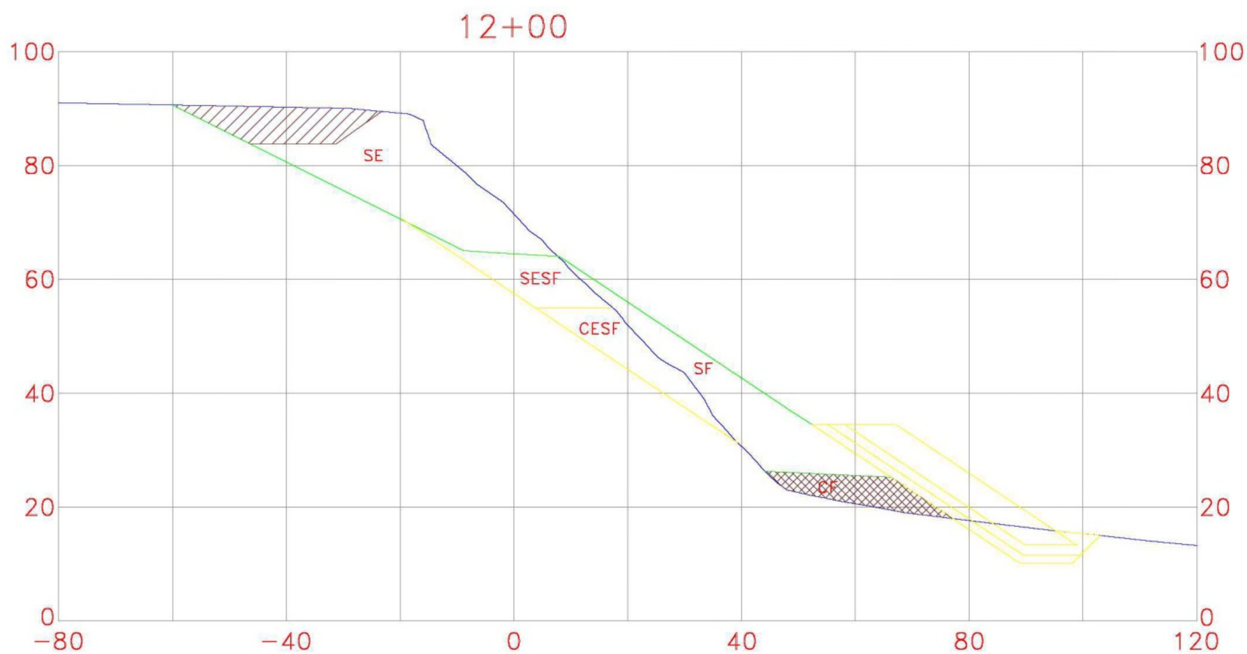


Figure F-5. Initial Excavation in Section View

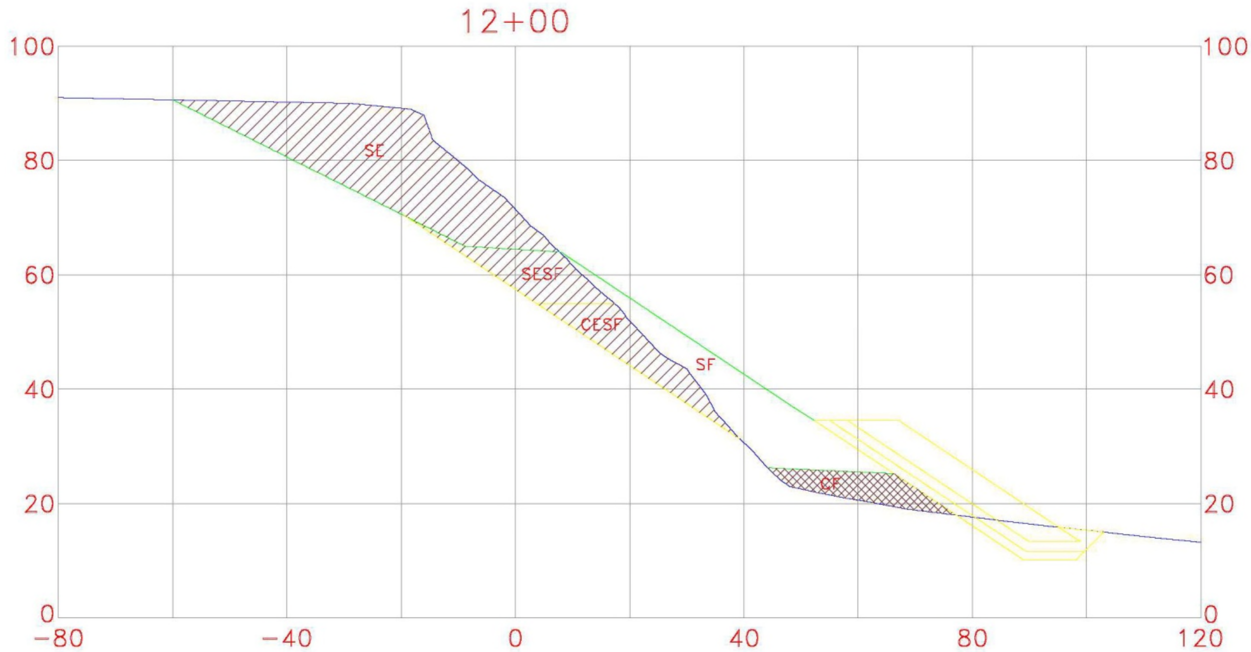


Figure F-6. Total Excavation in Section View

7. Sort material for use in filter layer

Most of the material located above the lag gravel layer would be suitable for use in backfilling the filter layer. This material would be sorted at the stockpile site, while additional material sourced from below the lag gravel layer will likely be unsuitable. This additional material (primarily glacial till) will be mixed with alluvium as necessary to meet requirements for fill zones outside of the filter layer, with the remainder hauled offsite for disposal. The stockpile areas may include piles up to 20 feet high to accommodate the amount of material being handled.

8. Place and compact backfill filter layer

The suitable material would be taken from the stockpile for placement in the filter layer above the haul road. Placement and compaction equipment could be operated on each successive layer of fill; the installation of a geogrid is proposed at every other compaction lift to improve the slope stability. Revised quantity estimates for suitable and unsuitable material are included in the MII cost report. The schematic location of the initial fill zone is shown in Figures F-7 and F-8.

Figure F-7. Fill Zones in Plan View

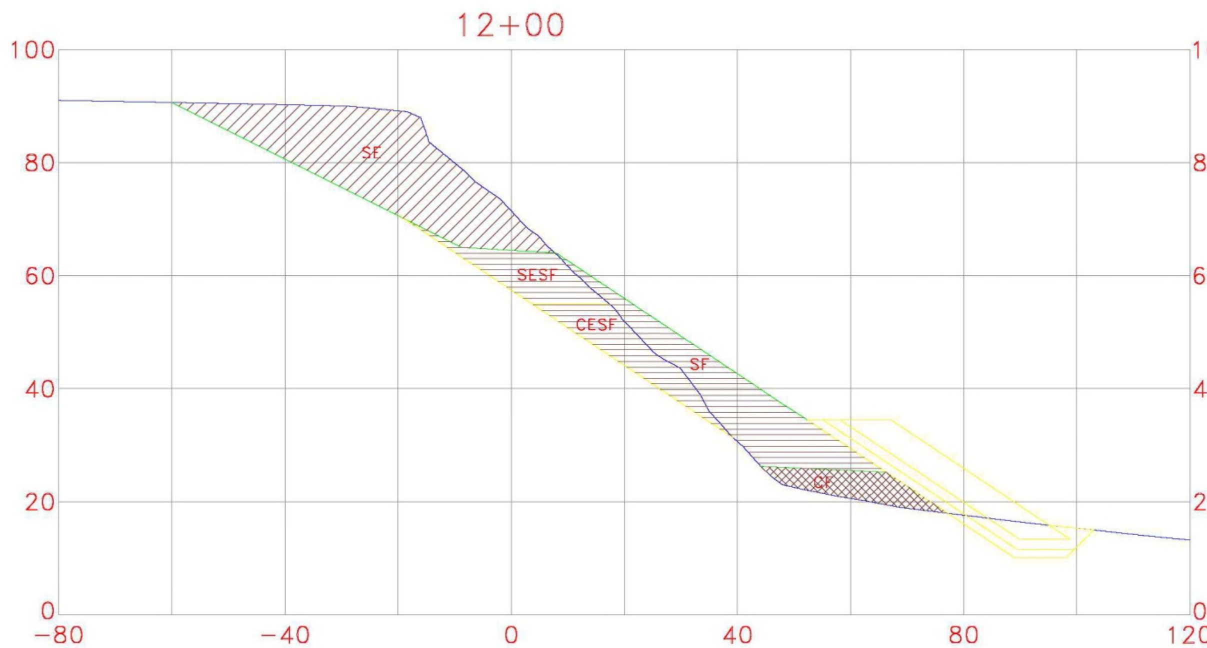


Figure F-8. Fill Zones in Section View

The exposed bluff face in any proposed fill areas would be notched to avoid a smooth interface between soil types. The proposed construction sequence does not include driving vehicles on the sloping bluff face but rather filling in horizontal layers with a bucket or other extension performing the final smoothing and compaction of the immediate face. The topsoil layer would be placed in several increments so as not to exceed the reach of the construction equipment.

9. Place rock

The geotextile fabric, sublayers, and armor rock would need to be placed while the haul road is at a sufficient elevation to allow equipment access. Rock is therefore likely to be placed in several stages as the backfill is placed on the haul road. Rock could be imported through a combination of barging and land-based equipment with the barge placing apron material at high tide, and the land-based equipment placing the remaining armoring at low tide. Complete segments of the armor section would be completed during each low tide cycle to at least the elevation of the maximum tide lines. It is assumed the land based equipment would operate for half of the shift and the water based equipment would operate the other half. Hauling has been assumed to be done entirely by land in the current estimate; barging the rock over water is also presented as an alternative in the design report to facilitate future agency coordination that may be required to leave that option open to the contractor. Placement of the rock is assumed to be by hydraulic excavator.

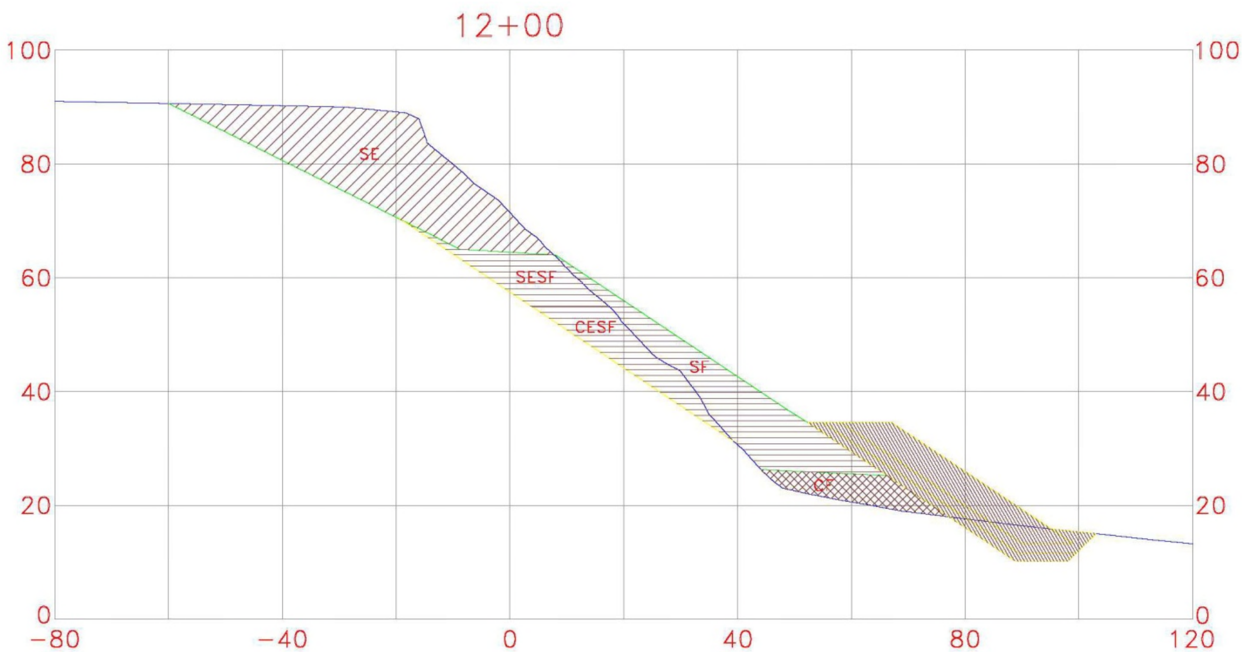


Figure F-9. Rock Placement in Section View

10. Place geotextile

Erosion control fabric is proposed along the entire bluff face due to the relatively steep slope. The fabric would be pinned to the compacted material below, with the spacing of the stakes doubled to provide an additional safety factor against the adverse conditions. Fabric staking would likely occur with hand placement and potentially ATV-mounted transport of materials to the bench area.

11. Additional features

Construction of the rock drainage chutes, stormwater basins, and other ancillary features will take place throughout the construction window. Road works, including the installation of a guardrail system and repaving disturbed areas will occur in keeping with the traffic control plan prepared by the contractor and adopted by the owner.

12. Initiate phased planting approach

Planting will commence following construction activities. The schedule for each phase will depend on the successful establishment of each previous phase. Placement would be manual, with limited equipment access along the bench.

13. Construct recreational features

Interpretive signage kiosks are proposed in three locations along the bench. Timber platforms are to be constructed along the top of the bluff, with stairs leading to the platforms where necessary. Three-seat benches are to be placed at each overlook along the top of the bluff.

14. Demobilization

The construction laborers, equipment and other personnel are assumed to come from Anchorage. It is estimated that overall construction would take approximately 15 months to construct. This duration has been used in the estimate to determine costs for the contractor to maintain field facilities and construction supervision. The overall schedule is based on a construction crew (1 shift) working 12hrs per day and 6 days per week. A tentative project schedule of the overall project is presented along with crews, equipment, and additional details in the cost engineering report.

ATTACHMENT G

DESIGN PLANS

Figure G-1. Conceptual Plan View, Zone A

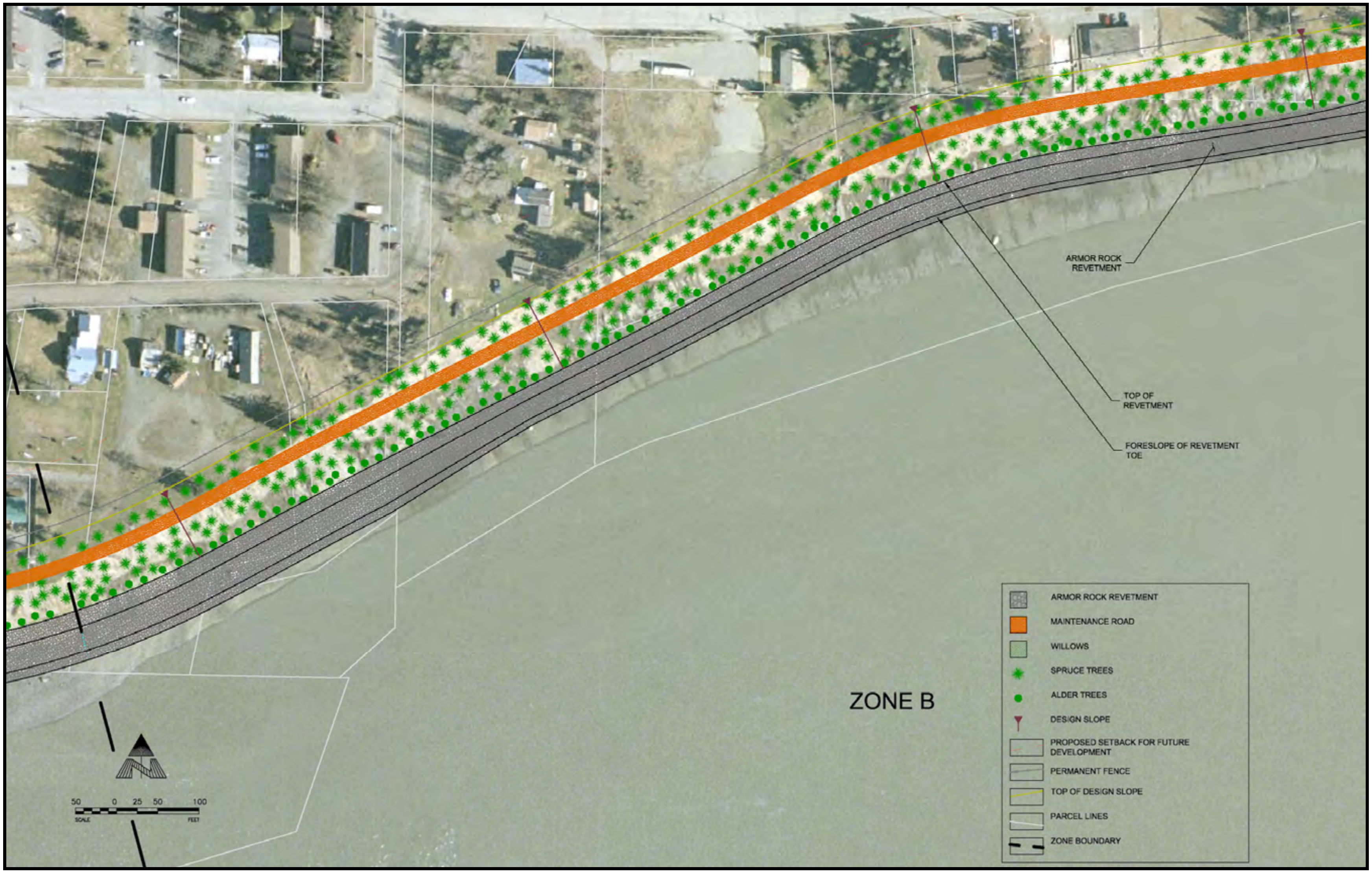


Figure G-2. Conceptual Plan View, Zone B

Figure G-3. Conceptual Plan View, Zone B (cont)

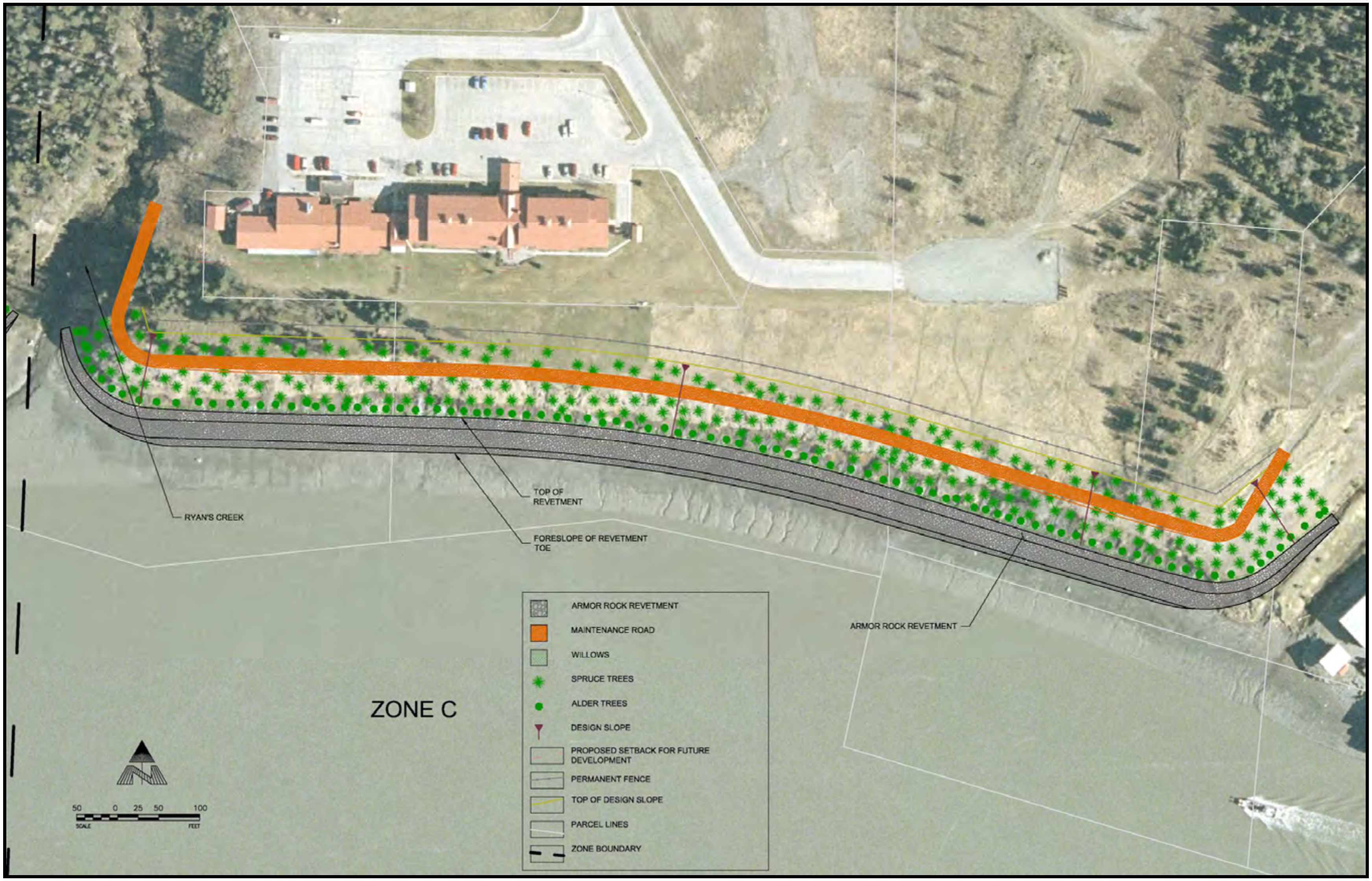


Figure G-4. Conceptual Plan View, Zone C

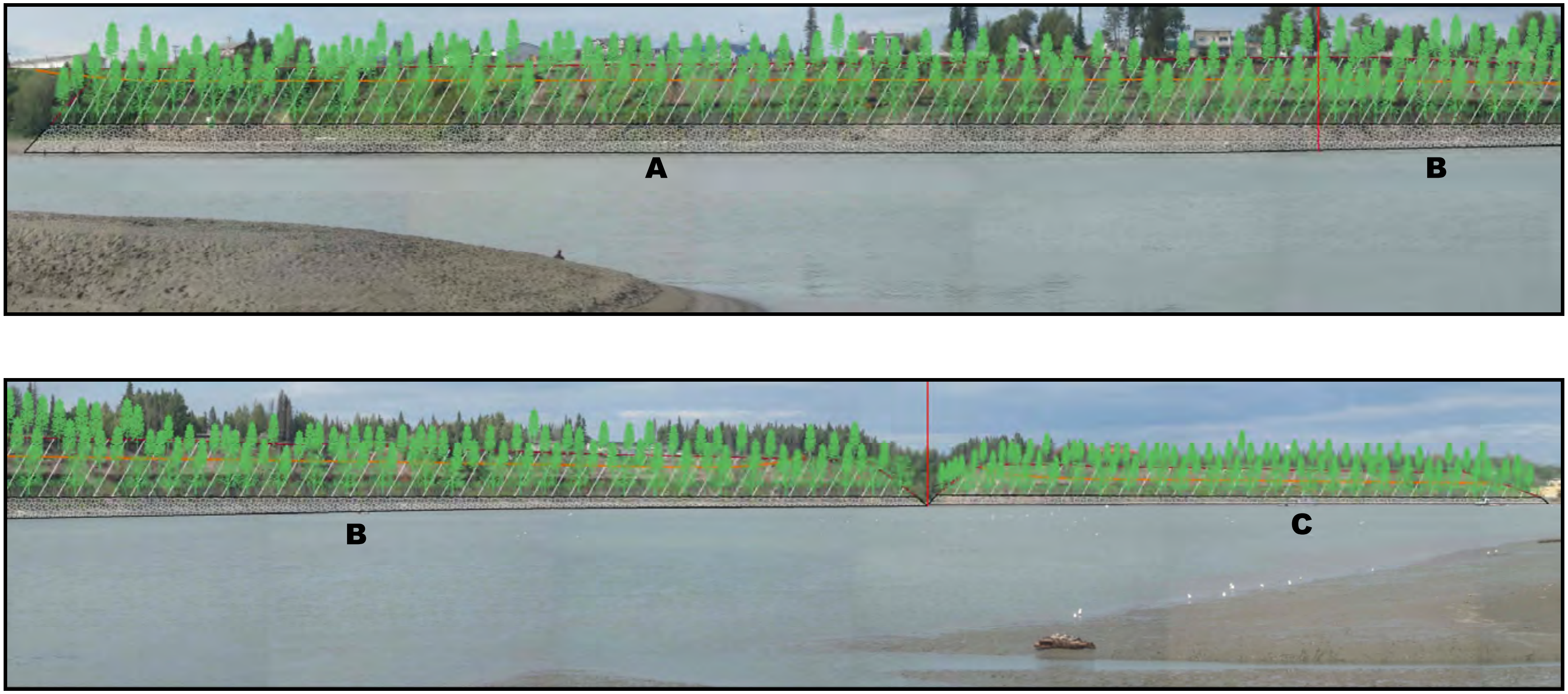


Figure G-5. Conceptual Bluff Elevation, Zone A (Top), Zone B and Zone C (bottom)

Table G-1: Design Sheet List

Kenai Bluff Stabilization		
Sheet List		
Sheet	Plate	Title
1	G-1	Cover, Vicinity, and Location
2	G-2	Sheet Index
3	G-3	Legend, Notes, and Abbreviations
4	G-4	Survey Control
5	G-5	Real Estate, Access and Staging
6	G-6	Erosion Control and Wetlands I
7	G-7	Erosion Control and Wetlands II
8	C-1	Civil Plan/Profile I
9	C-2	Civil Plan/Profile II
10	C-3	Civil Plan/Profile III
11	C-4	Civil Plan/Profile IV
12	C-5	Civil Plan/Profile V
13	C-6	Civil Plan/Profile VI
14	C-7	Civil Plan/Profile VII
15	C-8	Grading Cross Sections I
16	C-9	Grading Cross Sections II
17	C-10	Grading Cross Sections III
18	C-11	Typical Sections
19	C-12	Rock Revetment Details
20	C-13	Drainage Details
21	C-14	Miscellaneous Details
22	L-1	Planting Plan I
23	L-2	Planting Plan II
24	L-3	Planting Table and Details

US Army Corps
of Engineers
Alaska District

KENAI BLUFF STABILIZATION

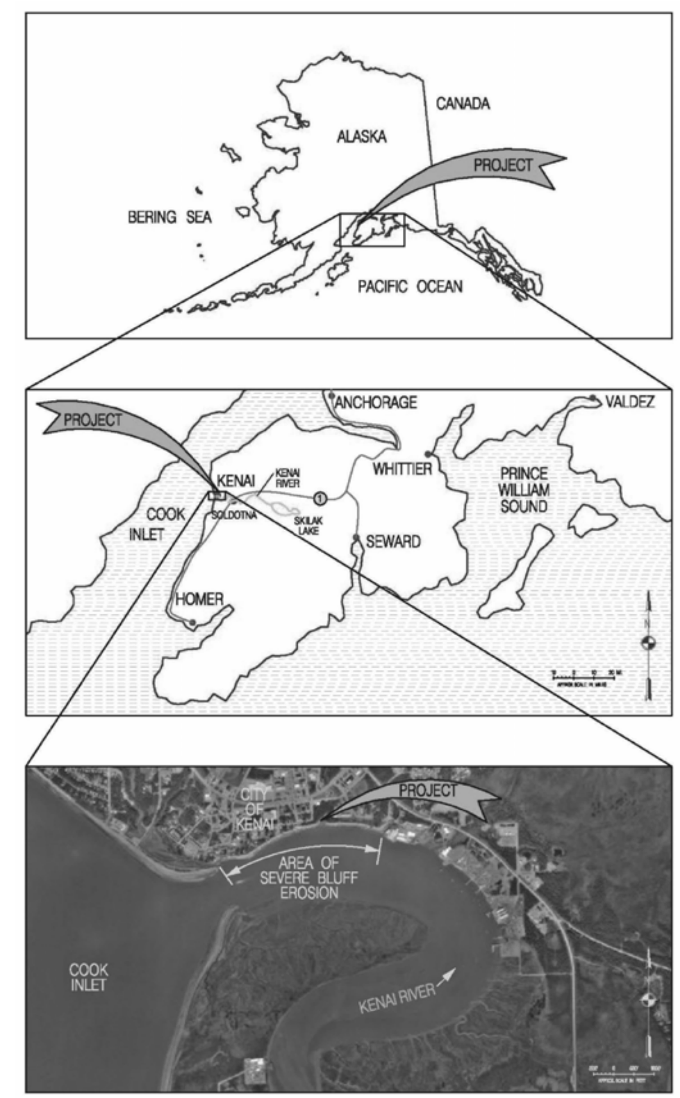
KENAI, ALASKA

PRELIMINARY DESIGN
02JUL2012

KENXXX

PN XXXXX

INV. NO. DACW85-03-D-0002



KENAI BLUFF STABILIZATION

KENAI, ALASKA

PRELIMINARY DESIGN - KENXXX/PN xxxxx, 02JUL2012
INV. NO. DACW85-03-D-0002

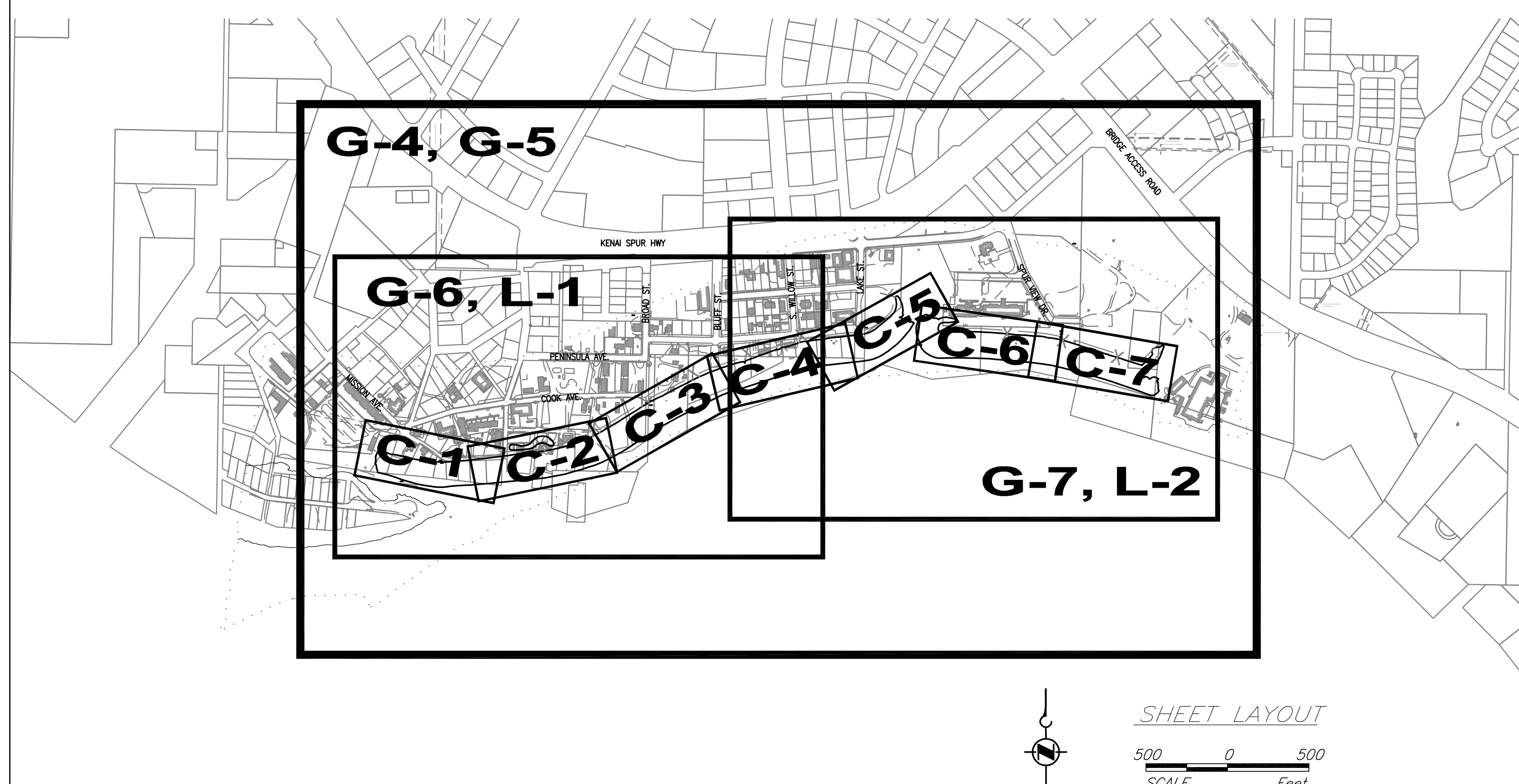
ALASKA DISTRICT U.S. ARMY CORPS OF ENGINEERS

SCHEDULE OF DRAWINGS

SHT	REF. NUM.	SHEET TITLE
		GENERAL
1	G-1	COVER, VICINITY, AND LOCATION
2	G-2	SHEET INDEX
3	G-3	LEGEND, NOTES, AND ABBREVIATIONS
4	G-4	SURVEY CONTROL
5	G-5	REAL ESTATE, ACCESS AND STAGING
6	G-6	EROSION CONTROL AND WETLANDS I
7	G-7	EROSION CONTROL AND WETLANDS II
		CIVIL
8	C-1	PROJECT PLAN AND SITE MAP
9	C-2	PROJECT PLAN AND SITE MAP
10	C-3	PROJECT PLAN AND SITE MAP
11	C-4	PROJECT PLAN AND SITE MAP
12	C-5	PROJECT PLAN AND SITE MAP
13	C-6	PROJECT PLAN AND SITE MAP
14	C-7	PROJECT PLAN AND SITE MAP
15	C-8	GRADING CROSS SECTIONS I
16	C-9	GRADING CROSS SECTIONS II
17	C-10	GRADING CROSS SECTIONS III
18	C-11	TYPICAL SECTIONS
19	C-12	ROCK REVETMENT DETAILS
20	C-13	DRAINAGE DETAILS
21	C-14	MISCELLANEOUS DETAILS
		LANDSCAPING PLANS
22	L-1	PLANTING PLAN I
23	L-2	PLANTING PLAN II
24	L-3	PLANTING TABLE AND DETAILS

SHT	REF. NUM.	SHEET TITLE

SHEET LAYOUT



Drawing C:\Projects\Kenai\GIS\dwg\2012\Kenai_G-2.dwg was plotted by Price, Krey on 06/16/11

LEGEND

EXISTING

HV-312 93.57	AERIAL PANEL POINTS
	ANCHOR
	ANTENNA
AP-25	AUGER POINT
	CATCH BASIN
	CATCH BASIN MANHOLE
	CLEANOUT
	COMMUNICATION PED
EM	ELECTRIC METER
	ELECTRIC PEDESTAL
	FIRE HYDRANT
	GUARD POST/BOLLARD
	LIGHT POLE
	MANHOLE
MW	MONITORING WELL
	NATURAL GAS METER
	POWER POLE
	ROCK / BOULDER
	SIGN
123.4	SPOT ELEVATION
	TREE / BUSH
	VENT PIPE
	WATER VALVE
	BUILDING
	CONCRETE
	CULVERT
	CURB AND GUTTER
	EDGE OF GRAVEL / DIRT
	EDGE OF PAVEMENT
	EDGE OF VEGETATION
x	FENCE LINE
	GUARD RAIL
	REGULATORY HIGH TIDE (25.5 MLLW)
	REGULATORY HIGH TIDE (19.1 MLLW)
100	MAJOR CONTOUR
	MINOR CONTOUR

PROPOSED

	DESIGN ELEVATION
	GRADING LIMITS
5'	MAJOR CONTOUR
	MINOR CONTOUR
	CENTERLINE
	FLOW PATH
	REG HIGH TIDE
	REG HIGH WATER
	GEOTEXTILE
X	WOOD FENCE
	CUT AREA
	DEMOLITION AREA
	COMPACTED FILL/ PIT-RUN GRAVEL
	ARMOR "A" ROCK
	SECONDARY "B" ROCK
	CORE "C" ROCK
	RIPRAP
	SECONDARY RIPRAP
	CRUSHED ROAD SFC

DISCLAIMER

THESE DOCUMENTS HAVE BEEN PREPARED FOR A SPECIFIC PROJECT AND SHALL NEITHER BE ALTERED NOR REUSED FOR ANY OTHER PURPOSE. ALSO, THESE DOCUMENTS DO NOT REPRESENT AS-BUILT CONDITIONS. IF THESE DOCUMENTS ARE ALTERED INTENTIONALLY OR UNINTENTIONALLY, OR REUSED WITHOUT THE DESIGN ENGINEER'S WRITTEN APPROVAL, IT WILL BE AT THE SOLE RISK AND RESPONSIBILITY OF THE USER. THE ACT OF ALTERING OR REUSING IS CONSTRUED AS INDEMNIFYING AND HOLDING THE DESIGN ENGINEERING FIRM AND ITS EMPLOYEES HARMLESS FROM ALL CLAIMS, DAMAGES, AND EXPENSES, INCLUDING ATTORNEY FEES, ARISING OUT OF SUCH ACT.

GENERAL NOTES

PROJECT LIMITS

ALL CONSTRUCTION ACTIVITY SHALL BE CONFINED TO THE PROJECT LIMITS (FOOTPRINT) INCLUDING THE STAGING/STOCKPILE AREA, DESIGNATED HAUL ROUTES AND PROJECT FEATURES AS SHOWN ON THE DRAWINGS, DO NOT DISTURB, EXCAVATE OR WORK BEYOND PROJECT LIMITS WITHOUT PERMISSION FROM CONTRACTING OFFICER OR REPRESENTATIVE.

SITE MAPPING

REPRESENTATIONS OF TRUE NORTH SHALL NOT BE USED TO IDENTIFY OR ESTABLISH THE BEARING OF TRUE NORTH AT THE JOB SITE. VERIFICATION OF MAPPING IS THE RESPONSIBILITY OF THE CONTRACTOR. CONTRACTOR IS RESPONSIBLE FOR ESTABLISHING AND MAINTAINING REQUIRED DATUM, BENCHMARKS, CONTROL LINES AND LEVELS.

SURVEY STAKING

SURVEY STAKING IS THE RESPONSIBILITY OF THE CONTRACTOR. SURVEY CONTROL POINTS EXISTS ON SITE, BUT SURVEY CONTROL LINES NEED FIELD LAYOUT.

PERMITS

THE CONTRACTOR SHALL COMPLY WITH ALL APPLICABLE REQUIREMENTS SET FORTH IN ALL PERMITS OBTAINED FOR THIS PROJECT. THE CONTRACTOR IS REQUIRED TO COMPLY WITH ALL CONSTRUCTION RELATED REQUIREMENTS IN EACH PERMIT.

UTILITIES

UTILITY LOCATIONS HAVE NOT BEEN SURVEYED. IT IS THE RESPONSIBILITY OF CONTRACTOR TO PERFORM ALL UTILITY LOCATIONS 48 HOURS PRIOR TO EXCAVATION, CALL (907) 278-3121. IT IS THE RESPONSIBILITY OF CONTRACTOR TO PROTECT ALL EXISTING SEWER, WATER, GAS AND ELECTRIC UTILITIES ENCOUNTERED IN THE WORK. ANY RELOCATION OR IMPROVEMENTS OF UTILITIES SHALL BE ACCURATELY NOTED ON AS-BUILT DRAWINGS AND ISSUED TO THE CONTRACTING OFFICER AT THE COMPLETION OF THE CONSTRUCTION.

TEMPORARY CONSTRUCTION FACILITIES

ALL TEMPORARY UTILITIES AND FACILITIES WILL BE THE RESPONSIBILITY OF THE CONTRACTOR. A CONSTRUCTION TRAILER IS NOT REQUIRED. POTABLE WATER AND ELECTRICITY ARE NOT AVAILABLE ON SITE AND SHALL BE PROVIDED BY CONTRACTOR. A CHEMICAL TOILET OF SUITABLE TYPE SHALL BE PROVIDED AND MAINTAINED BY THE CONTRACTOR AT ALL TIMES. THE CONTRACTOR IS RESPONSIBLE FOR JOB SITE CONDITIONS AND THE SAFETY OF HUMAN LIFE, DURING THE COURSE OF CONSTRUCTION. THIS REQUIREMENT SHALL APPLY CONTINUOUSLY DURING THE PERIOD OF CONSTRUCTION AND NOT LIMITED TO NORMAL WORKING HOURS. THE CONTRACTOR SHALL PROVIDE SIGNAGE AND BARRIERS NECESSARY TO PROVIDE SECURITY AND SAFETY TO WORKERS AND THE PUBLIC DURING THE ENTIRETY OF THE CONSTRUCTION PERIOD.

THE CONTRACTOR SHALL KEEP JOB SITE AREA CLEAN, HAZARD FREE AND DISPOSE OF ALL DEBRIS, RUBBISH AND CONSTRUCTION WASTE, AND REMOVE ALL MATERIALS FROM THE SITE. ALL DISTURBED STAGING AND ACCESS AREAS ARE TO BE REHABILITATED TO PRE-CONSTRUCTION CONDITION. THE CONTRACTOR IS RESPONSIBLE TO RECLAIM (REGRADE AND SEED) CONSTRUCTION FEATURES NOT SPECIFIED AS REMAINING ON THE SITE AND CLEAN UP ALL AREAS AT THE COMPLETION OF THE CONSTRUCTION.

ENVIRONMENTAL PROTECTION

ENVIRONMENTAL PROTECTION IS THE PREVENTION/CONTROL OF POLLUTION AND HABITAT DISRUPTION THAT MAY OCCUR TO THE ENVIRONMENT DURING CONSTRUCTION. THE CONTROL OF ENVIRONMENTAL POLLUTION AND DAMAGE REQUIRES CONSIDERATION OF LAND, WATER, AND AIR; BIOLOGICAL AND CULTURAL RESOURCES; AND INCLUDES MANAGEMENT OF VISUAL AESTHETICS; NOISE; SOLID, CHEMICAL, GASEOUS, AND LIQUID WASTE; RADIANT ENERGY AND RADIOACTIVE MATERIAL AS WELL AS OTHER POLLUTANTS. THE CONTRACTOR SHALL MINIMIZE ENVIRONMENTAL POLLUTION AND DAMAGE THAT MAY OCCUR AS THE RESULT OF CONSTRUCTION OPERATIONS. THE ENVIRONMENTAL RESOURCES WITHIN THE PROJECT BOUNDARIES AND THOSE AFFECTED OUTSIDE THE LIMITS OF PERMANENT WORK SHALL BE PROTECTED DURING THE ENTIRE DURATION OF THIS CONTRACT. THE CONTRACTOR SHALL COMPLY WITH ALL APPLICABLE ENVIRONMENTAL FEDERAL, STATE, AND LOCAL LAWS AND REGULATIONS.

THE CONTRACTOR IS RESPONSIBLE FOR IMPLEMENTING AND UTILIZING BEST MANAGEMENT PRACTICES (BMPS) TO PREVENT STORMWATER RUNOFF AND WATER POLLUTION DURING CONSTRUCTION ACTIVITIES. CONTRACTOR SHALL PROVIDE COR WITH STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR APPROVAL PRIOR TO CONSTRUCTION. THE CONTRACTOR SHOULD USE CAUTION WHEN WORKING IN AND AROUND LOCAL DUMPING AREAS. IF POTENTIAL HAZARDOUS MATERIALS ARE ENCOUNTERED, THE CONTRACTING OFFICE SHOULD BE CONTACTED IMMEDIATELY.

CONSTRUCTION SPOILS AND WASTE HANDLING

ALL CONSTRUCTION SPOILS AND WASTE SHALL BE DISPOSED OF AT AN APPROVED DISPOSAL SITE AND/OR LANDFILL FACILITY.

CLEARING AND GRUBBING

EXISTING ON-SITE MATERIALS SHALL BE CAREFULLY REMOVED AND STORED, OR DISPOSED OF. COMPLETELY REMOVE STUMPS, ROOTS, WILLOWS, SHRUBS, WEEDS, AND OTHER DEBRIS PROTRUDING FROM THE GROUND IN AREAS TO BE EXCAVATED. ALL CLEARED AND GRUBBED STUMPS, ROOTS, WILLOWS, SHRUBS, WEEDS, AND LIMBS SHALL BE DISPOSED PER CONSTRUCTION WASTE HANDLING SPECIFICATIONS. TREES DESIGNATED TO BE CLEARED, SHALL BE DISPOSED OF BY THE CONTRACTOR.

SITE EARTHWORK AND GRADING

THE CONTRACTOR IS RESPONSIBLE FOR ALL SITE EARTHWORK AND GRADING ACTIVITIES TO MEET DESIGNS IDENTIFIED IN PLANS AND DETAILS, WHICH ARE INTENDED TO SHOW FINAL RESULT OF DESIGN. MODIFICATIONS MAY BE REQUIRED TO SUIT JOB SITE CONDITIONS AND SHALL BE INCLUDED IN AS-BUILT DRAWINGS PROVIDED TO CONTRACTING OFFICER AT COMPLETION OF CONSTRUCTION. AT THE END OF EACH DAY OF WORK THE CONTRACTOR SHALL MAINTAIN ALL EXPOSED AREAS AS ACCEPTABLE TO COR AND PERMIT REQUIREMENTS.

BACKFILL MATERIAL SHALL BE IN ACCORDANCE WITH THE SPECIFICATIONS. ADDITIONAL IMPORTED FILL MATERIAL MAY BE REQUIRED FOR CONSTRUCTION ALONG THE LANDWARD SIDE OF THE ARMORED EMBANKMENT IF THE OPTION IS EXERCISED. ALL MATERIAL SHALL BE FREE FROM ORGANIC MATTER, SILTS, CLAYBALLS AND OTHER DELETERIOUS MATERIALS EXCEPT WHERE EXPLICITLY STATED.

ABBREVIATIONS

AC	ACRE
APPROX	APPROXIMATE
BDY	BOUNDARY
BOB	BASIS OF BEARING
BM	BENCH MARK
BMP	BEST MANAGEMENT PRACTICES
CLR	CLEARANCE
CMP	CORRUGATED METAL PIPE
CONC	CONCRETE
CONT	CONTINUE
COR	CONTRACTING OFFICER'S REPRESENTATIVE
DIA	DIAMETER
DET	DETAIL
D/S	DOWNSTREAM
E	EAST, EASTING
EA	EACH
EL	ELEVATION
EG	EXISTING GRADE
EP	EDGE OF PAVEMENT
EXIST	EXISTING
FG	FINISH GRADE
G1	ENTRANCE GRADE
G2	EXIT GRADE
GB	GRADE BREAK
GRND	GROUND
H, HORIZ	HORIZONTAL
HGL	HYDRAULIC GRADE LINE
IE	INVERT ELEVATION
INV	INVERT
LF	LINEAR FOOT
MAX	MAXIMUM
MIN	MINIMUM
N	NORTH, NORTHING
N/A	NOT APPLICABLE
NTS	NOT TO SCALE
OC	ON CENTER
OD	OUTSIDE DIAMETER
PERM	PERMANENT
PCL	PRIMARY CONTROL LINE
PC	POINT OF CURVATURE
POC	POINT ON CURVE
POB	POINT OF BEGINNING
POE	POINT OF END
PI	POINT OF INTERSECTION
PRV	PRIVATE
PVI	POINT OF VERTICAL INTERCEPT
PVT	POINT OF VERTICAL TANGENCY
PT	POINT OF TANGENCY
POT	POINT ON TANGENT
PROP	PROPOSED
PUB	PUBLIC
Q	FLOW
R	RADIUS
R/W	RIGHT OF WAY
REINF	REINFORCED
REG	REGULATORY
S	SOUTH
SCL	SECONDARY CONTROL LINE
SF	SQUARE FEET
SS	SANITARY SEWER
SPEC	SPECIFICATION
STA	STATION
SW	SIDEWALK
SWPPP	STORMWATER POLLUTION PREVENTION PLAN
SY	SQUARE YARD
TBD	TO BE DETERMINED
TOB	TOP OF BANK
TOE	TOE OF BANK
TYP	TYPICAL
ULT	UNDER GROUND
VERT	VERTICAL
W	WEST
WSEL	WATER SURFACE ELEVATION

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

CONTRACT NO. CONTRACTOR CITY STATE

Recommended: PRIME CONTRACTOR Approved: RESIDENT ENGINEER Date:

Sym Action Description Date Apprvl

Date: JULY 2012
Dwg Scale: AS NOTED
Plot Scale:
File: Kenai_G-3
Drawing #:

Designed: KHP
Drawn: MRG
Reviewed: YHC
Submitted:

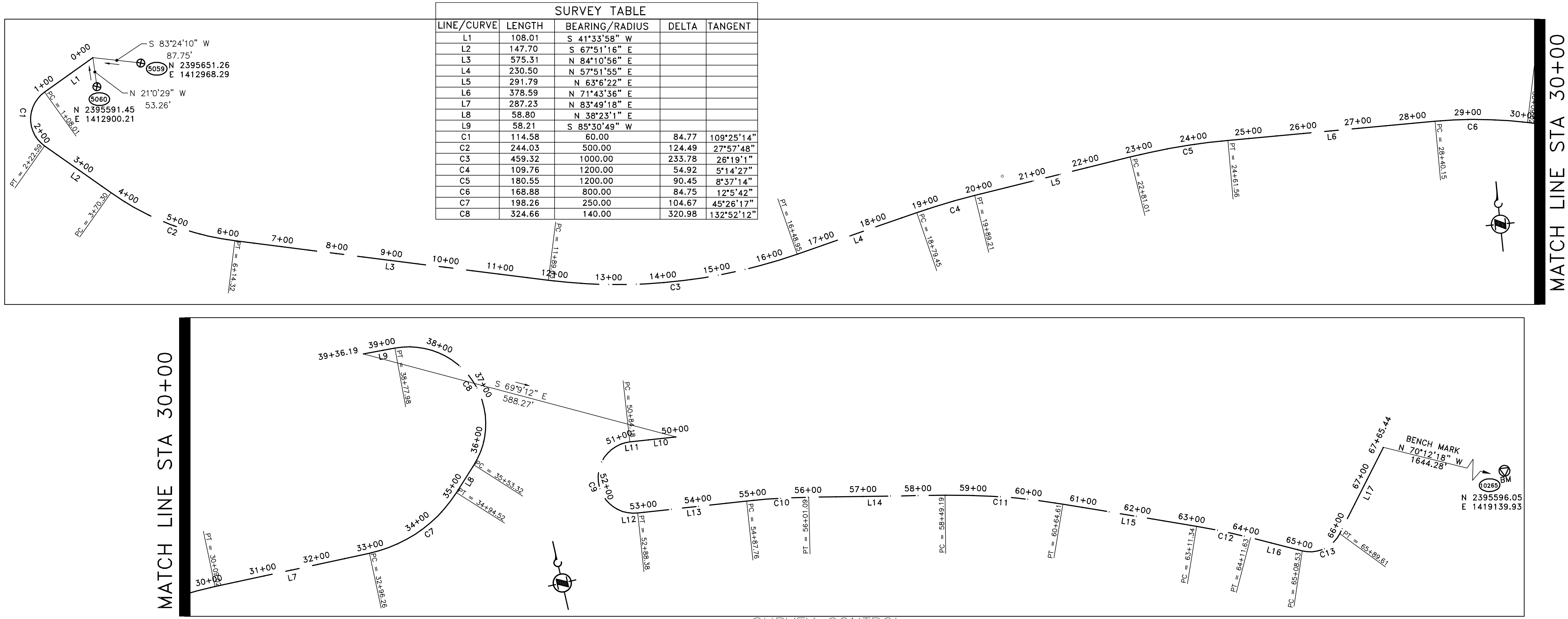
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA

LEGEND, NOTES, AND ABBREVIATIONS

Reference number:
G-3



SURVEY CONTROL

100 0 100
SCALE Feet

SURVEY TABLE				
LINE/CURVE	LENGTH	BEARING/RADIUS	DELTA	TANGENT
L1	108.01	S 41°33'58" W		
L2	147.70	S 67°51'16" E		
L3	575.31	N 84°10'56" E		
L4	230.50	N 57°51'55" E		
L5	291.79	N 63°6'22" E		
L6	378.59	N 71°43'36" E		
L7	287.23	N 83°49'18" E		
L8	58.80	N 38°23'1" E		
L9	58.21	S 85°30'49" W		
C1	114.58	60.00	84.77	109°25'14"
C2	244.03	500.00	124.49	27°57'48"
C3	459.32	1000.00	233.78	26°19'1"
C4	109.76	1200.00	54.92	5°14'27"
C5	180.55	1200.00	90.45	8°37'14"
C6	168.88	800.00	84.75	12°5'42"
C7	198.26	250.00	104.67	45°26'17"
C8	324.66	140.00	320.98	132°52'12"

AEROMETRIC AERIAL MAPPING NOTES

1. This map was compiled to meet horizontal accuracy in accordance with ASPRS Class II Accuracy Standards.
2. This map was compiled to meet vertical accuracy in accordance with ASPRS Class II Accuracy Standards.
3. Areas denoting vegetation cover on the ground should be considered less accurate and not used for engineering purposes until field checked in accordance with ASPRS Accuracy Standards.
4. The map projection is Alaska State Plane, Zone 4, NAD83 as expressed in U.S. Survey Feet.
5. Vertical data is referenced to MLLW based on NOAA Tidal Station "Nikiski".
6. This map is based on photography acquired 09-27-2007 at a nominal scale of 1"=300'.
7. This map produced for output at a scale of 1"=100' with a contour interval of 1 foot.

PHOTO CONTROL SURVEY NOTES

1. The information provided here is based on Aerial Mapping produced by Aerometric and controlled by field surveys performed by R&M Consultants. The aerial photography was acquired September 9th, 2007. R&M Control Surveys took place in 2007 and 2008.
2. Primary horizontal control and aerial photo control was established using Static GPS techniques with Trimble duel frequency receivers. GPS vectors were adjusted using simultaneous least-squares methods.
3. Project coordinates are referenced to the Alaska Coordinate System of 1983 (ACS83), Zone 4 values, reported in U.S. Survey Feet and are based on Survey Control Station "McLane CP 1" as shown on the DOWL Engineers drawing "Kenai River Bluff Erosion Survey Topography" dated July 16, 2003. McLane CP 1 zone 4 coordinates = N 2,395,666.774, E 1,419,401.413.
4. Project bearings are NAD83 Zone 4 state plane grid bearings based on GPS adjusted measurements constrained at McLane CP 1.
5. Primary vertical control was established with a combination of Trimble dual frequency GPS measurements and differential leveling. GPS measurements incorporated Geoid06. Differential levels were performed with a Leica DNA10 digital level and barcode rod.
6. Project vertical datum is referenced to Mean Lower Low Water (MLLW) based on NOAA Tidal Station Nikiski, Station ID No. 945 5760, publication date 10/30/2003. Station Nikiski is referenced by BM No. 8, et al., which was held for all project elevations (BM No. 8 elevation was verified by measurements to BM Nos. 7 & 9). The official station designation for BM No. 8 is "945 5760 TIDAL 8" (see PID No. AB7150). NOAA MLLW elevation for BM No. 8 = 109.659 U.S. Survey Feet (33.424 meters).

   Elevations were transferred from BM No. 8 roughly 10 miles south to the project site using the following sequence:

BM No. 8 to nearby set point CP 51	Differential levels.
CP 51 to McLane CP 1	GPS & Geoid06
CP 1 to nearby Kenai BM No. 3	Differential levels.

   Note that CP 1 is vertically unstable and that Kenai BM No. 3 has been used to control and adjust the elevation of CP 1 at each visit for GPS observations. The most recent visit found CP 1 with aluminum cap lying nearby. The cap was reset and the elevation reestablished from Kenai BM No. 3. The elevation for Kenai BM No. 3, established from Nikiski, is 31.18 feet.

   Elevations of tidal datums referred to station Nikiski MLLW in feet:

Highest Observed Water Level (12/26/1976)	= 29.02
Mean Higher High Water (MHHW)	= 20.42
Mean High Water (MHW)	= 19.68
Mean Sea Level (MSL)	= 11.18
North American Vertical Datum-1988 (NAVD88)	= 6.76
Mean Low Water (MLW)	= 2.05
Mean Lower Low Water (MLLW)	= 0.00
Lowest Observed Water Level (12/25/1999)	= -6.37

7. Aerial Mapping contours were ground-truthed using RTK GPS broadcasted from station McLane CP 1. Elevations fit well in areas without foliage and less well where trees and brush existed. No extreme discrepancies were discovered.
8. Geotechnical borehole positions were located using RTK GPS together with differential levels.
9. The contour interval shown is one foot.
10. Property lines, street rights-of-way, street names, etc. were taken from the Kenai Peninsula Borough (KPB) Geographical Information Systems (GIS) website. The KPB GIS was inserted and fit to physical features within the aerial mapping (street intersections, etc).

SURVEY TABLE				
LINE	LENGTH	BEARING	DELTA	TANGENT
L10	84.18	S 89°45'1" W		
L11	0.00	N 89°45'1" E		
L12	0.00	S 89°45'1" W		
L13	199.38	N 89°45'1" E		
L14	248.09	S 84°50'18" E		
L15	246.73	S 74°33'10" E		
L16	96.90	S 69°45'50" E		
L17	175.83	N 32°48'54" E		
C9	204.20	65.00	180°0'2"	INFINITE
C10	113.34	1200.00	5°24'41"	56.71
C11	215.42	1200.00	10°17'8"	108.00
C12	100.30	1200.00	4°47'20"	50.18
C13	81.08	60.00	77°25'16"	48.09

MONUMENT LEGEND

- RECOVERED BLM MONUMENT
- RECOVERED PRIMARY MONUMENT (BRASS CAP)
- RECOVERED PRIMARY MONUMENT (ALCAP)
- RECOVERED SECONDARY MONUMENT
- SET PRIMARY SURVEY CONTROL POINT
- BENCH MARK
- TEMPORARY BENCH MARK
- 123 SURVEY POINT NUMBER

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

CONTRACT NO. ____
CONTRACTOR ____
CITY ____ STATE ____
Recommended: ____ PRIME CONTRACTOR
Approved: ____ RESIDENT ENGINEER
Date: ____

Sym.	Action	Description	Date	Appvd

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.
SURFACE WATER GROUP
1020 SW Taylor Street, Suite 530
Portland, OR 97205
(503) 223-5388 Fax (503) 228-8631

Designed: KHP
Drawn: MRG
Reviewed: YHC
Submitted:

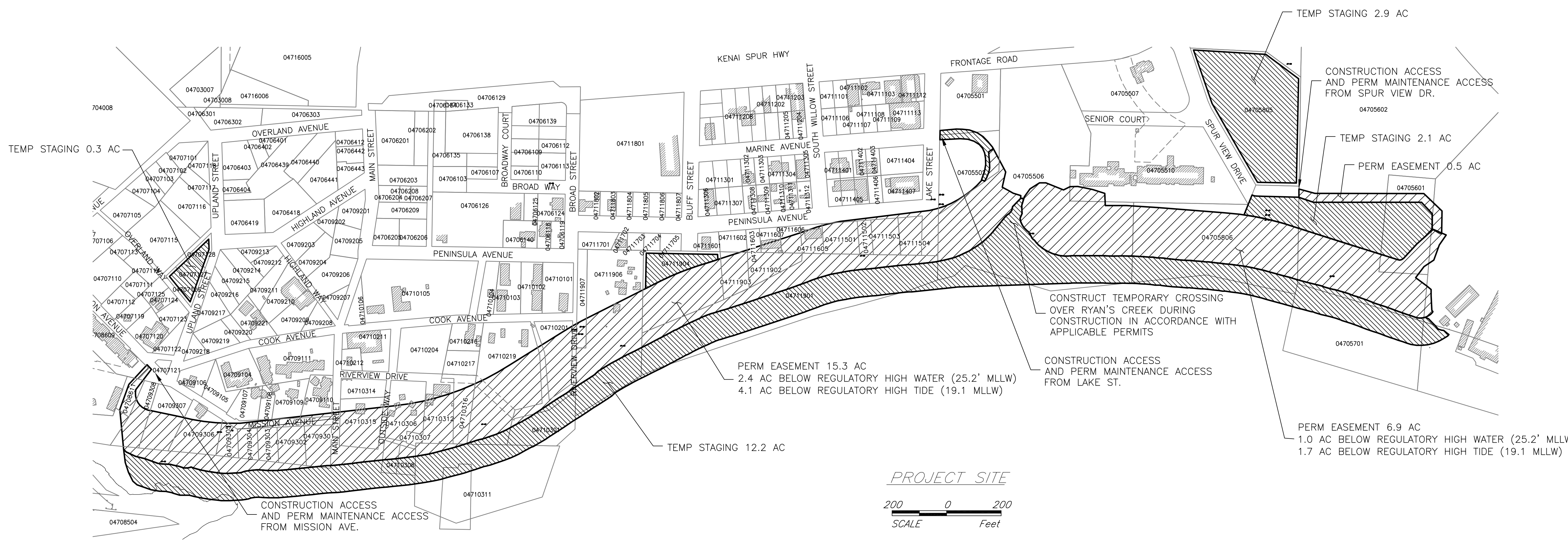
Date: JULY 2012
Dwg Scale: AS NOTED
Plot Scale:
File: Kenai_G-4
Drawing #:

KENAI BLUFF STABILIZATION
KENAI, ALASKA

SURVEY CONTROLS

Reference number:
G-4

Sheet 4 of 24



KEY

PERMENANT EASEMENT

TEMPORARY EASEMENT

PROJECT EASEMENT AREAS BY PARCEL

Parcel ID	Ownership Type	Usage	Required Easement (Acres)	Total Lot Size (Acres)	Required Easement (% of Lot)	Affected Structures (square feet)	Owner
4709308	PRV	VA	0.41	0.41	100%	0	OCONNELL ROBERT D ET AL, SWARNER LINDA
4709307	PUB	VA	0.64	0.64	100%	0	CITY OF KENAI
4709306	PRV	RS	0.44	0.58	76%	0	SHOWALTER JENNIFER F
4709305	PUB	VA	0.19	0.19	100%	0	KENAI CITY OF
4709304	PRV	VA	0.19	0.19	100%	0	WEBBER CHARLES R
4709303	PRV	VA	0.21	0.21	100%	0	KNIGHT KEITH K
4709302	PUB	VA	0.32	0.32	100%	0	KENAI CITY OF
4709301	PRV	VA	0.33	0.33	100%	0	KENAI BIBLE CHURCH
4709109	PRV	RS	0.004	0.37	1%	0	ANDERSON HARRY K & NELLIE MAE
4709110	PRV	CH	0.02	0.35	7%	0	KENAI BIBLE CHURCH
4710315	PRV	RS	0.63	0.63	100%	1314	LOFSTEDT DIANA
4710308	PRV	VA	0.17	0.30	56%	0	STERLING GLENDA A ET AL, MCCANN BILLY ESTATE
4710306	PRV	CM	0.63	0.63	100%	1938	LOFSTEDT DIANA
4710307	PRV	VA	0.06	0.06	100%	0	ERREA JULIAN & HILDERBRAND DAN L
4710311	PRV	VA	0.10	2.77	4%	0	CLARK RUSSELL S
4710312	PRV	RS	0.43	0.57	76%	3137	FOSTER GARY L & KATHLEEN
4710316	PRV	VA	0.30	0.33	91%	0	SEELINGER DONALD P
4710219	PRV	RS	0.66	1.40	47%	0	SEELINGER DONALD P
4710301	PUB	VA	0.03	0.69	4%	0	KENAI CITY OF
4710201	PRV	VA	0.47	0.62	75%	0	PETERKIN ROBERT T & BONNIE
4711907	PUB	VA	0.08	0.29	27%	0	CITY OF KENAI
4711906	PRV	RS	1.13	2.67	42%	637	KARAFFA PAUL P & CONSIEL ROGER D

Parcel ID	Ownership Type	Usage	Required Easement (Acres)	Total Lot Size (Acres)	Required Easement (% of Lot)	Affected Structures (square feet)	Owner
4711904	PRV	VA	1.08	1.60	67%	0	VANN RICKY L & CONNIE L TRUSTEES
4711901	PRV	VA	2.98	4.31	69%	0	JOHNSON JAMES E, JOHNSON LANCET ANN ET AL
4711903	PRV	VA	0.35	0.35	100%	0	COOPER DOROTHY M
4711902	PRV	VA	0.36	0.36	100%	0	SANDS PATRICIA R TRUSTEE B B SANDS
4711603	PRV	AB	0.02	0.10	20%	0	FREITAG HERBERT & JUDITH
4711602	PUB	VA	0.18	0.18	100%	0	KENAI CITY OF
4711607	PRV	RS	0.07	0.16	42%	2369	VANHORNE ALAN K & MARIAN F
4711606	PRV	VA	0.11	0.17	65%	0	HANNAH TONEY A & LINDA M
4711605	PRV	CM	0.17	0.19	86%	2040	HUTCHINGS STEPHEN PAUL SR CUST
4711501	PRV	VA	0.35	0.35	100%	0	ALASKA LABORERS BUILDING CORP
4711502	PRV	VA	0.14	0.14	100%	0	YOUNG WILLIAM C TRUSTEE
4711503	PRV	VA	0.30	0.30	100%	0	CENTRAL PENINSULA MENTAL HEALTH
4711504	PRV	VA	0.27	0.27	100%	0	LEDOUX CLARENCE E SR ESTATE OF
4705506	PUB	VA	3.14	8.22	38%	0	CITY OF KENAI
4205502	PUB	VA	0.22	1.11	20%	0	CITY OF KENAI
4705501	PRV	CH	0.02	1.14	2%	0	SHELDON DENTON SHILLING
4705510	PUB	VA	0.14	3.43	4%	0	CITY OF KENAI
4705806	PUB	VA	3.13	3.37	93%	0	CITY OF KENAI
4705602	PUB	VA	3.24	14.98	22%	0	PACIFIC STAR SEAFOODS INC
4705601	PRV	CH	1.24	1.43	87%	0	DIOCESE OF SITKA & ALASKA ORTHODOX
4705703	PRV	ID	0.32	14.50	2%	0	PACIFIC STAR SEAFOODS INC

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

Date: JULY 2012
Dwg Scale: AS NOTED
File: Kenai_G-5

Designed: KHP
Drawn: MRG
Reviewed: YHC

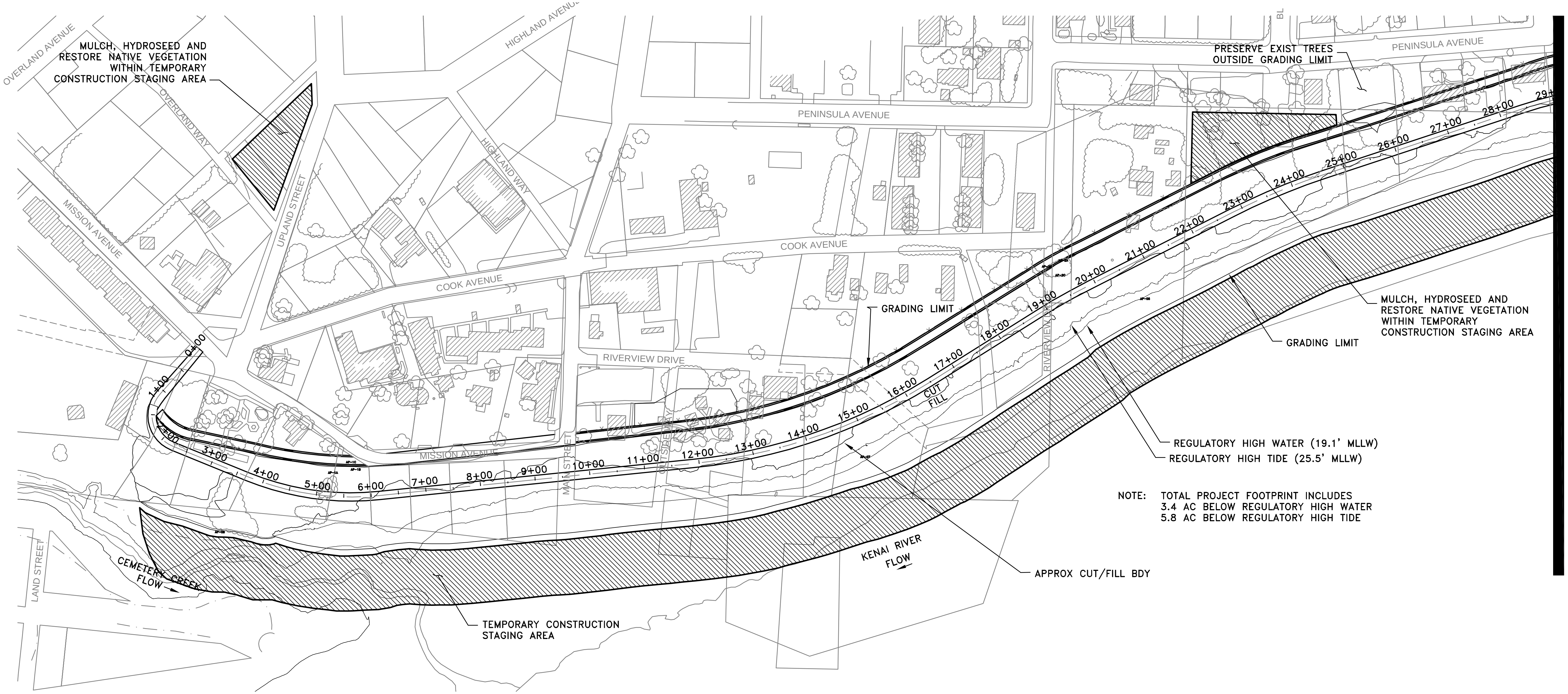
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA

REAL ESTATE, ACCESS AND STAGING

Reference number: G-5



NOTE:
CONTRACTOR SHALL SUBMIT STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR APPROVAL PRIOR TO CONSTRUCTION. SWPPP MAY INCLUDE TEMPORARY SILT FENCES, TURBIDITY CURTAINS, STRAW BALES, OR OTHER BMPS AND SHALL DEMONSTRATE ADHERENCE WITH ALL APPLICABLE ENVIRONMENTAL GUIDELINES.

EROSION CONTROL AND WETLAND PLAN

100 0 100
SCALE Feet

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

Date: JULY 2012
Dwg Scale: AS NOTED
File: Kenai_G-6

Designed: KHP
Drawn: MRG
Reviewed: YHC

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.

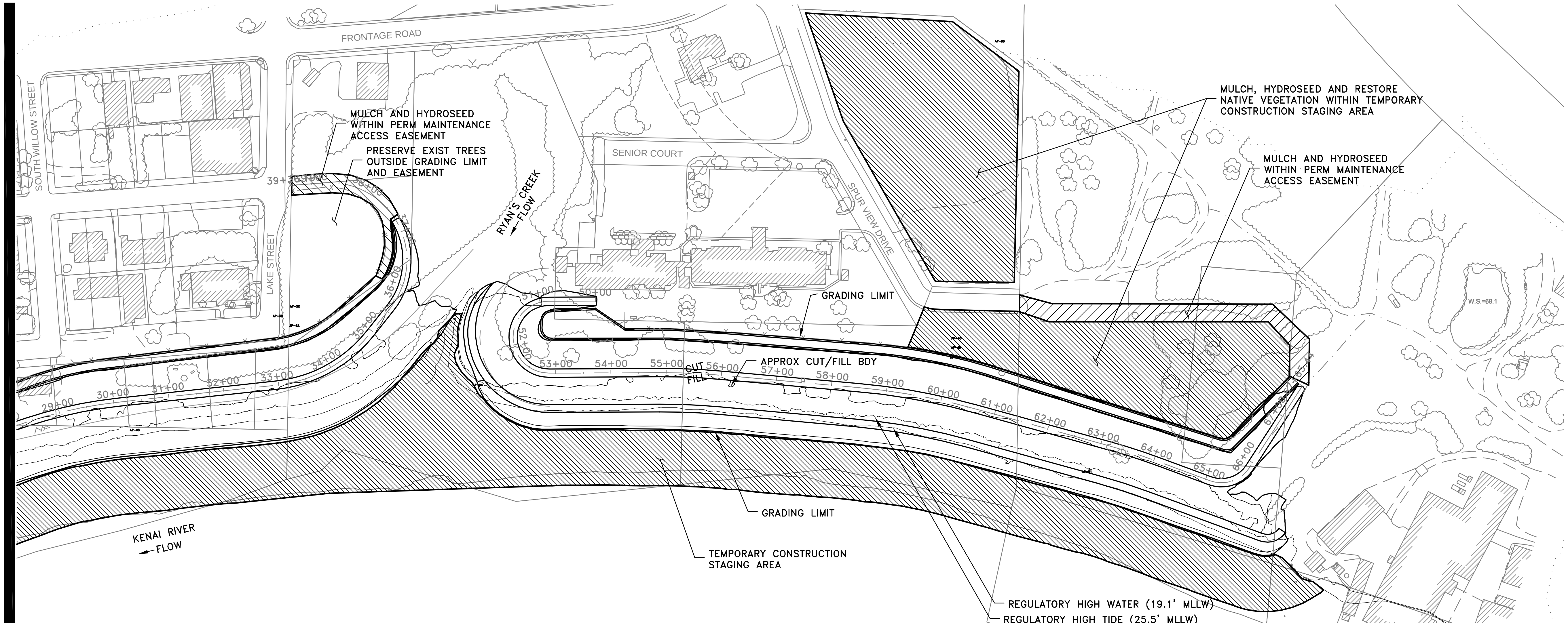
KENAI BLUFF STABILIZATION
KENAI, ALASKA
GENERAL
EROSION CONTROL AND
WETLANDS I

PRELIMINARY DESIGN

Reference number:
G-6

Sheet 6 of 24

MATCH LINE SEE SHEET G-6



NOTE:
CONTRACTOR SHALL SUBMIT STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR APPROVAL PRIOR TO CONSTRUCTION. SWPPP MAY INCLUDE TEMPORARY SILT FENCES, TURBIDITY CURTAINS, STRAW BALES, OR OTHER BMPS AND SHALL DEMONSTRATE ADHERENCE WITH ALL APPLICABLE ENVIRONMENTAL GUIDELINES.

EROSION CONTROL AND WETLAND PLAN

100 0 100
SCALE Feet

NOTE: TOTAL PROJECT FOOTPRINT INCLUDES
3.4 AC BELOW REGULATORY HIGH WATER
5.8 AC BELOW REGULATORY HIGH TIDE

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

CONTRACT NO.
CONTRACTOR
CITY STATE
Recommended: PRIME CONTRACTOR
Approved: RESIDENT ENGINEER
Date:

Sym	Action	Description	Date	Appvd

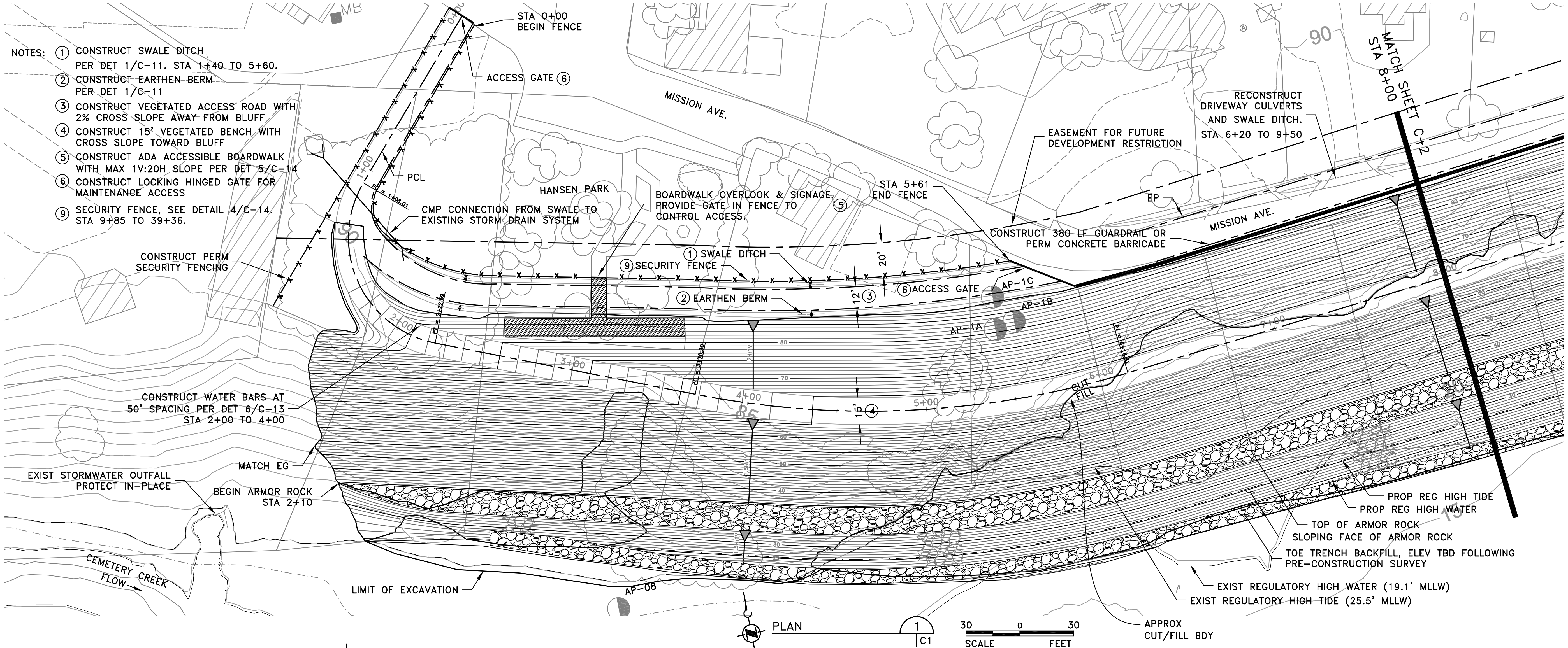
Designed: KHP
Drawn: MRG
Reviewed: YHC
Submitted:
Date: JULY 2012
Dwg Scale: AS NOTED
Plot Scale:
File: Kenai_G-7
Drawing #:

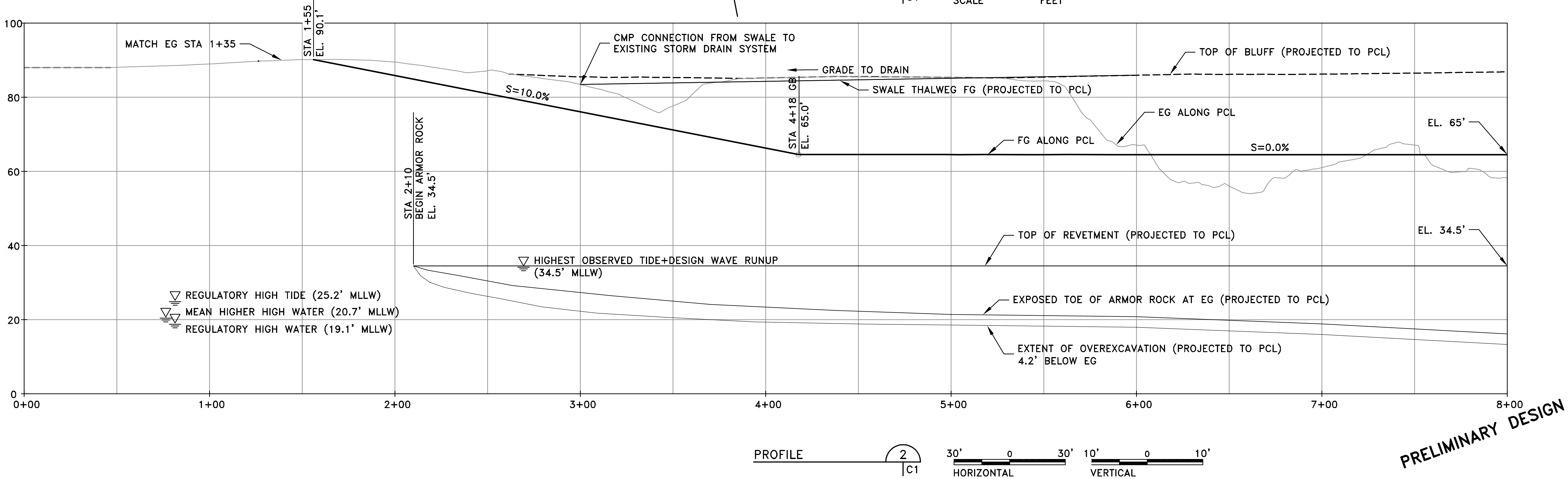
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA
GENERAL
EROSION CONTROL AND WETLANDS II

Reference number:
G-7
Sheet 7 of 24





PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

CONTRACT NO.
CONTRACTOR
CITY STATE
Recommended: PRIME CONTRACTOR
Approved: RESIDENT ENGINEER
Date:

Sym	Description	Date	Approval

Date: JULY 2012
Dwg Scale: AS NOTED
Plot Scale:
File: Kenai_C-1
Drawing #:

Designed: KHP
Drawn: MRG
Reviewed: YHC
Submitted:

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

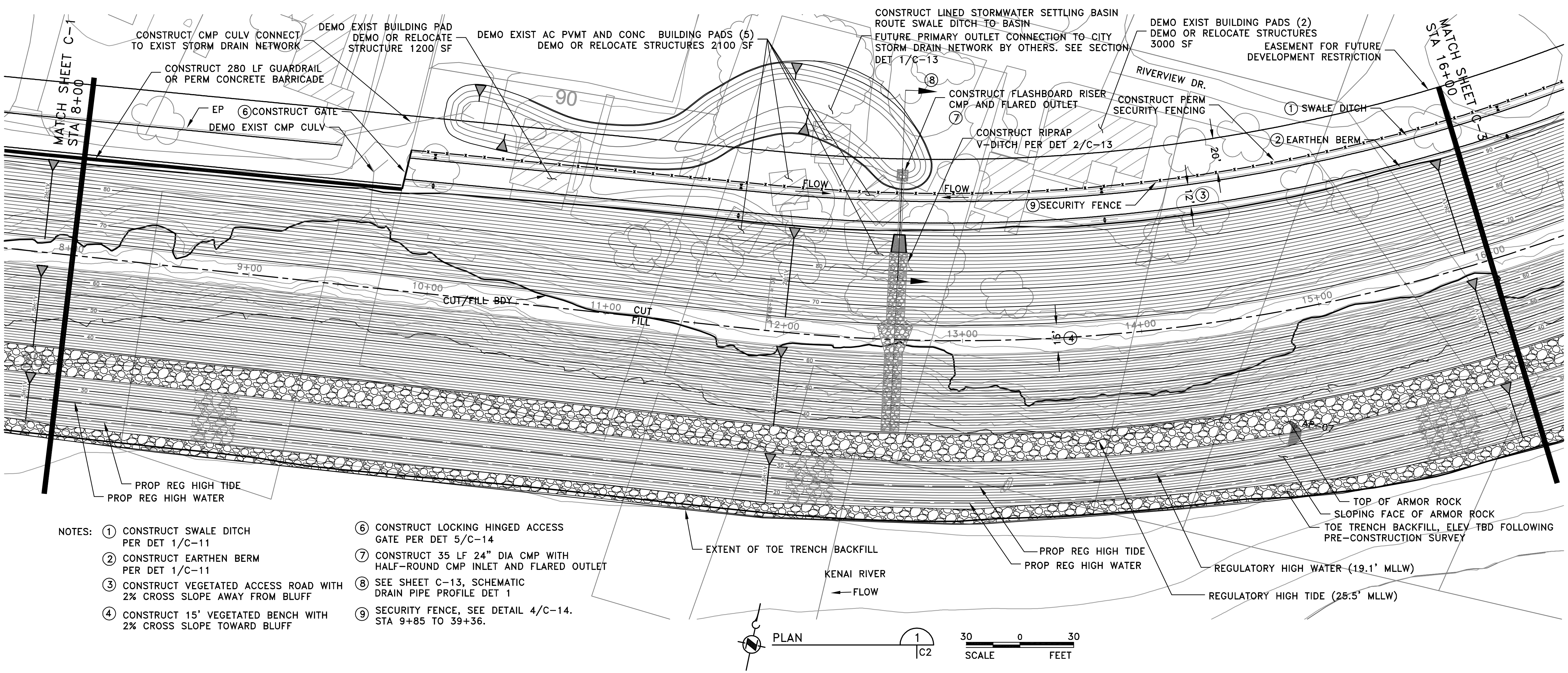
TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA

PROJECT PLAN
AND SITE MAP

Reference number:
C-1

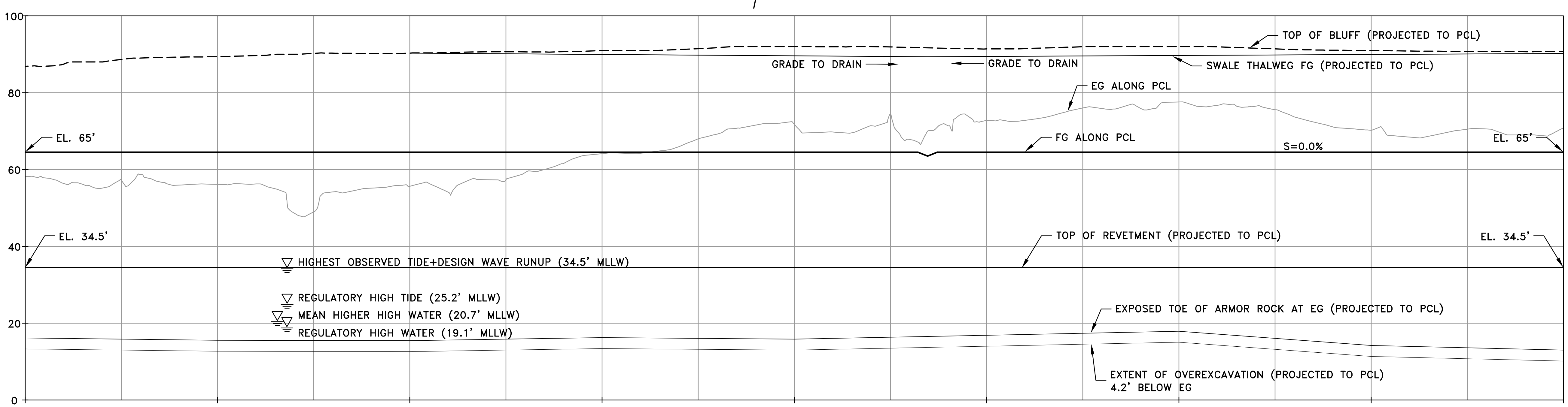
Sheet 8 of 24



NOTES:
1. CONSTRUCT SWALE DITCH PER DET 1/C-11
2. CONSTRUCT EARTHEN BERM PER DET 1/C-11
3. CONSTRUCT VEGETATED ACCESS ROAD WITH 2% CROSS SLOPE AWAY FROM BLUFF
4. CONSTRUCT 15' VEGETATED BENCH WITH 2% CROSS SLOPE TOWARD BLUFF
6. CONSTRUCT LOCKING HINGED ACCESS GATE PER DET 5/C-14
7. CONSTRUCT 35 LF 24" DIA CMP WITH HALF-ROUND CMP INLET AND FLARED OUTLET
8. SEE SHEET C-13, SCHEMATIC DRAIN PIPE PROFILE DET 1
9. SECURITY FENCE, SEE DETAIL 4/C-14. STA 9+85 TO 39+36.

PLAN 1/C2

SCALE 30 0 30 FEET



PROFILE 2/C2

30' 0 30' HORIZONTAL

10' 0 10' VERTICAL

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

CONTRACT NO. | CONTRACTOR | CITY | STATE | Recommended: PRIME CONTRACTOR | Approved: RESIDENT ENGINEER | Date:

Sym	Action	Description	Date	Appvd.

Date: JULY 2012
Dwg Scale: AS NOTED
Plot Scale:
File: Kenai_C-2
Drawing #:

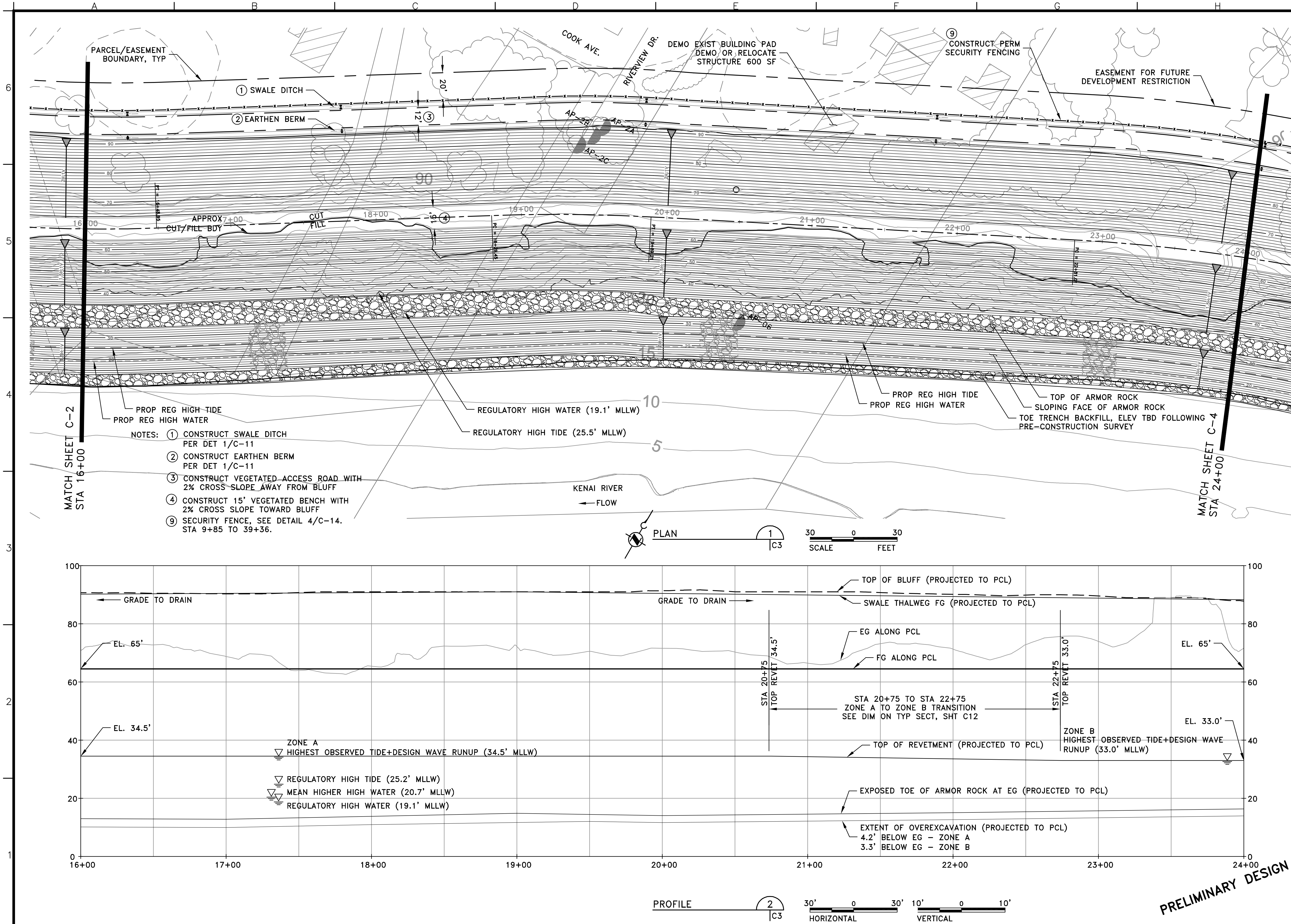
Designed: KHP
Drawn: MRG
Reviewed: YHC
Submitted:

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA
CIVIL
PROJECT PLAN AND SITE MAP

Reference number:
C-2



US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

CONTRACT NO.
CONTRACTOR
CITY STATE
Recommended: PRIME CONTRACTOR
Approved: RESIDENT ENGINEER
Date:

Sym	Action	Description	Date	Approval

Designed: KHP
Drawn: MRG
Reviewed: YHC
Submitted:
Date: JULY 2012
Dwg Scale: AS NOTED
Plot Scale:
File: Kenai_C-3
Drawing #:

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS ANCHORAGE, ALASKA

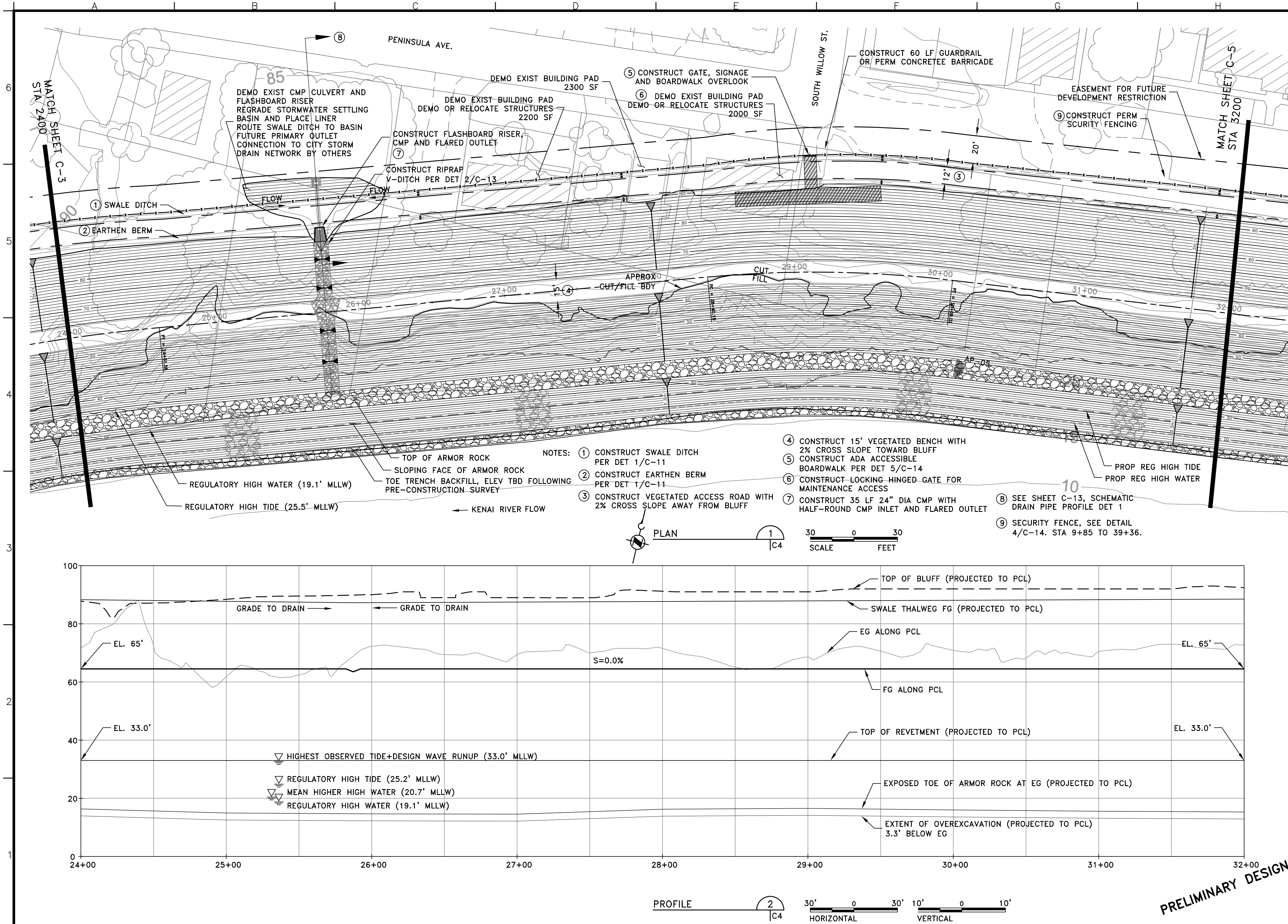
TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA

PROJECT PLAN AND SITE MAP

Reference number:
C-3

Sheet 10 of 24



US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

Date: JULY 2012
Dwg Scale: AS NOTED
File: Kenai_C-4

Designed: KHP
Drawn: MRG
Reviewed: YHC

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

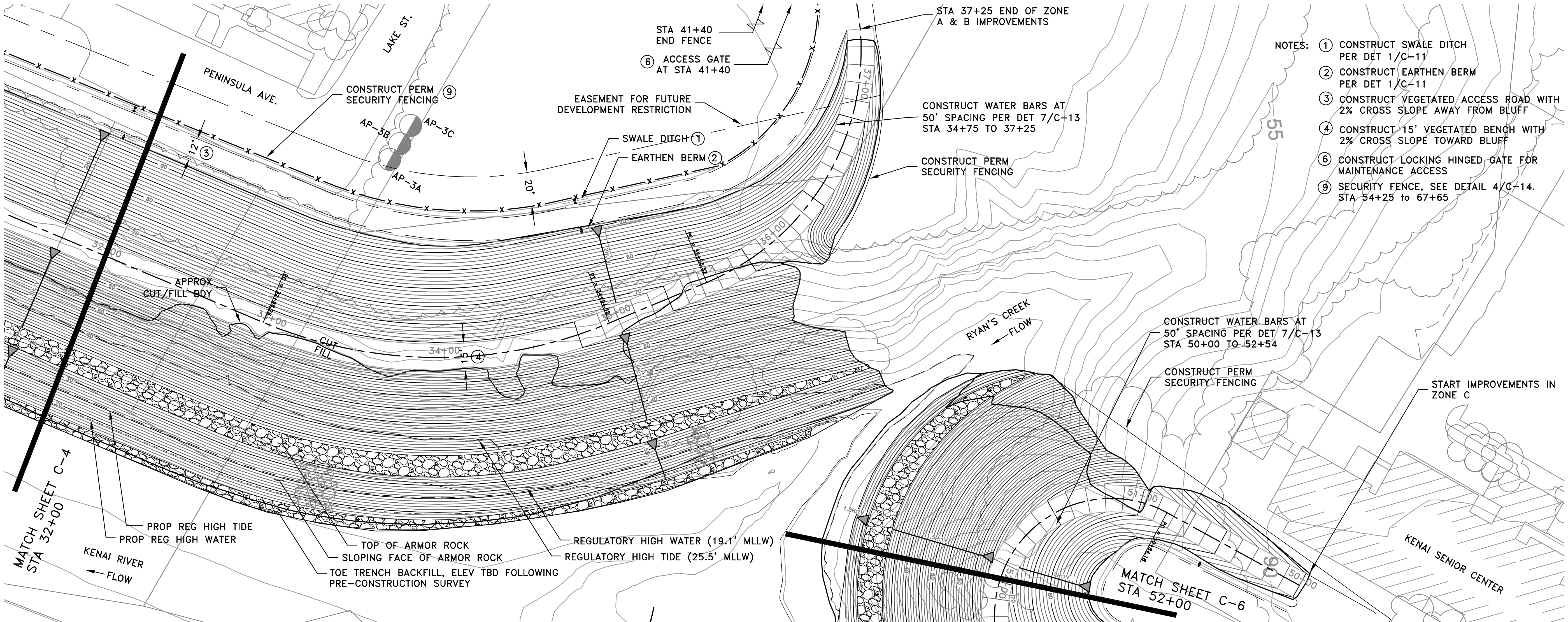
TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA

PROJECT PLAN AND SITE MAP

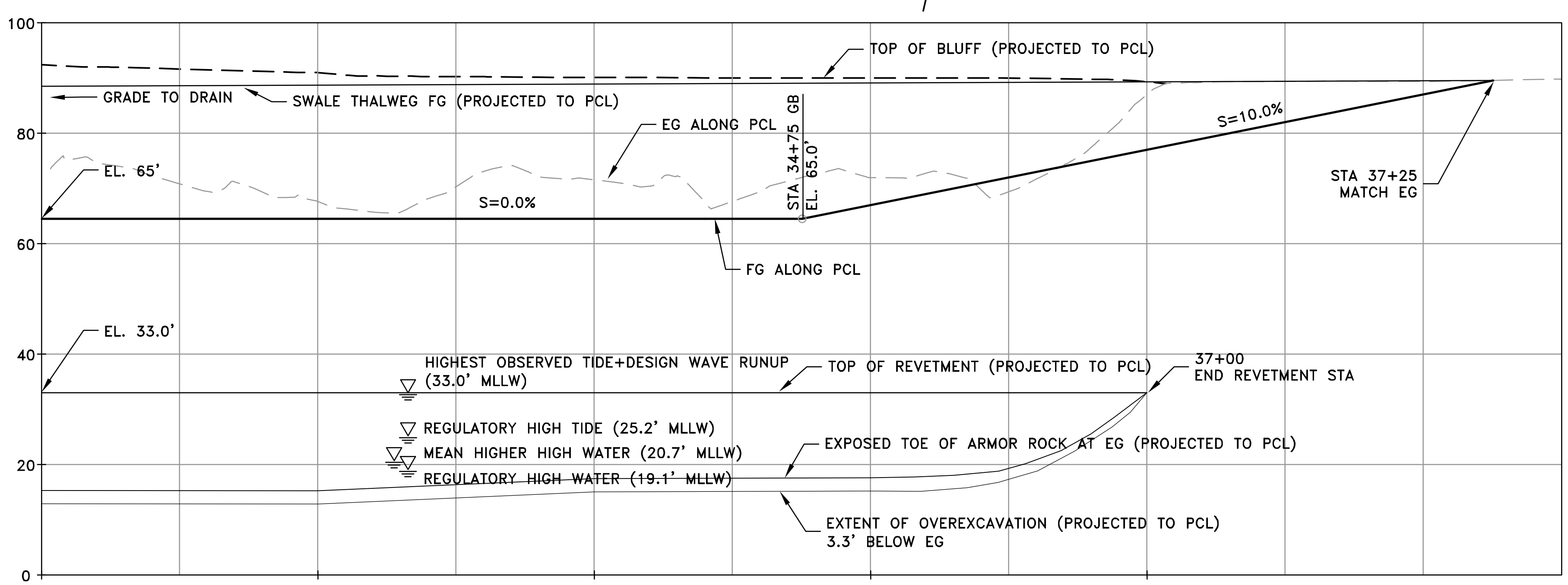
Reference number:
C-4

Sheet 11 of 24



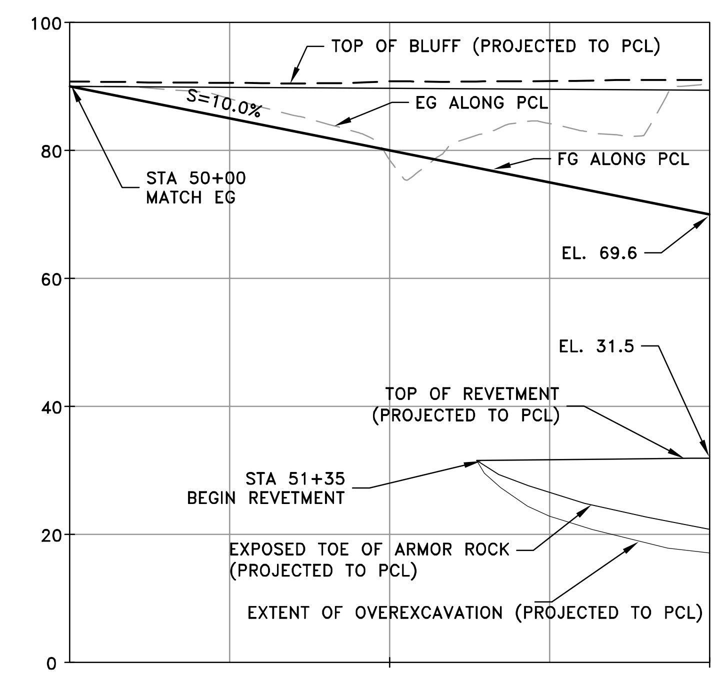
PLAN 1 / C5

30 0 30
SCALE FEET



PROFILE 2 / C5

30' 0 30' HORIZONTAL
10' 0 10' VERTICAL



PROFILE 4 / C5

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

CONTRACT NO.
CONTRACTOR
CITY STATE
Recommended: PRIME CONTRACTOR
Approved: RESIDENT ENGINEER
Date:

Sym | Action | Description | Date | Apprvd

Date: JULY 2012
Dwg Scale: AS NOTED
Plot Scale:
File: Kenai_C-5
Drawing #:

Designed: KHP
Drawn: MRG
Reviewed: YHC
Submitted:

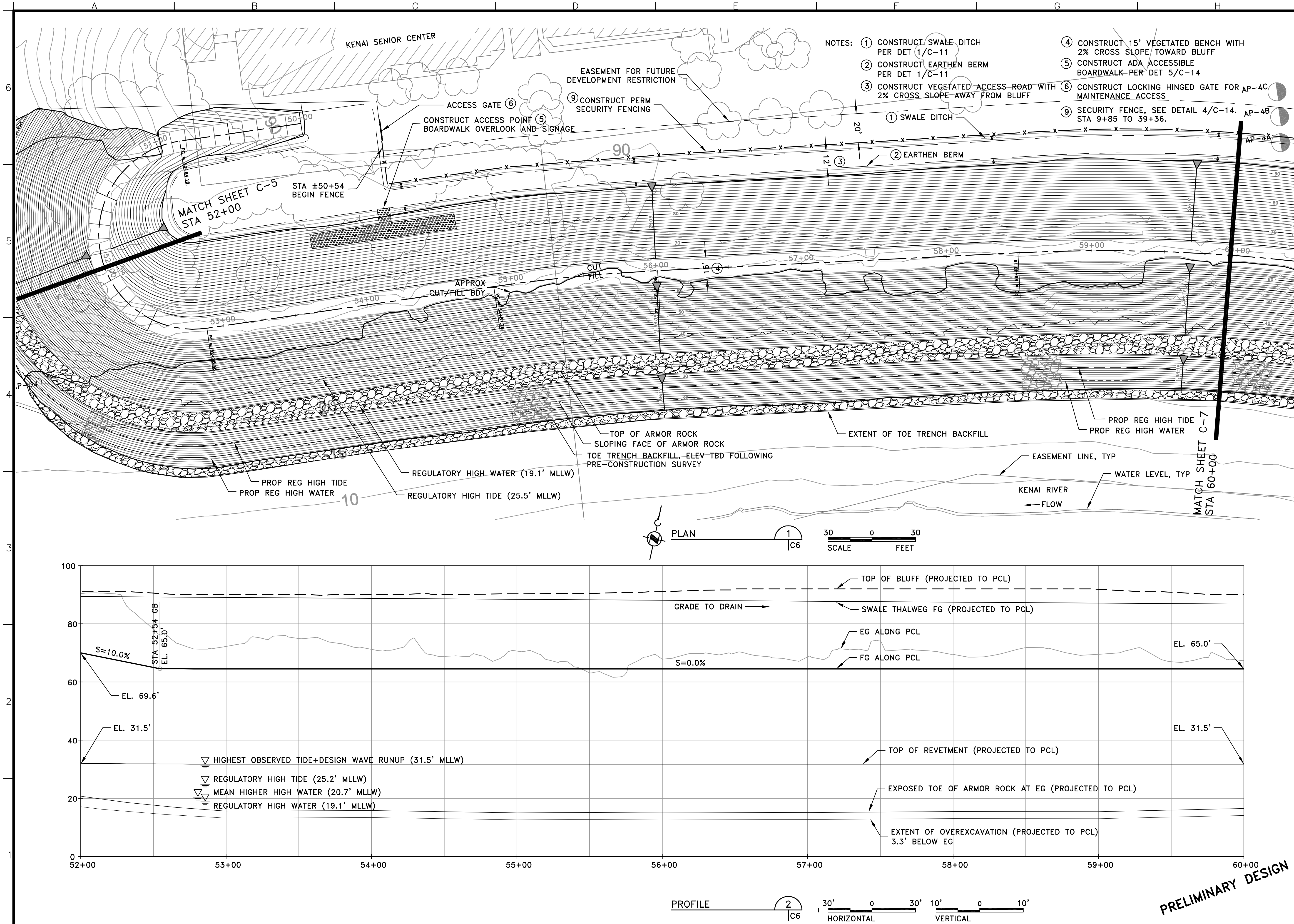
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA
CIVIL
PROJECT PLAN
AND SITE MAP

Reference number:
C-5

Sheet 12 of 24



US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

Date: JULY 2012
Dwg Scale: AS NOTED
File: Kenai_C-6

Designed: KHP
Drawn: MRG
Reviewed: YHC

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS ANCHORAGE, ALASKA

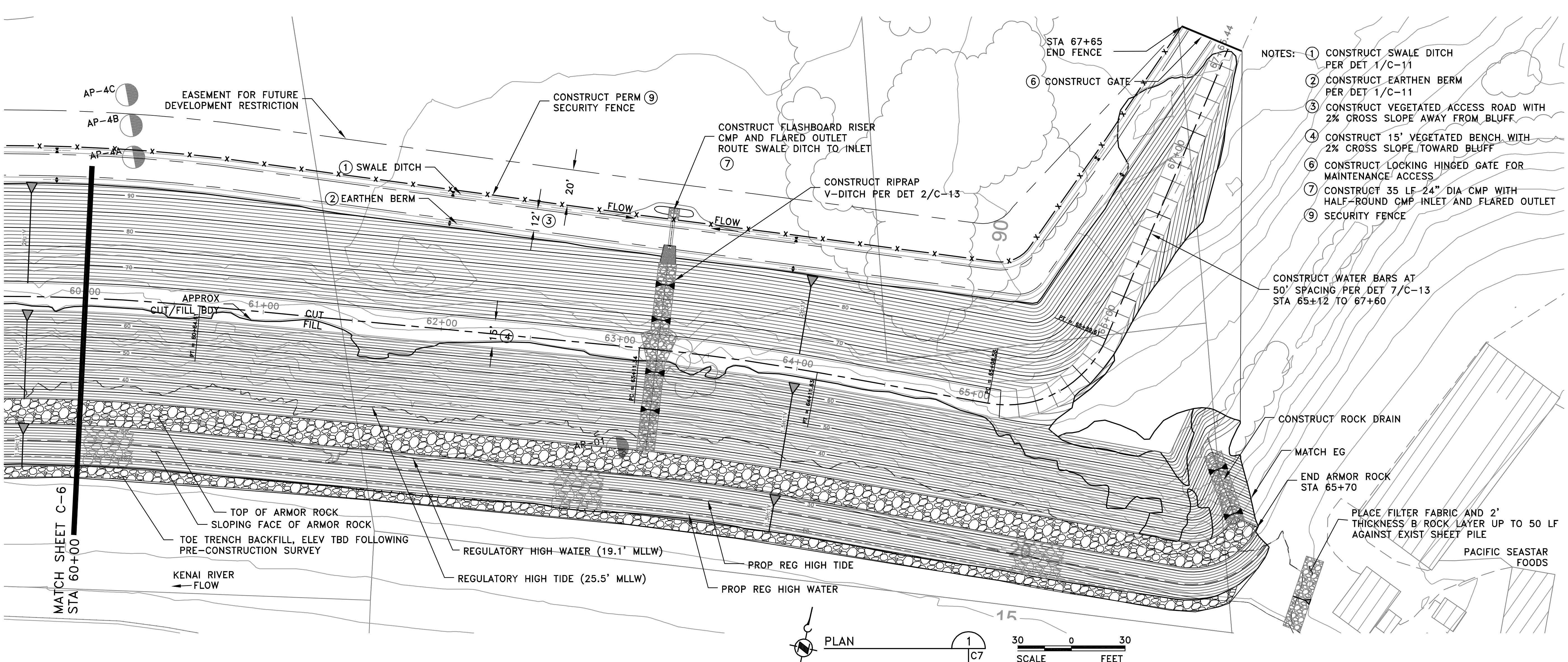
TETRA TECH, INC.

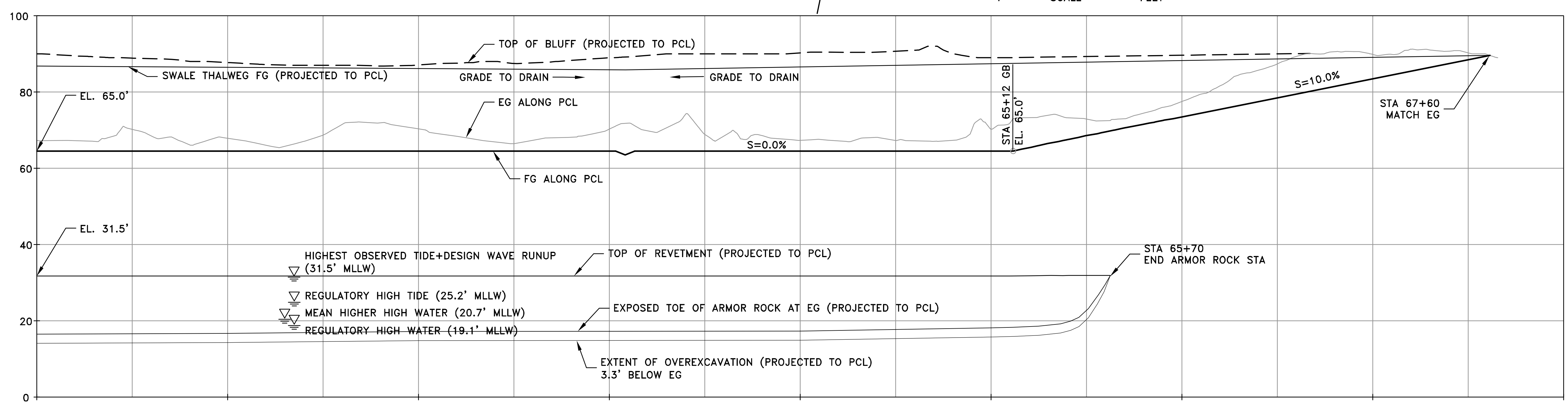
KENAI BLUFF STABILIZATION
KENAI, ALASKA

PROJECT PLAN AND SITE MAP

Reference number:
C-6

Sheet 13 of 24





PROFILE 2 C7

30' 0 30' HORIZONTAL

10' 0 10' VERTICAL

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS ALASKA DISTRICT

Date: JULY 2012
Dwg Scale: AS NOTED
File: Kenai_C-7

Designed: KHP
Drawn: MRG
Reviewed: YHC

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS ANCHORAGE, ALASKA

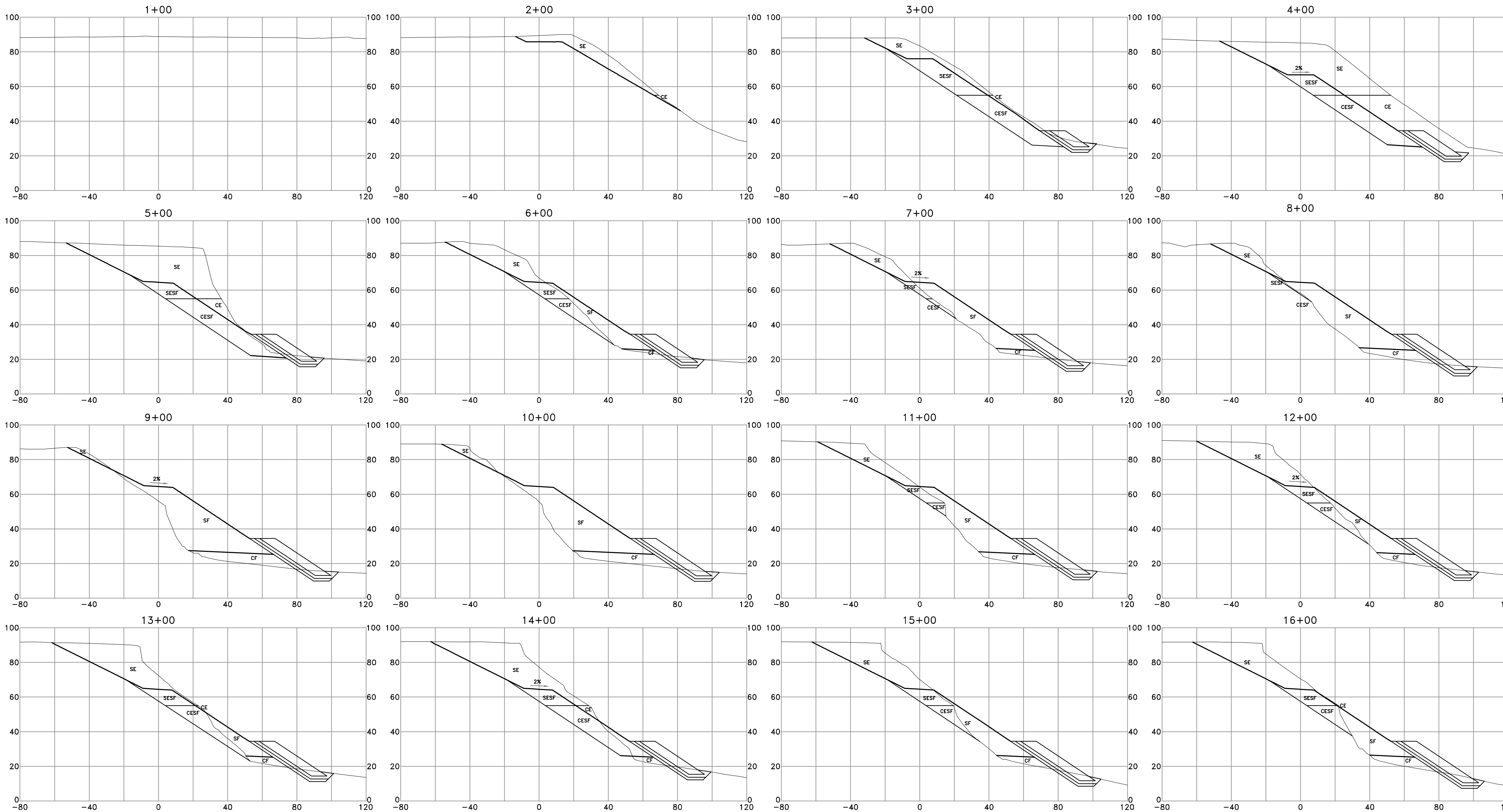
TETRA TECH, INC.

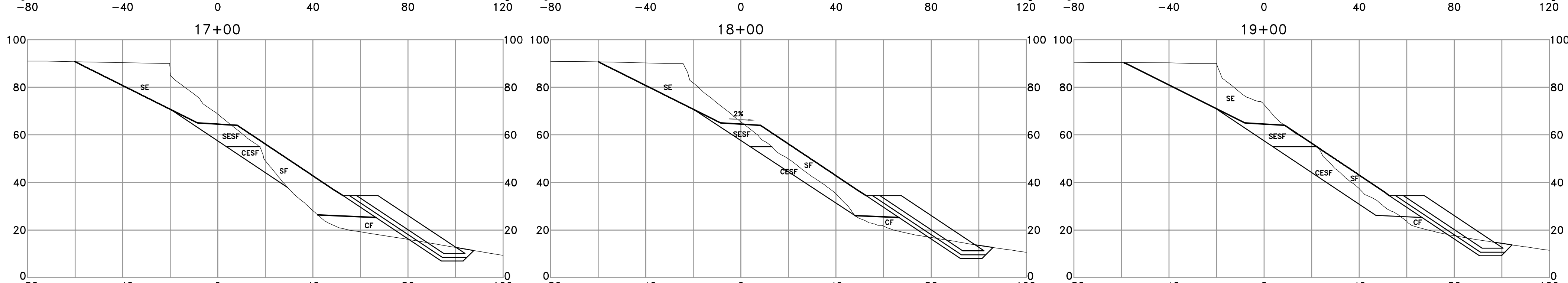
KENAI BLUFF STABILIZATION KENAI, ALASKA

PROJECT PLAN AND SITE MAP

Reference number: C-7

Sheet 14 of 24





KEY

SE	EXCAVATE ALLUVIUM
SESF	EXCAVATE ALLUVIUM BACKFILL ALLUVIUM
CESF	EXCAVATE TILL BACKFILL ALLUVIUM
CE	EXCAVATE TILL
SF	FILL ALLUVIUM
CF	FILL ALLUVIUM/TILL MIX

NOTE: EXISTING GROUND SHOWN IN CROSS SECTIONS BASED ON 2006 TOPOGRAPHY. CONTRACTOR SHALL CONDUCT TOPOGRAPHIC SURVEY PRIOR TO CONSTRUCTION TO VERIFY CHANGES TO THE EXISTING CONDITIONS.

CROSS SECTIONS 1
SCALE: 1"=30' C8

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

Date: JULY 2012
Dwg Scale: AS NOTED
File: Kenai_C-8

Designed: KHP
Drawn: MRG
Reviewed: YHC

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

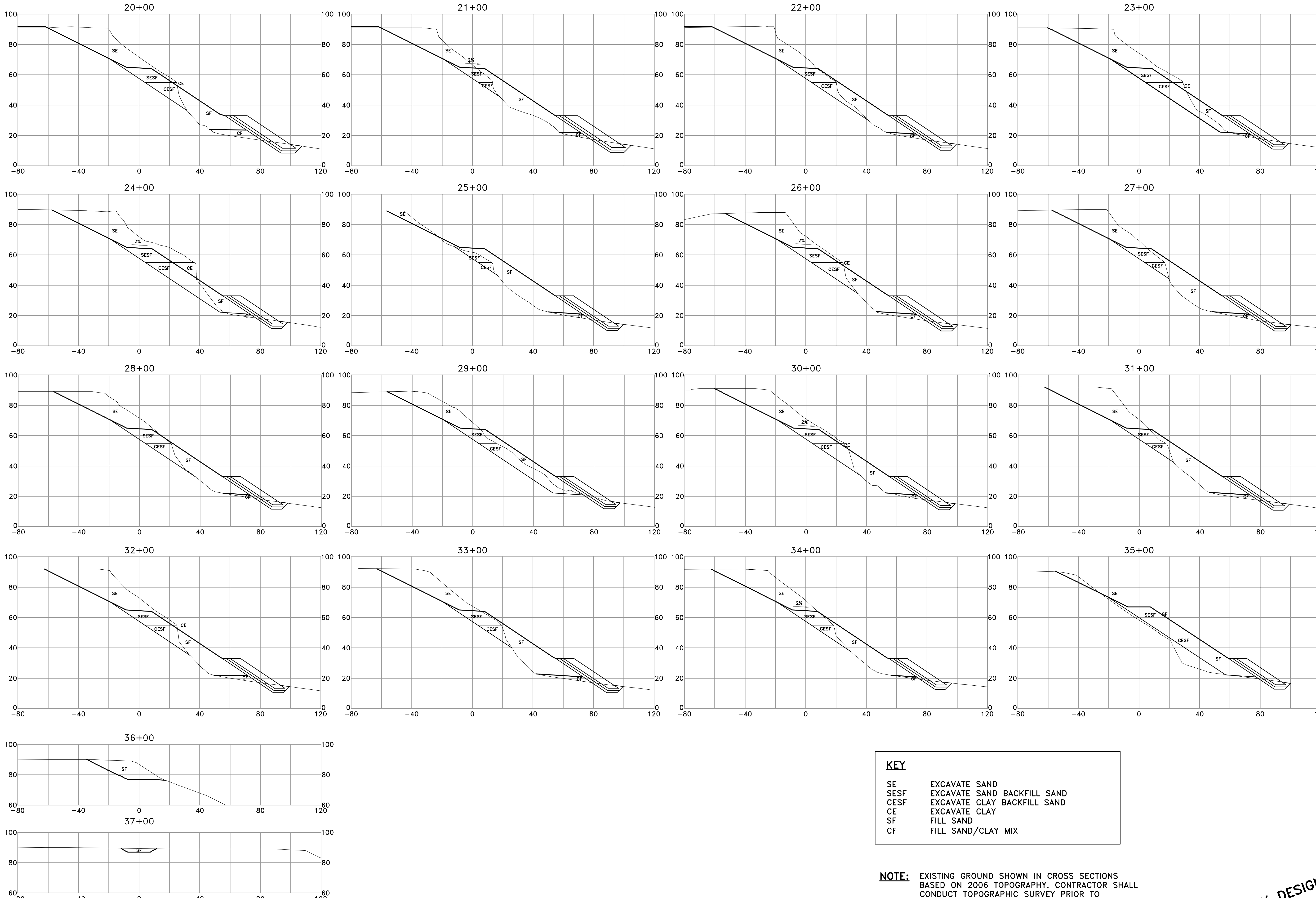
TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA

GRADING CROSS SECTIONS I

Reference number:
C-8

Sheet 15 of 24



CROSS SECTIONS 1 / C9
SCALE: 1"=30'

KEY

SE	EXCAVATE SAND
SESF	EXCAVATE SAND BACKFILL SAND
CESF	EXCAVATE CLAY BACKFILL SAND
CE	EXCAVATE CLAY
SF	FILL SAND
CF	FILL SAND/CLAY MIX

NOTE: EXISTING GROUND SHOWN IN CROSS SECTIONS BASED ON 2006 TOPOGRAPHY. CONTRACTOR SHALL CONDUCT TOPOGRAPHIC SURVEY PRIOR TO CONSTRUCTION TO VERIFY CHANGES TO THE EXISTING CONDITIONS.

PRELIMINARY DESIGN

US ARMY CORPS
OF ENGINEERS
ALASKA DISTRICT

Date: JULY 2012
Dwg Scale: AS NOTED
File: Kenai_C-9

Designed: KHP
Drawn: MRG
Reviewed: KHP

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

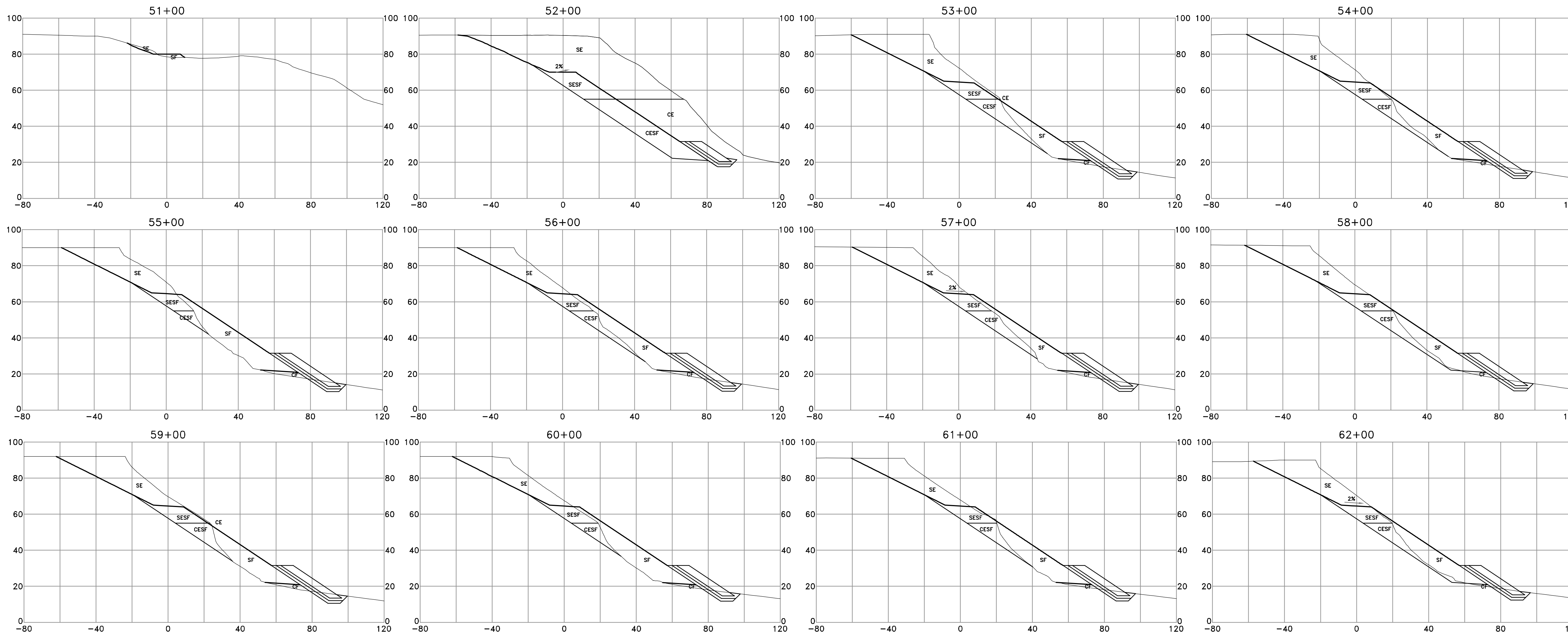
TETRA TECH, INC.

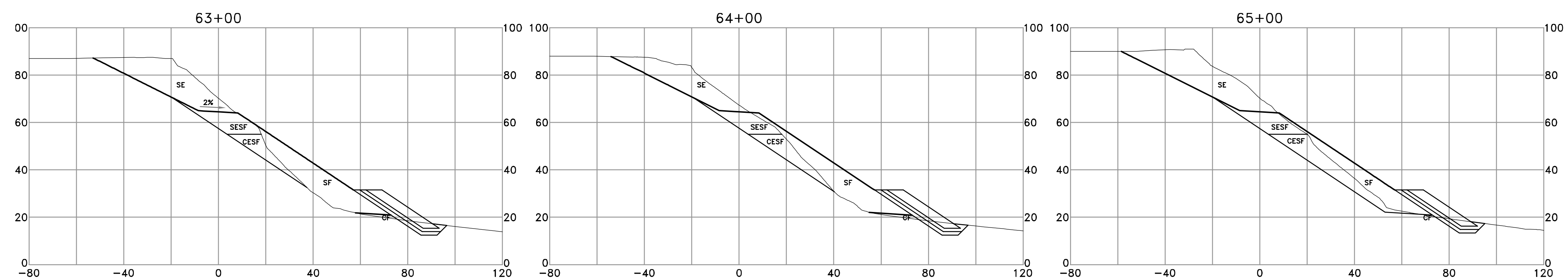
KENAI BLUFF STABILIZATION
KENAI, ALASKA

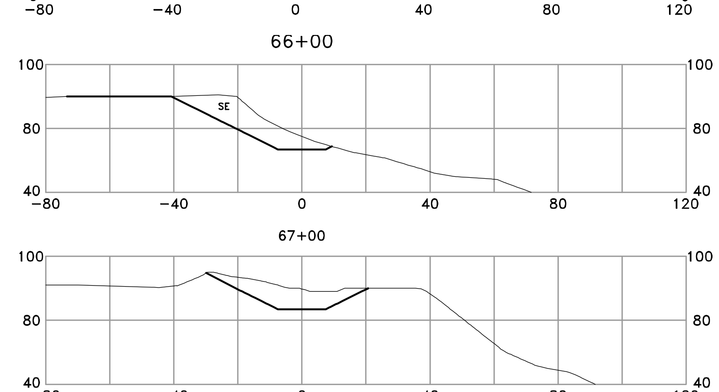
GRADING CROSS SECTIONS II

Reference number:
C-9

Sheet 16 of 24





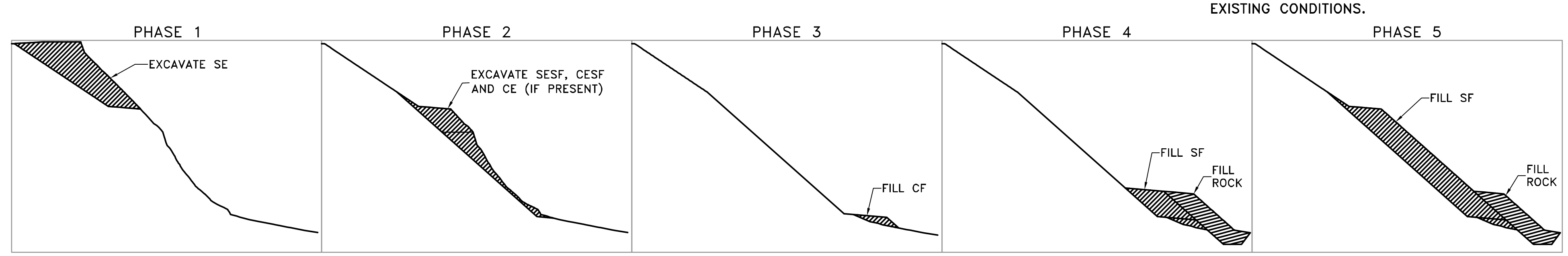


KEY

SE	EXCAVATE SAND
SESF	EXCAVATE SAND BACKFILL SAND
CESF	EXCAVATE CLAY BACKFILL SAND
CE	EXCAVATE CLAY
SF	FILL SAND
CF	FILL SAND/CLAY MIX

CROSS SECTIONS 1
SCALE: 1"=30' C10

NOTE: EXISTING GROUND SHOWN IN CROSS SECTIONS BASED ON 2006 TOPOGRAPHY. CONTRACTOR SHALL CONDUCT TOPOGRAPHIC SURVEY PRIOR TO CONSTRUCTION TO VERIFY CHANGES TO THE EXISTING CONDITIONS.



CONST. PHASING 2
SCALE: NTS C10

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

CONTRACT NO.
CONTRACTOR
CITY
STATE
Recommended:
PRIME CONTRACTOR
Approved:
RESIDENT ENGINEER
Date:

Sym	Action	Description	Date	Approval

Date: JULY 2012
Dwg Scale: AS NOTED
Plot Scale:
File: Kenai_C-10
Drawing #:

Designed: KHP
Drawn: MRG
Reviewed: YHC
Submitted:

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

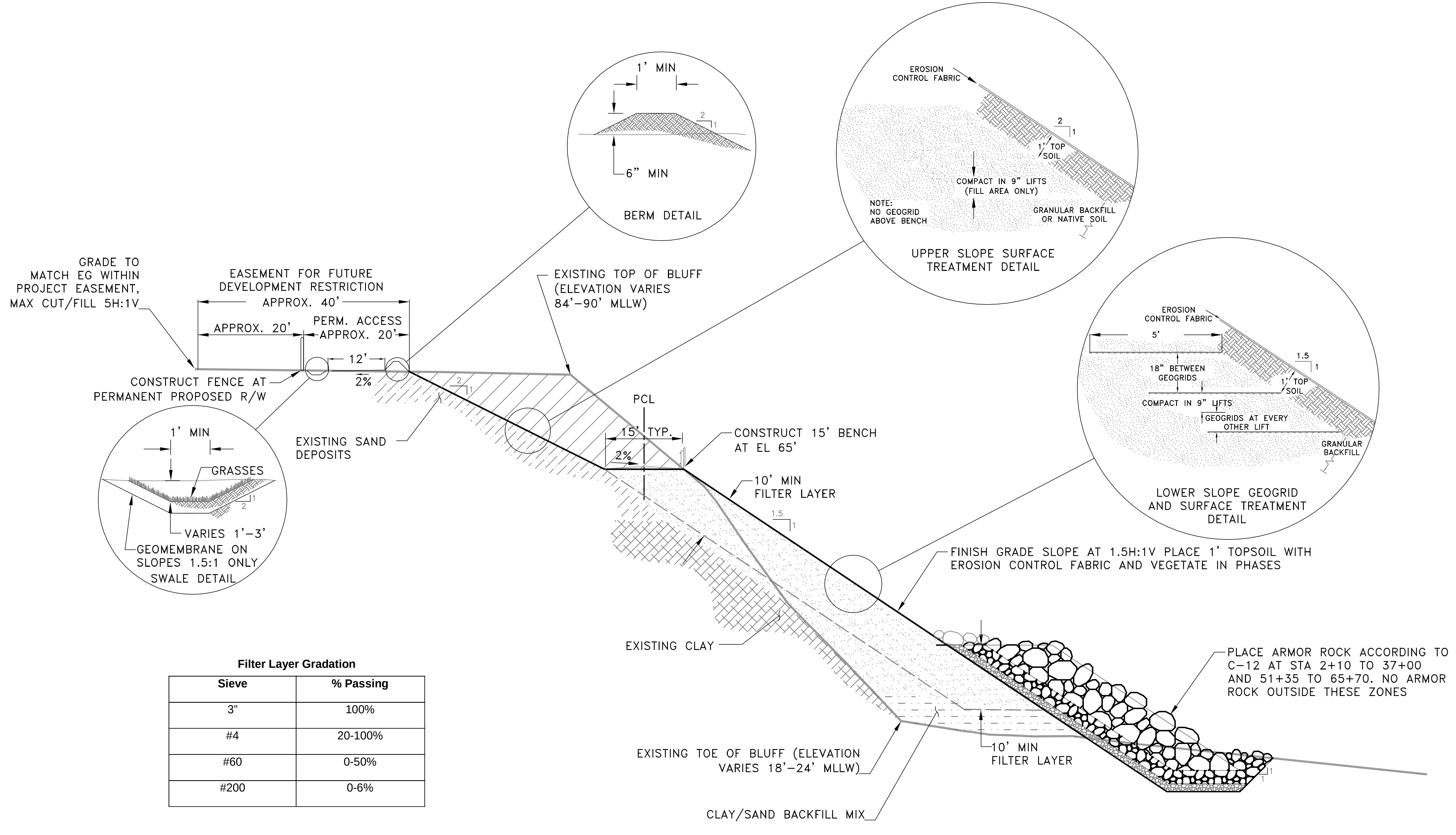
TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA

GRADING CROSS SECTIONS III

Reference number:
C-10

Sheet 17 of 24



Filter Layer Gradation

Sieve	% Passing
3"	100%
#4	20-100%
#60	0-50%
#200	0-6%

STA 2+10 TO 37+00 AND STA 51+35 TO 65+70

TYPICAL SECTION 1 C11

SCALE: NTS

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS ALASKA DISTRICT

Date: JULY 2012
Dwg Scale: AS NOTED
File: Kenai_C-11 rev

Designed: KHP
Drawn: MRG
Reviewed: YHC

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS ANCHORAGE, ALASKA

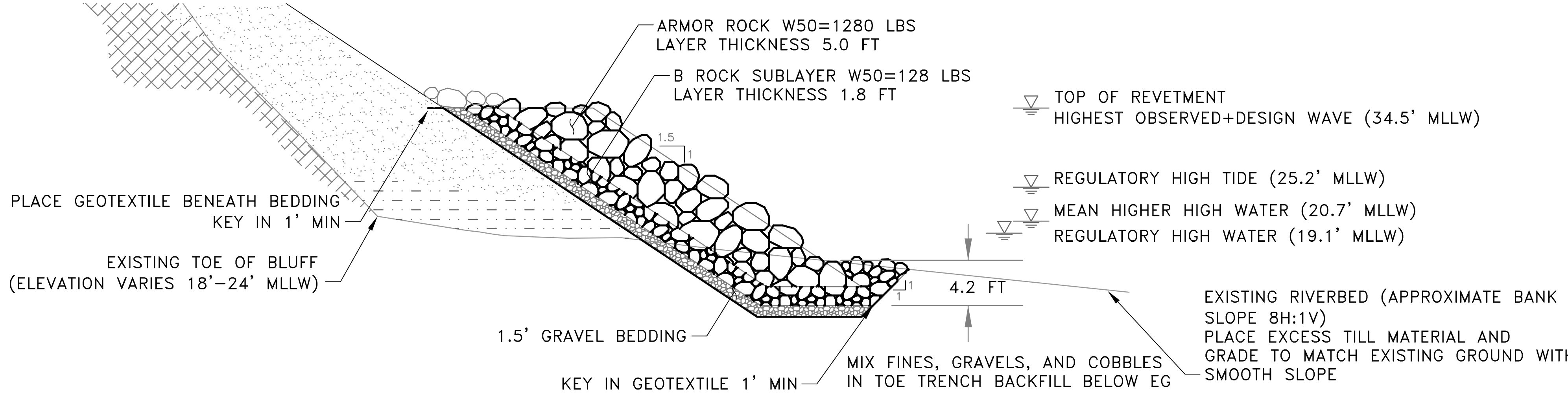
TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA

TYPICAL SECTIONS

Reference number: C-11

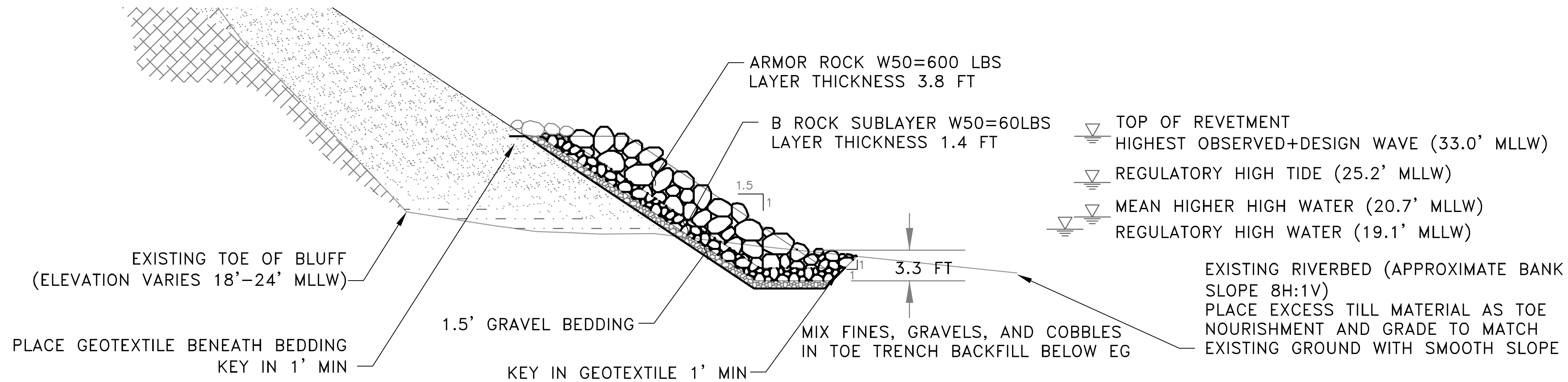
Sheet 18 of 24



STA 0+00 TO STA 21+75

TYPICAL SECTION A C12

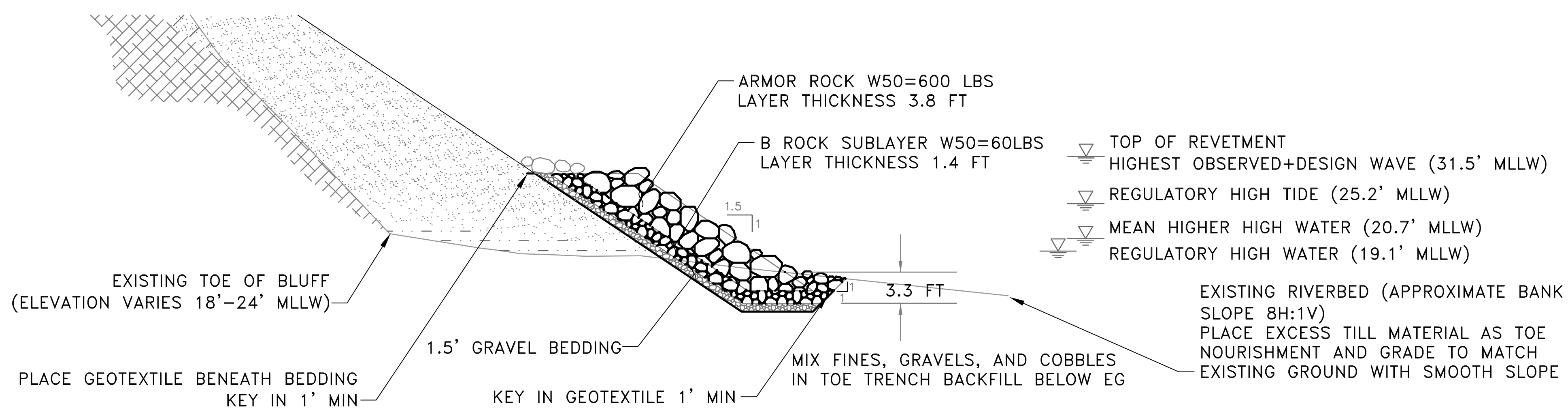
SCALE: NTS



STA 21+75 TO STA 37+00

TYPICAL SECTION B C12

SCALE: NTS



STA 51+35 TO 65+70

TYPICAL SECTION C C12

SCALE: NTS

NOTE: ROCK SHALL BE UNIFORM IN SIZE AND SELECTIVELY PLACED, ADHERING TO PLACEMENT AND GRADATION REQUIREMENTS AND PROJECT SPECIFICATIONS

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

Date: JULY 2012
Dwg Scale: AS NOTED
File: Kenai_C-12

Designed: KHP
Drawn: MRG
Reviewed: YHC

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.

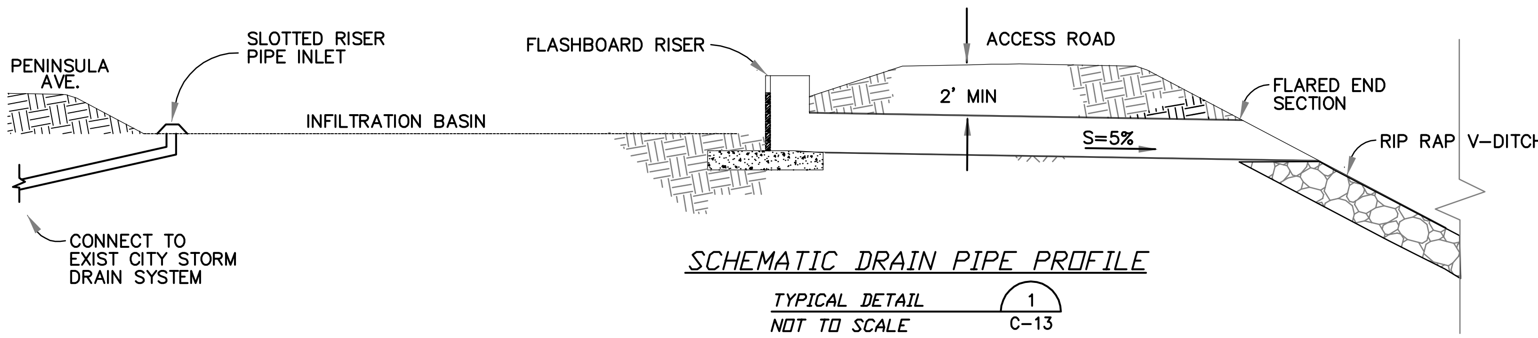
KENAI BLUFF STABILIZATION
KENAI, ALASKA

ROCK REVETMENT DETAILS

Reference number: C-12

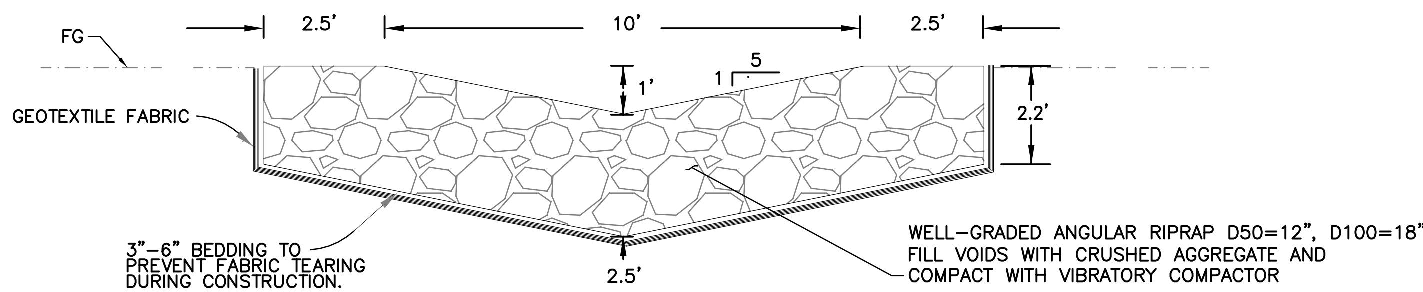
Sheet 19 of 24

NOTE: PRIMARY BASIN OUTLET CONNECTED TO CITY STORM DRAIN NETWORK TBD. FLASHBOARD RISER AND V-DITCH ACT AS SECONDARY OUTLET FOR EMERGENCY OVERFLOW ONLY.



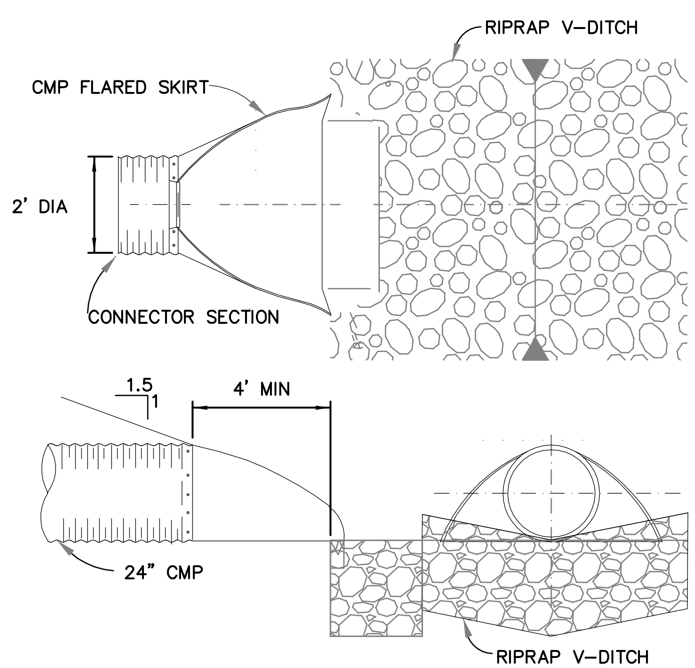
SCHEMATIC DRAIN PIPE PROFILE

TYPICAL DETAIL 1
NOT TO SCALE C-13



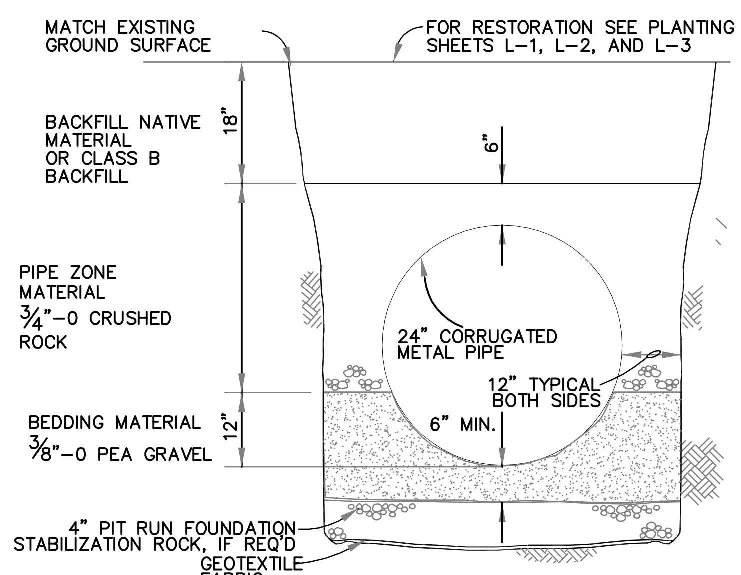
RIPRAP V-DITCH

TYPICAL DETAIL 2
NOT TO SCALE C-13



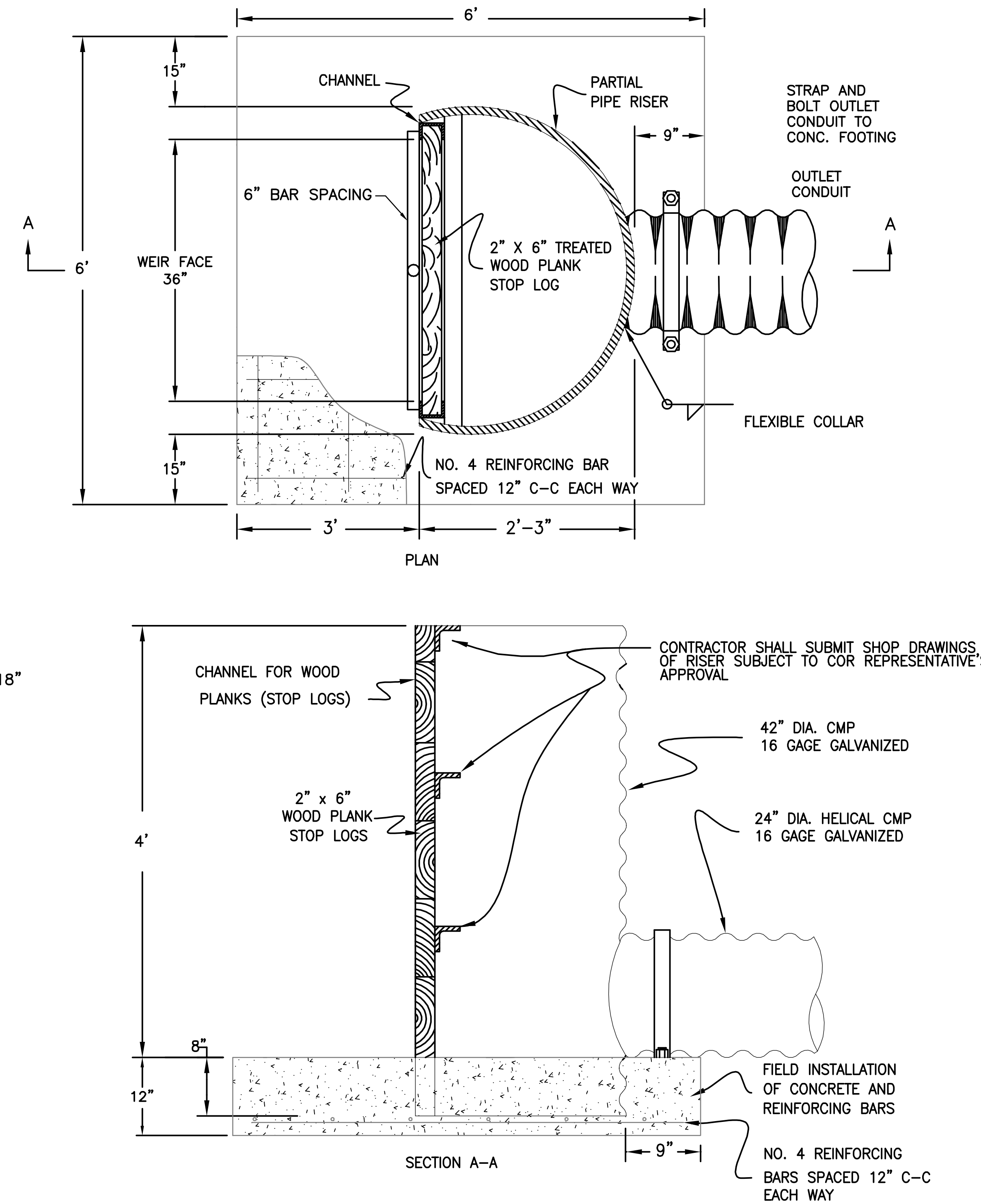
FLARED END SECTION

TYPICAL DETAIL 3
NOT TO SCALE C-13



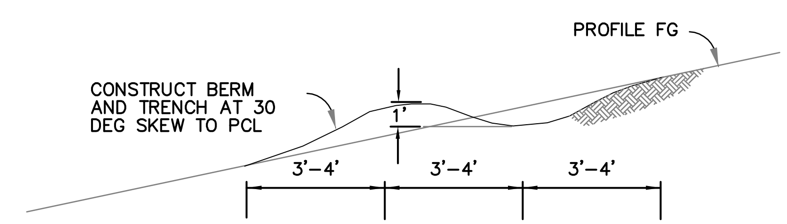
TRENCH DETAIL

TYPICAL DETAIL 4
NOT TO SCALE C-13



FLASHBOARD RISER PLAN AND SECTION

TYPICAL DETAIL 5
NOT TO SCALE C-13



WATER BAR

TYPICAL DETAIL 6
NOT TO SCALE C-13

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

CONTRACT NO.
CONTRACTOR
CITY STATE
Recommended: PRIME CONTRACTOR
Approved: RESIDENT ENGINEER
Date:

Sym | Action | Description | Date | Apprvd

Designed: KHP
Drawn: MRG
Reviewed: YHC
Submitted:

Date: JULY 2012
Dwg Scale: AS NOTED
Plot Scale:
File: Kenai_C-13
Drawing #:

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.

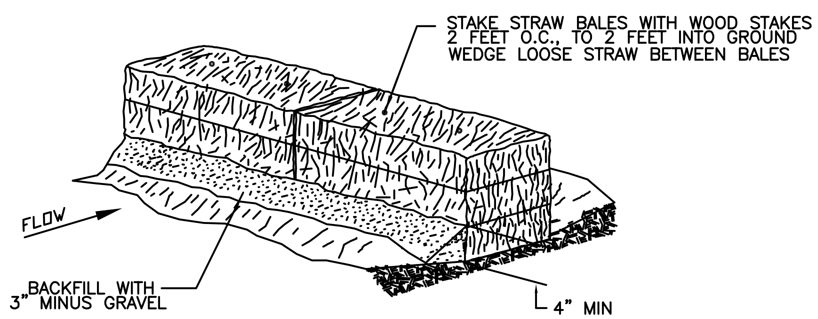
KENAI BLUFF STABILIZATION
KENAI, ALASKA
GENERAL
DRAINAGE DETAILS

Reference number:
C-13

Sheet 22 of 24

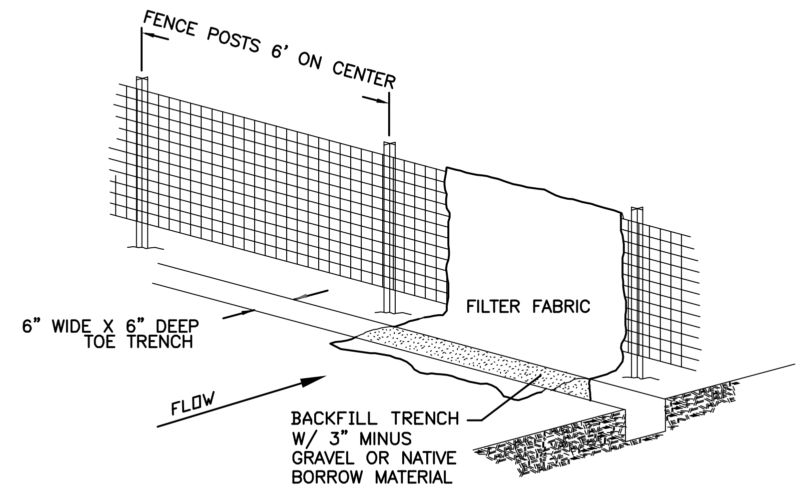
NOTE:

CONTRACTOR SHALL SUBMIT STORMWATER POLLUTION PREVENTION PLAN (SWPPP) FOR APPROVAL PRIOR TO CONSTRUCTION. SWPPP MAY INCLUDE TEMPORARY SILT FENCES, TURBIDITY CURTAINS, STRAW BALES, OR OTHER BMPS AND SHALL DEMONSTRATE ADHERENCE WITH ALL APPLICABLE ENVIRONMENTAL GUIDELINES. DETAILS SHOWN HEREIN ARE PROVIDED AS EXAMPLES ONLY.



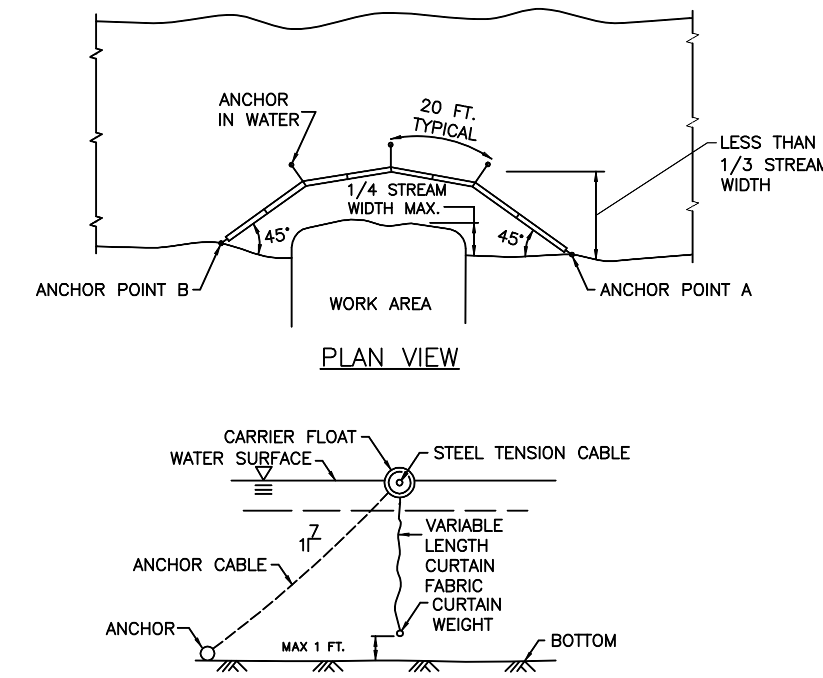
STRAW BALE

TYPICAL DETAIL 1 TYP
SCALE: NOT TO SCALE



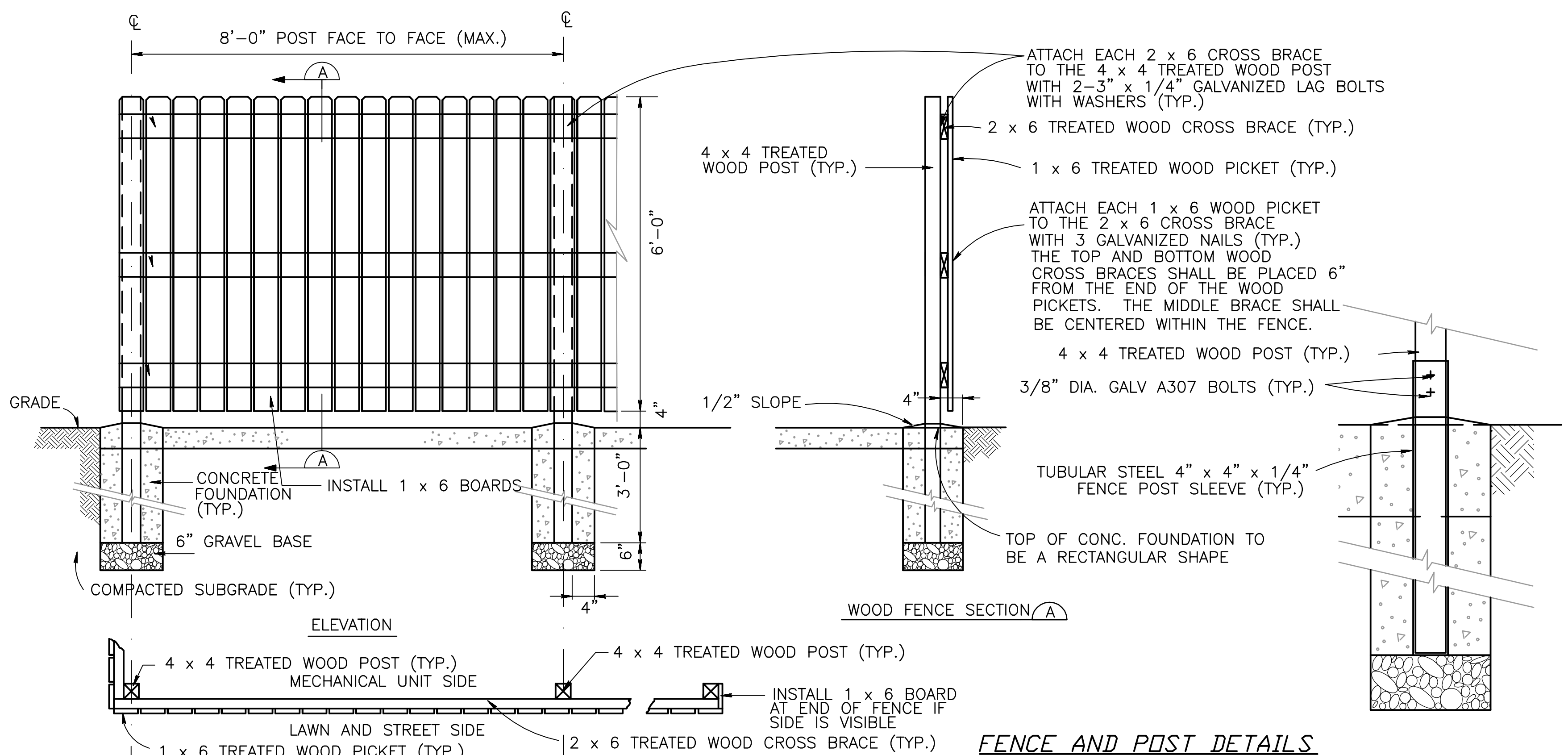
SILT FENCE

TYPICAL DETAIL 2 TYP
SCALE: NOT TO SCALE



TURBIDITY CURTAIN

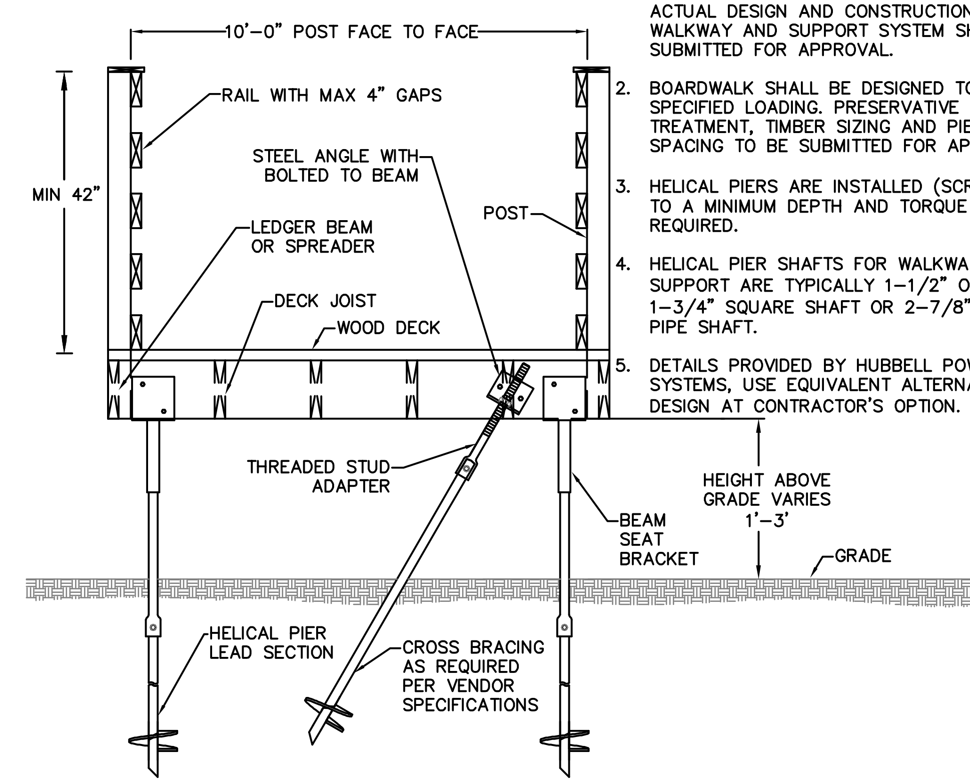
TYPICAL DETAIL 3 TYP
SCALE: NOT TO SCALE



FENCE AND POST DETAILS

TYPICAL DETAIL 4 TYP
SCALE: NOT TO SCALE

NOTES
1. THIS IS A CONCEPT DRAWING ONLY. ACTUAL DESIGN AND CONSTRUCTION OF WALKWAY AND SUPPORT SYSTEM SHALL BE SUBMITTED FOR APPROVAL.
2. BOARDWALK SHALL BE DESIGNED TO MEET SPECIFIED LOADING. PRESERVATIVE TREATMENT, TIMBER SIZING AND PIER SPACING TO BE SUBMITTED FOR APPROVAL.
3. HELICAL PIERS ARE INSTALLED (SCREWED) TO A MINIMUM DEPTH AND TORQUE AS REQUIRED.
4. HELICAL PIER SHAFTS FOR WALKWAY SUPPORT ARE TYPICALLY 1-1/2" OR 1-3/4" SQUARE SHAFT OR 2-7/8" O.D. PIPE SHAFT.
5. DETAILS PROVIDED BY HUBBELL POWER SYSTEMS, USE EQUIVALENT ALTERNATE DESIGN AT CONTRACTOR'S OPTION.



BOARDWALK DETAILS

TYPICAL DETAIL 5 TYP
SCALE: NOT TO SCALE

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

CONTRACT NO. CONTRACTOR CITY STATE
Recommended: PRIME CONTRACTOR Approved: RESIDENT ENGINEER Date:

Sym	Action	Description	Date	Appvd

Date: JULY 2012
Dwg Scale: AS NOTED
Plot Scale:
File: Kenai_C-14
Drawing #:

Designed: KHP
Drawn: MRG
Reviewed: YHC
Submitted:

U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS ANCHORAGE, ALASKA

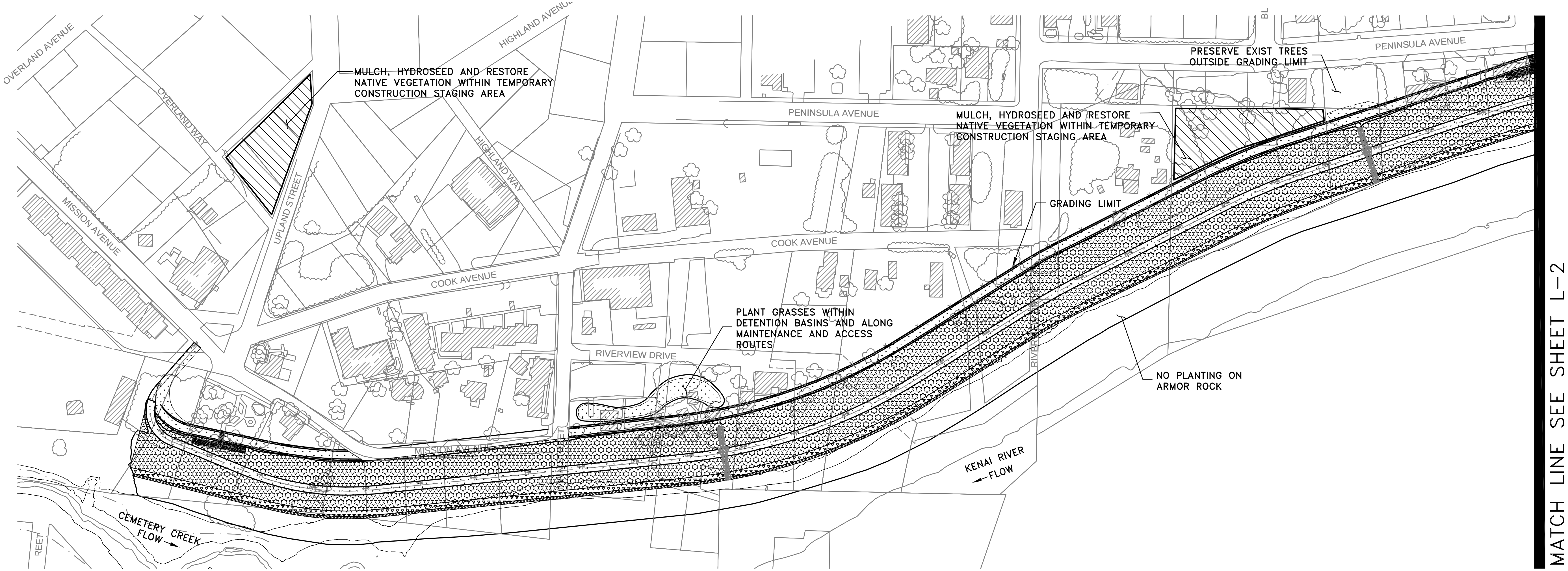
TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA
GENERAL

MISCELLANEOUS DETAILS

Reference number:
C-14

Sheet 21 of 24



PLANTING PLAN

100 0 100
SCALE Feet

LEGEND

- WILLOW
- ALDERS
- CONIFER
- GRASS

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

CONTRACT NO. ____
CONTRACTOR ____
CITY ____ STATE ____
Recommended: ____ PRIME CONTRACTOR
Approved: ____ RESIDENT ENGINEER
Date: ____

Sym.	Action	Description	Date	Appvd

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.
SURFACE WATER GROUP
1020 SW Taylor Street, Suite 530
Portland, OR 97205
(503) 223-5388 Fax (503) 228-8631

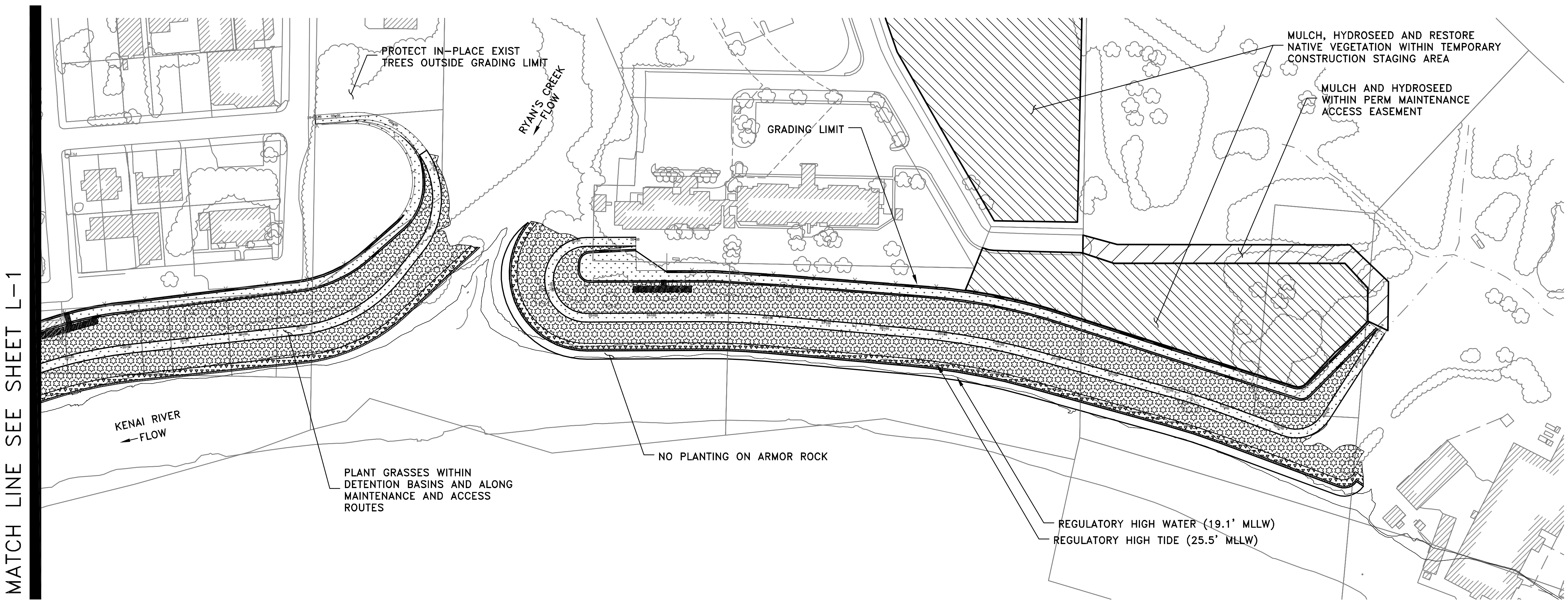
Designed: KHP
Drawn: MRG
Reviewed: YHC
Submitted:

Date: JULY 2012
Dwg Scale: AS NOTED
Plot Scale:
File: Kenai_L-1
Drawing #:

KENAI BLUFF STABILIZATION
KENAI, ALASKA
GENERAL

PLANTING PLAN I

Reference number:
L-1



PLANTING PLAN

100 0 100
SCALE Feet

LEGEND

- WILLOW
- ALDERS
- CONIFER
- GRASS

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

Designed: KHP
Drawn: MRG
Reviewed: YHC
Date: JULY 2012
Dwg Scale: AS NOTED
File: Kenai_L-2

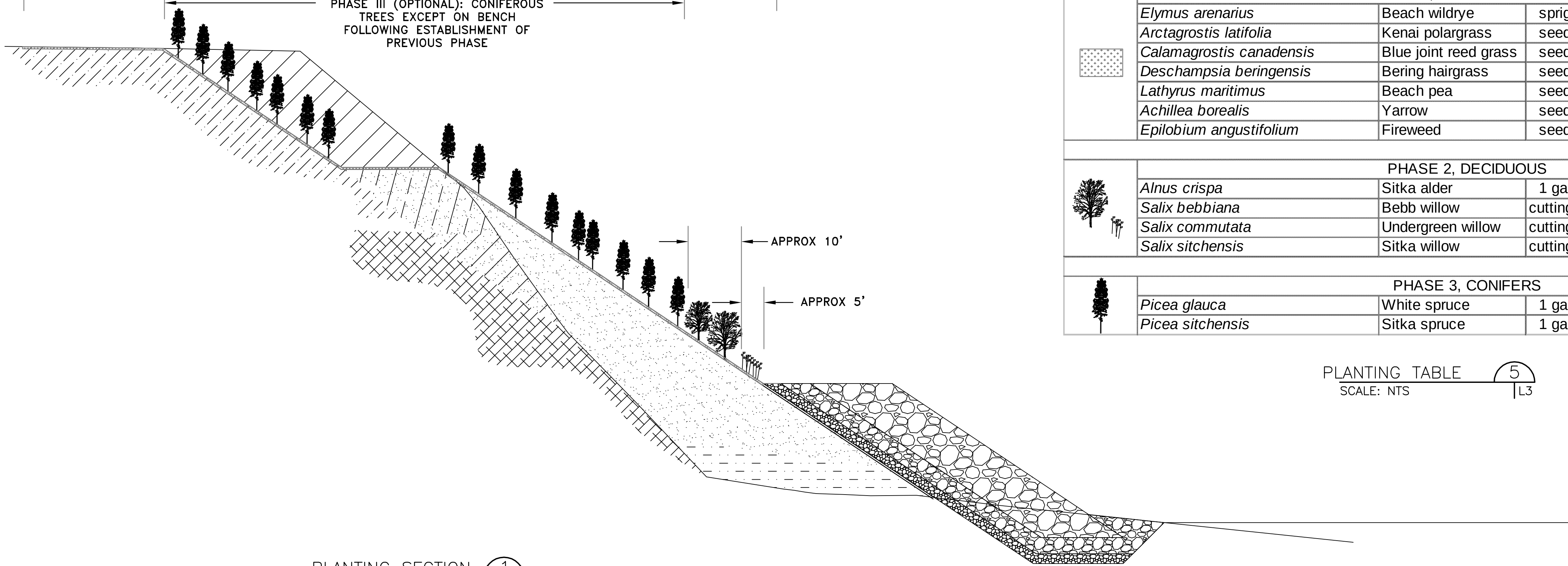
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA
GENERAL

PLANTING PLAN II

Reference number:
L-2
Sheet 23 of 24



PLANTING SECTION 1 / L3
SCALE: NTS

SYMBOL	SPECIES NAME	COMMON NAME	SIZE	DENSITY	QUANTITY/acre
	PHASE I, GRASS SEED MIX				
	Elymus arenarius	Beach wildrye	sprig	2' o.c.	10,000
	Arctagrostis latifolia	Kenai polargrass	seed		5 lbs/ac
	Calamagrostis canadensis	Blue joint reed grass	seed		10 lbs/ac
	Deschampsia beringensis	Bering hairgrass	seed		3 lbs/ac
	Lathyrus maritimus	Beach pea	seed		1 lb/ac
	Achillea borealis	Yarrow	seed		2 lbs/ac
	Epilobium angustifolium	Fireweed	seed		1 lb/ac
	PHASE 2, DECIDUOUS				
	Alnus crispa	Sitka alder	1 gal	10' o.c.	435
	Salix bebbiana	Bebb willow	cuttings	5' o.c.	580
	Salix commutata	Undergreen willow	cuttings	5' o.c.	580
	Salix sitchensis	Sitka willow	cuttings	5' o.c.	580
	PHASE 3, CONIFERS				
	Picea glauca	White spruce	1 gal	15' o.c.	190
	Picea sitchensis	Sitka spruce	1 gal	25' o.c.	70

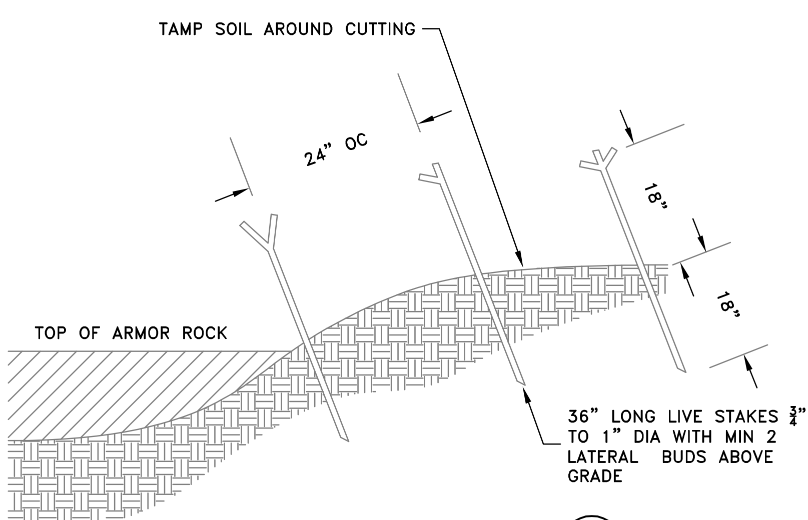
PLANTING TABLE 5 / L3
SCALE: NTS

NOTES:

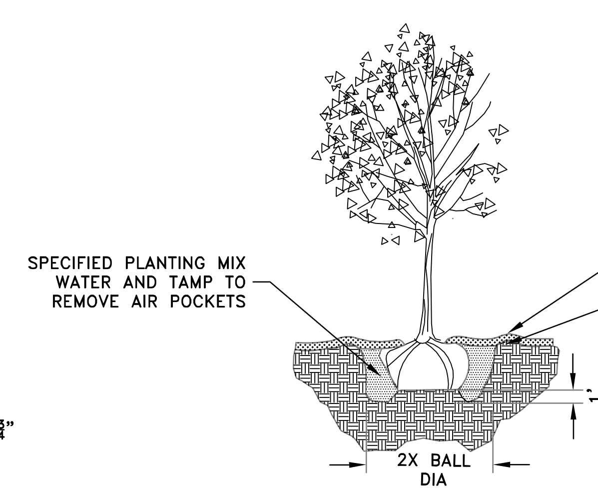
PLANT DECIDUOUS AND CONIFEROUS TREES SO THAT TOP OF ROOT BALL IS EVEN WITH THE FINISHED GRADE ON THE DOWNHILL SIDE

SCARIFY SIDES OF PLANTING PIT PRIOR TO BACKFILLING

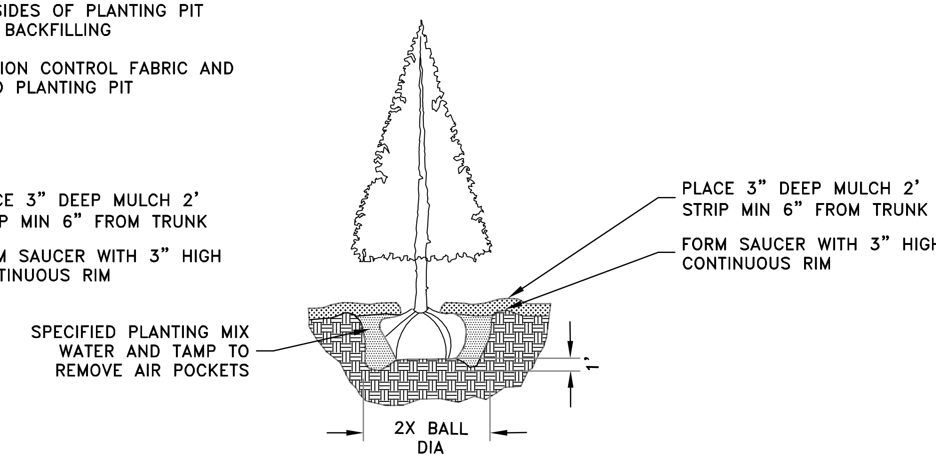
CUT EROSION CONTROL FABRIC AND KEY IN TO PLANTING PIT



WILLOW DETAIL 2 / L3
SCALE: NTS



DECIDUOUS TREE DETAIL 3 / L3
SCALE: NTS



CONIFER TREE DETAIL 4 / L3
SCALE: NTS

PRELIMINARY DESIGN

US ARMY CORPS OF ENGINEERS
ALASKA DISTRICT

Date: JULY 2012
Dwg Scale: AS NOTED
File: Kenai_L-3

Designed: KHP
Drawn: MRG
Reviewed: YHC

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
ANCHORAGE, ALASKA

TETRA TECH, INC.

KENAI BLUFF STABILIZATION
KENAI, ALASKA
GENERAL
PLANTING TABLE AND DETAILS

Reference number:
L-3