BEAUTY BAY MINE
EE/CA
KENAI FJORDS
NATIONAL PARK, ALASKA

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Prepared by:
Shannon & Wilson, Inc.
P.O. Box 70843
Fairbanks, Alaska 99707

under contract to:
Charles Bettisworth and Company
P.O. Box 73209
Fairbanks, Alaska 99707

for the:
National Park Service
Alaska Regional Office
2525 Gambell Street, Room 107
Anchorage, Alaska 99503-2892

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
2055 Hill Road
P.O. Box 70843
Fairbanks, Alaska 99707 ▪ 0843
907 ▪ 479 ▪ 0600

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF TABLES AND FIGURES

EXECUTIVE SUMMARY

The discovery of a deceased moose calf on the Beauty Bay Mine site, which is located in Kenai Fjords National Park, Alaska, prompted the collection of source/media samples at the site. The results of the initial sampling indicated that arsenic concentrations within the uncontained tailings ponds exceed established human health risk-based limits. A transient, white, crystalline precipitate coating the tailings ponds has been noted during site visits in June and August 1994, but not at other times. Due to the abundance of arsenopyrite, it was assumed that the precipitate may be toxic, arsenic oxides. Subsequent removal of the moose corpse by a bear prevented performing an autopsy to conclusively link the death of the moose to the arsenic. Results of subsequent arsenic speciation studies indicate that arsenic is present as a component of relatively insoluble arsenopyrite, and within soluble arsenic-bearing oxides. This results in uncertainty regarding whether the arsenic in the tailings is currently of a form which could have caused the death of the moose, and what conditions, if any, may have resulted in an increase in toxicity.

The Beauty Bay Mine is one of many small-scale gold mines in the Nuka Bay area. The site is remote, consequently it receives very few visitors. Gold was mined from several quartz veins which contained arsenopyrite ($FeAsS$) in association with the gold. The gold was free milling, and was separated from the quartz gangue by crushing and gravity separation. The rejected byproducts of this beneficiation process were placed on the ground surface of the site with no form of containment. The estimated volume of the fine tailings is about 61 cubic yards.

The primary objective of this removal action is to isolate the potentially toxic mine tailings from the local wildlife and occasional human visitor. Additional objectives include reduction of the potential for the contaminants to spread due to infiltration or surface water transport. This Engineering Evaluation/Cost Analysis (EE/CA) studied seven alternatives for removal actions at the Beauty Bay Mine site. These included fencing, containment, off-site disposal, and on-site treatment. Based on the comparative analysis of the alternatives and comments on the draft of this EE/CA by the National Park Service and the Environmental Protection Agency (EPA), stabilizing the tailings with a concrete mixture is the recommended removal action alternative. This alternative has a cost near the median of the range of estimated costs, a moderate impact on the park and the environment, and meets the removal action objective of isolating the tailings from humans and wildlife, while also limiting infiltration and reducing the potential for surface water transport of the tailings.

BEAUTY BAY MINE
EE/CA
KENAI FJORDS NATIONAL PARK, ALASKA

1.0 INTRODUCTION

This Engineering Evaluation/Cost Analysis (EE/CA) identifies proposed alternatives for removal actions at the Beauty Bay Mine, Kenai Fjords National Park, Alaska. It was prepared by Shannon & Wilson, Inc. under the direction of the National Park Service, Alaska Regional Office. Shannon & Wilson's work on this project was performed as a subconsultant to Charles Bettisworth and Company, as Task Order 1443 TO 200065067 to their Indefinite Quantities Contract Number 1443-CX-2000-92-017 with the National Park Service (NPS). The work was authorized on March 23, 1995. Additional tasks related to the preparation of this EE/CA were authorized by Modification No. 1 to the Task Order, dated July 24, 1995.

A draft of this EE/CA was issued to the NPS on April 26, 1995. That draft was issued for agency and public comment for the 30-day period required by law. This current final EE/CA supercedes the draft and incorporates both the comments received and the results of subsequent investigations.

The discovery of a dead moose calf on the site on June 28, 1994, prompted the collection of soil samples in an attempt to determine if on-site hazards had been the cause of death. By the time that sample results had been received which tentatively linked the moose's death to arsenic present in the mine tailings at the site, and funding had been secured for a removal action, winter weather prevented immediate execution of a removal action. The need to wait until snow melted at the site resulted in a greater than 6-month period, after the determination that a response was necessary, before the removal action could start. Therefore, the action became classified as non-time-critical. In accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), an analysis of removal alternatives must be conducted for the site [40 CFR 300.415 (b)(4)(I)]. This analysis is referred to as an EE/CA. Procedures for conducting an EE/CA are outlined in "Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA" (EPA/540-R-93-057, August 1993).

This EE/CA is presented in seven sections. Section 2.0 presents site characterization based on previous investigations. Section 3.0 identifies the removal action objectives. Section 4.0 identifies and analyzes removal action alternatives, and Section 5.0 compares these alternatives using several criteria. Section 6.0 presents a recommended alternative based on these criteria. A list of references is presented in Section 7.0.

There are several other steps in the non-time-critical removal action process which are not addressed in this document. The first is the preparation of an EE/CA Approval Memorandum, which precedes the performance of an EE/CA. The second is a public comment period of not less than 30 days following the completion of an EE/CA; the April 26, 1995, draft has previously been issued for public comment. Lastly, an Action Memorandum is a written record of the decision to select an appropriate removal action; Shannon & Wilson is preparing the Action Memorandum under a separate contract with the NPS.

This revised draft of the EE/CA incorporates the results of additional sampling conducted by the NPS on May 31 and August 29, 1995, and Shannon & Wilson's sampling and site visit on August 29, 1995. According Linda Stromquist, with the NPS Alaska Regional Office, no public comments on the first draft of the EE/CA were received during a 30-day public comment period in July and August 1995. This final EE/CA is also revised, based on comments on the first draft of the EE/CA from the National Park Service administration and Mr. Mark Ader of the EPA. Section 2.0 has been revised to include recent data on site conditions and the characterization of the tailings; Section 4.0 has been revised to reflect the reduced area and volume of the tailings found to be present at the site; and Section 5.0 has been altered to incorporate agency comments and the withdrawal of the Cashman Process as a potential removal action. Additional detail has been provided regarding the solidification/stabilization alternative based on revisions in the approach to this alternative. In most cases the costs of the various alternatives have not been revised, since the reduction of area covered by the tailings only minimally reduces the materials and labor required.

2.0 SITE CHARACTERIZATION

2.1 Site Location and Accessibility

The site is located in southcentral Alaska on the southeastern coast of the Kenai Peninsula, about 60 miles southwest of the port of Seward (Figure 1). The Beauty Bay Mine is located in Kenai Fjords National Park, about 1 mile from the beach at the head of Beauty Bay. The geographic coordinates of the site are approximately 59 degrees 33 minutes north latitude and 150 degrees 40 minutes west longitude (Reference 1). The mine has also been referred to as the Glass-Heifner Claims, the Earl Mount Prospect, the Knaack and Kramer Claims, or the Little Creek Mine. The site is not located on the main road system, but is accessible by boat from Seward or by float plane from either Seward or Homer. A reportedly unusable airstrip is located approximately ⅝ mile to the southeast of the site on the Nuka River flats, adjacent to the tidewater. An unimproved dirt road leads to the site from the airstrip, but the road would require repair to support vehicular traffic.

2.2 Background and Site Description

The following discussion is based on a literature review and a site visit conducted by Mark S. Lockwood, a geologist with Shannon & Wilson, on August 29, 1995.

Gold was discovered at the site in 1924 and, by the end of 1925, 50 feet of adit had been advanced. In 1933 an additional 400 feet of adit was excavated. Operations ceased in 1934, and the property was idle until the claims were restaked in 1958 (Reference 2). The ownership was transferred in 1965, and in 1967 the mill building was constructed and a minor amount of ore was produced (Reference 3). Work continued at the mine until the mid-1970s, at which time the mine was abandoned. Kenai Fjords National Park was established in 1980, and at that time the National Park Service acquired the surface rights to the site. Currently the two unpatented federal mining claims (numbers AA028078 and AA028079) which encompass the site are held by [redacted] and [redacted]. The claims are currently leased to [redacted].

The Beauty Bay Mine is one of many small gold mines in the Nuka Bay area. The site comprises approximately 40 acres of unpatented mining claims, which are located on the west side of Ferrum Creek at the head of Beauty Bay, at an elevation of about 200 feet above sea level (Figure 2). The surrounding area has extremely rugged topography, with surrounding peaks reaching 3,500 feet above sea level within 1 mile of the coast. The area surrounding the site is densely vegetated with conifers and alder. The site is located approximately 200 feet to the southwest of Ferrum Creek. Ferrum Creek is about 24 to 30 feet wide and up to 3 feet deep; the creek has a high velocity and carries a moderate suspended load, reflecting upstream glacial erosion (Reference 4). Flow was estimated at 400 to 500 cubic feet per minute (cfm) in a report based on a November 1959 site visit (Reference 2). This same reference cites a flow of 25 to 30 cfm in "Little Creek," which is not identified on available maps of the area, but it may be the "2-meter wide stream located 100 meters west of the prospect" cited in Reference 4.

Gold ore was mined from at least three east-west trending, near-vertical quartz veins, ranging from 1 to 5 feet in width. The principal sulfide within the vein system was arsenopyrite ("fool's gold," FeAsS), which occurred in lenses, sheets, and irregular masses (Reference 3). The gold was apparently free-milling and was liberated by crushing. The veins discordantly cut massive graywacke and slate. Wallrock alteration in the vicinity of the veins consists of carbonatization and silicification (Reference 4). Clay gouge and sulfate development were also noted along the vein-wallrock contact (Reference 3).

The site is developed with a mill building, several storage sheds, a bunkhouse, and the remains of another bunkhouse, which are located on a level pad approximately 200 feet by 225 feet in size. The pad is constructed from coarse waste rock which is comprised of slate and graywacke with minor amounts of quartz. The milling equipment included two jaw crushers, a ball mill, and a Wilfrey concentrating table (Reference 3). The mine workings consist of surface trenches and a collapsed adit.

There is a series of what have been termed "tailings ponds" to the northwest of the mill. There is some question whether the ponds are true "tailings ponds," in the sense that tailings were carried to them in a water suspension. Both the small amount of water apparently available, and the small amount of water needed to operate a Wilfrey table, suggest that perhaps the ponds were used to contain tailings which had been physically transported to them by some means other than by flowing water. However, the term "tailings pond" is used as the best descriptor of the inferred contents of the ponds.

Based on a sieve analysis, the tailings consist of fine- to coarse-grained, sand-sized granules with approximately 6 percent silt. Silt contained in the tailings is present in small clumps, and may be a byproduct of the crushing operation. Based on visual classification, the composition of the tailings material appears to be about 85 to 90 percent white quartz, 10 to 15 percent sedimentary rock fragments, with minor amounts of oxide fragments or tarnished sulfides. A white precipitate has been noted by others coating the surface of tailings pond D (Figure 3). According to NPS personnel, the existence of the white precipitate is transient, having been observed on several of the ponds during the June and August 1994 visits, and not during previous and subsequent site visits. A "white material . . . encrusted on the soil surface" was also reported near the ore box (Reference 7).

Based on field observations, the tailings in ponds C, D, F, and G cover an estimated area of about 1,225 square feet. Based on a limited number of test pits excavated on August 29, 1995, the thickness of the tailings in these areas ranges from a minimum of 2 inches to a maximum of about 36 inches. The volume of tailings is estimated at about 61 cubic yards.

The site is relatively level, and surface drainage appears to be restricted to broad, shallow channels. Water drains from the now-collapsed mine adit and flows through the site and over a portion of the tailings. This flow can be described as a "rill" less than 1½-feet wide (Reference 4), but reportedly the flow increases during the rainy season. At the time of Shannon & Wilson's site visit in August 1995 flow from the adit was estimated at 0.02 cubic feet per second, and the pH of the water was 7.1. At this flow rate, the surface water entered the ground prior to reaching the tailings ponds. No information is available regarding the maximum flow rate from mine adit. Based on the existing channel configuration, bankfull flow is anticipated to result at a flow rate of less than 1 cubic foot second.

Reports from NPS personnel (References 5 and 6) describe the surface water flow pattern and the layout of the pond system at the time of their site visits as follows (refer to Figure 3):

> "The only surface water was coming down from the adit to the collapsed mill shed... At higher flows, this water continues through the camp and spreads out into a series of shallow ponds... It looked as though some of the water from the rocker table (inside the mill shed) was drained off into this box [the ore box] where this sediment was then collected. The soils outside and down slope from the box were clearly discolored, looking similar to the sediments that were in the box. It appeared that water flowing out of the box had flowed through this discolored area and then joined the stream feeding the ponds mentioned previously." (Reference 5)

> "Several of the settling areas which contained coarse sand were also covered with a white granular substance... Water to wash the material comes from groundwater flow out of the adit above the mill around the mill building and then into the small drainage..." (Reference 6)

Based on observations during Shannon & Wilson's site visit, the stained soil which is located down slope from the ore box appeared to be the result of rusting mill parts, and did not contain an obvious accumulation of fine tailings. Anomalously high concentrations of arsenic in this area may be related to spillage during ore transfer operations.

A breach in the containment berm located on the downstream end of Pond C has resulted in the redistribution of fine tailings onto a bench along a rocky gully, which flows over the edge of the gravel pad toward Ferrum Creek. The fine tailings are sporadically distributed in an area about 50 to 150 feet beyond the edge of the gravel pad. The tailings are located on a bench above the base of the gully, and range in thickness from 0.5 to 1 inch.

The depth to a regional groundwater aquifer is not known, although it is anticipated that the subsurface hydrology is largely controlled by the presence of the bedrock, or possibly by glacial till. In general, the rock types anticipated to underlie the site are relatively impermeable; therefore, groundwater flow within the bedrock is anticipated to be limited to discontinuities (joints, fractures, and faults). Based on a review of air photos, the site may be mantled with a veneer of glacio-alluvial deposits; a perched groundwater table may be present above the bedrock/sediment interface. There is likely a colluvial/alluvial gravel aquifer along the base of the hillslope along Ferrum Creek. At the time of Shannon & Wilson's visit in August 1995, water was encountered within Pond D at a depth of about 0.8 feet below the ground surface. Subsurface water was not encountered within the 1- to 1.5-foot depth explored in any of the other tailings areas. The pH of the water within the Pond D tailings pile was 4.0 at the time of our visit. The configuration of Pond D appeared to be such that rainwater accumulated within the pond, and the flow of the rainwater out of the pond is restricted by the underlying silty soil. Due to the presence of a berm around Pond D, the input of surface water into Pond D appeared limited.

Based on a lack of deeply-incised erosion gullies or other evidence of large volumes of surface water running through the site, the potential for catastrophic redistributing of the tailings is considered to be low. Although snow avalanche chutes are present adjacent to the mine site, apparently none cross the site.

2.3 Climatic Conditions

The site is located within a climatic zone dominated by maritime influences which result in small temperature variations, high precipitation, high humidity, gusty winds, and high frequency of clouds and fog. The mean minimum January temperature is 16 degrees Fahrenheit. The mean maximum July temperature is 48 degrees Fahrenheit. Annually the site receives at least 60 inches of rain (Reference 8). According to NPS personnel the site receives in excess of 6 feet of snow annually, which blankets the site from November to mid-May.

2.4 Receptors

No workers are currently present at the site. A recreational cabin is located approximately 6 miles from the site. No year-round residents are known to be located in the vicinity of the site. Access to the mine is extremely limited, and the location of the mine site is not shown on USGS maps or in the NPS brochure which describes the park; therefore the site receives few visitors, estimated by the NPS at possibly 10 to 15 per year. Two valid federal mining claims currently encompass the site. There are no known users of surface water or groundwater in the vicinity of the Beauty Bay Mine. The site is located within the Kenai Fjords National Park; therefore, all of the surrounding area may be considered a sensitive environment.

2.5 Previous Studies

The earliest previous investigative studies were mainly directed at characterizing the geologic conditions of the site, particularly the mining geology. In 1970, the United States Geological Survey (USGS) prepared a report describing the regional geologic conditions and ore deposit geology of the Nuka Bay area (Reference 3). Recently the USGS has conducted sampling of surface waters in the area of several small-scale gold mines in the Nuka Bay area (Reference 4). The NPS conducted limited sampling at the site on four occasions, and have prepared trip reports and a summary report detailing their activities and sampling results for their July and August 1994 site visits (References 5, 6, and 7). This final draft of the EE/CA presents the results of the samples collected by the NPS during their May and August 1995 site visits.

Results of the 1970 USGS sampling of the sediment from 44 streams draining into Nuka Bay indicated that concentrations of arsenic in the sediments range from below the detection limit of 10 ppm to a maximum of 160 ppm. The concentration of arsenic in the panned stream sediment concentrates from Ferrum Creek, above and below the Beauty Bay Mine, was 40 ppm in both samples. Four samples of sulfide-bearing quartz vein material were collected from the underground and surface workings. The samples contained from 1,200 to 6,000 ppm arsenic.

Results of sampling conducted during the 1993 USGS study indicated that background metals concentrations of less than 0.05 ppb silver, less than 2 ppb arsenic, less than 1 ppb cadmium, less than 1 ppb copper, 10 ppb iron, less than 1 ppb antimony, and 3 to 6 ppb zinc characterize waters that drain from areas upstream of any known mineral occurrences. The results of a field-filtered water sample collected from the small rill exiting the mine workings at the Beauty Bay Mine contained 130 ppb arsenic and 2 ppb antimony; no iron enrichment was noted in the sample. Water samples collected from Ferrum Creek upstream and downstream of the mine site generally did not detect concentrations of metals which exceeded the local background values established by this study. Arsenic concentration in both the upstream and downstream sample was 2 ppb.

On June 28, 1994, an NPS explosives removal team conducted a visit to the site. During this visit a deceased moose calf, believed to be 1 month old, was found on the site. Apparently there was no indication of trauma, birth defects, or other blemishes or injuries noted. The presence of hoof and nose prints and kneel marks in the tailings ponds indicated that moose have been disturbing the tailings, and potentially ingesting the material. NPS personnel returned to the site on July 7, 1994, to obtain tissue samples from the moose calf to determine the cause of death, but it appeared that the moose had been carried off by a bear. Two samples of soil from the tailings were collected and analyzed for metals. The results indicated that material in the ore box adjacent to the mill building contained 257,359 ppm arsenic, and the sample of tailings from the ground surface at pond C contained 7,325 ppm arsenic. The NPS again returned to the site on August 24, 1994, and collected 22 soil samples, three mineral samples, a vegetation sample, and two samples of the water which was draining from the collapsed adit. The locations of the 17 soil samples are shown in Figure 4, along with the summarized results of the analyses. A concentration of 220,000 ppm arsenic in the ore box closely matched the previous result. Samples from the stained soil area generally contained 7,400 to 19,000 ppm arsenic, with one sample containing 230,000 ppm. Samples from the site pad (presumed waste rock) in a transect across the front of the ore box and Wilfrey table at the Mill Building contained from 6,300 to 19,000 ppm arsenic. Samples from the drainage channel below the stained area contained 24,000 to 50,000 ppm. A test pit near the pond C/pond D boundary contained 50,000 ppm arsenic at the pond surface, 3,200 ppm at a depth of 4 inches, and 7,800 ppm at a depth of 9 inches. A sample taken about 100 feet down slope of the breech in pond C contained 5,600 ppm arsenic. The water sample of the adit drainage collected above the mill building contained 87 ppb arsenic; the water sample of the adit drainage collected below the mill building contained 86 ppb arsenic. Five of the soil samples were analyzed using the Toxicity Characteristic Leaching Procedure (TCLP) extraction method. The TCLP results indicate that material within the ore box contains 8.4 ppm leachable arsenic; which exceeds the regulatory limit of 5 ppm. The remaining TCLP samples contained from 0.46 to 1.2 ppm leachable arsenic. Six of the samples were analyzed for total mercury. Samples from the transect in front of the ore box and Wilfrey table contained 2.1 to 5.7 ppm mercury. Samples in the drainage channel below the stained area contained 0.25 to 0.54 ppm mercury. The sample from a depth of 9 inches in a tailings pond contained 1.1 ppm mercury.

NPS visited the site on May 31 and August 29, 1995, and collected an additional 26 soil samples and seven water samples. The location of the samples and a summary of the analytical results are presented in Figure 4. The soil samples were collected from the tailings ponds and undisturbed areas in the vicinity of the site. Three water samples were collected from Ferrum Creek in locations upstream at the probable point of entry, and downstream from the mine site. No white precipitate was present on the tailings ponds during these site visits.

A representative from Shannon & Wilson accompanied the NPS to the site on August 29, 1995. Shannon & Wilson observed site conditions and collected soil samples for characterization and for soil stabilization mix design testing. The characterization samples were submitted to Dr. Scott Fendorf, a soil chemist with the University of Idaho, Moscow, for arsenic speciation studies and Dr. Hsing K. Lin, hydrometallurgist with the University of Alaska, Fairbanks, for physical characterization and arsenic speciation studies.

2.6 Source, Nature, and Extent of Contamination

Soils containing anomalous concentrations of arsenic are present at several locations at the Beauty Bay mine site. Although arsenic is a naturally-occurring element in the area, it is assumed that the current distribution and form of arsenic (as crushed fine tailings) present at the site are attributable to the mining activity. The ore assemblage which was mined at the Beauty Bay Mine was comprised of the following minerals: quartz, arsenopyrite ($FeAsS$), and gold. During the beneficiation, the ore was crushed to sand-size particles and gold was separated by gravity. The resulting waste product was a fine-grained mixture (tailings) comprised mostly of quartz with varying amounts of arsenopyrite. The tailings were apparently placed in what has been termed tailings ponds, following removal of the gold. The tailings currently cover an area of about 1,225 square feet (four areas, labeled C, D, F, and G in Figure 3). The "stained area" and the drainage channel downslope of the ore box did not appear to contain a significant accumulation of tailings. The staining appeared to be the result of rusting of steel mill parts.

Reportedly on June 28, 1994, Pond D was encrusted with white crystals, which appeared to have formed in place. The white crystals were noted in less abundance elsewhere on tailings ponds. According to NPS personnel, the white precipitate had not been present during previous visits to the site and has not been observed since the June and August 1994 site visit; therefore, it is assumed that the formation of the precipitate is related to some specific conditions developed at certain times of the year.

The concentration of arsenic in the vein material ranges from 1,200 to 6,000 ppm (Reference 3). The concentration of arsenic in background soil samples collected from undisturbed areas in the vicinity of the mine site ranged from not greater than the laboratory detection limit to 2,890 ppm arsenic. The arsenic concentration of the material which forms the gravel pad ranges from 60 ppm to 9,620 ppm. The arsenic concentration in the tailing ponds ranges from 3,200 ppm to 50,000 ppm. Material in the ore box, or elsewhere on the site where concentrations greatly exceed background, are assumed to represent a concentrate containing a high abundance of arsenopyrite. This concentrate may be the result of the milling process or the reworking of the material in the water channels on the pad. Arsenopyrite is comprised of approximately one-third arsenic; therefore, values in excess of 25 percent (250,000 ppm) could be expected in the mill concentrate samples collected from the ore box. The average arsenic concentration of all but the three samples which exceeded 200,000 ppm is about 12,950 ppm.

Based on the 1993 USGS and 1995 NPS sampling results, surface water in Ferrum Creek, which is located approximately 200 feet to the northeast of the site, has not been impacted. Water samples collected from the mine adit drainage contained concentrations of arsenic which ranged from below the laboratory detection limit to 144 ppb. A water sample collected from Pond D contained 29,600 ppb arsenic. As discussed in Section 2.2, the water within Pond D is assumed to be an isolated collection of rainwater unique to this tailings pond area.

According to Dr. Lin (Reference 9), the samples from Pond D (SW1 and SW2) contain 85 to 90 percent silicate and approximately 0.04 percent (400 ppm) arsenic in a soluble oxide form; sample SW3 collected from the ore box contains 0.76 percent (7,600 ppm) soluble arsenic oxides.

According to Dr. Fendorf (Reference 10), the results of his analyses indicate that 61 to 73 percent of the arsenic present in the tailings collected from Pond D is bound to unstable, amorphous iron-aluminum oxides. The remaining fraction of arsenic species is present as relatively stable sulfides, organic arsenic compounds, and crystalline iron-arsenic oxides. The lability (stability) of the amorphous oxides is dependent on the availability of oxygen. Under aerobic conditions the oxide compounds are relatively stable; under anaerobic conditions the oxides become unstable and have a high potential for releasing arsenic. The availability of oxygen in the tailings pile is presumably dependent on the moisture content and the rate at which oxygenated water enters the pile. Based on our observations, the main source of water to Pond D appears to be rainwater; surface water influx to Pond D is limited by the drainage patterns and the presence of a berm. Based on Dr. Fendorf's results, the arsenic contained in the tailings may become mobile once the conditions within the tailings ponds change from aerobic to anaerobic. However, this is contradictory to the low TCLP results obtained on similar tailings material from the site. It should be noted that the analysis performed by Dr. Fendorf does not follow the TCLP procedure. However, Dr. Fendorf's analytical procedure allows for the selective quantification of relatively insoluble, arsenic-iron-aluminum oxides.

Dr. Fendorf's results revealed that only 11 percent of the arsenic present in the material from the ore box is bound to amorphous iron-aluminum oxides. This suggests that this material is less weathered, which is to be anticipated since it is under cover and not subjected to persistent wetting, as are the tailings in Pond D. The material in the ore box failed the TCLP test for arsenic.

The arsenic in arsenopyrite is bound strongly to sulfur and iron; therefore, it weathers (oxidizes) slowly and is relatively insoluble in its natural state, under atmospheric conditions. At the Beauty Bay Mine site the arsenopyrite has been crushed, resulting in a greater surface area exposed to the atmosphere. This fine grain size and wet conditions which exist in Pond D appear to have accentuated the oxidation of arsenopyrite. Byproducts of the oxidation of arsenopyrite in water are the constituents of sulfuric acid (Reference 11). The presence of relatively low pH water in Pond D suggests that conditions within the tailings pond are oxidizing, and the weathering of arsenopyrite has resulted in the formation of acidic conditions.

The arsenic which is released during the weathering of arsenopyrite under atmospheric conditions bonds with other available cations and oxygen to form arsenic-bearing complexes.

Without direct observation of the white precipitate, it is impossible to determine its composition. Based the limited data regarding chemical conditions, the potential for the precipitation of soluble arsenic-bearing complexes is moderate to high. The toxicity of these compounds is not known.

In an attempt to understand the unique conditions under which the white crystalline precipitate may have formed on the surface of the tailings, a scenario depicting the possible factors influencing the mobility of arsenic and its precipitation has been hypothesized. If Pond D was flooded with rain or meltwater, arsenic would be mobilized into solution, as a result of the oxidation of the arsenopyrite. As time progresses and the oxidation process proceeds, the concentration of arsenic in the tailings pore water would increase, and the pH would decrease. If at this time evaporation (lack of rain) reduced the volume of water, arsenic may co-precipitate with sulphates on the surface of the tailings. If and when the precipitate forms, it would be soluble in water; due to the predominantly maritime climate in the area, the precipitate would dissolve during the next rainstorm.

2.7 Streamlined Risk Evaluation

Arsenic is currently the contaminant of concern at the Beauty Bay Mine. The arsenic present in the environment of the site is assumed to have originated from naturally-occurring arsenopyrite, which was mined along with the gold. The arsenic-bearing fine tailings are not contained and are subject to heavy rainfall. The site is very remote, and therefore, human access to the site is limited; currently the site is posted with signs warning visitors of the potential health risks. The tailings are accessible to wildlife and, based on observations of hoof and knee marks and nose pushes, it appears that they are attractive, at least, to moose. Based on the high concentration of arsenic and the moderate to high potential for the presence of toxic, soluble, arsenic-bearing compounds, the conservative assumption has been made that the arsenic-bearing material caused a fatal reaction in a 1-month-old moose calf. No other reports of fatalities have been recorded. However, the dead moose was apparently carried off by a bear 9 days or less after its death. This rapid scavenging, and the infrequent NPS visits to the site, may have resulted in other deaths not being observed. Other than wildlife and very occasional visitors, no receptors have been identified in the area of the site.

2.8 Regulatory Requirements

There are limited federal and state regulations which provide information on the allowable level of arsenic in soils. The Alaska Department of Environmental Conservation (ADEC) guidance document *Interim Guidance for Non-UST Soil Cleanup Levels* dated July 17, 1991, states that "Soils contaminated by hazardous substances other than crude oil or refined petroleum products must be cleaned to background levels or to levels that are shown through a contaminant leaching assessment to not lead to groundwater contamination through leaching nor pose a risk to potential surface receptors."

The drinking water Maximum Contaminant Level (MCL) for arsenic is currently 50 ppb. This limit is exceeded by a factor of about 2 to 3 in the rill draining from the mine adit. However, the water in Ferrum Creek downstream of the site showed no elevation in arsenic concentration, containing 2 ppb. Water in Pond D greatly exceeds the MCL, containing 29,600 ppb arsenic.

The Alaska surface water quality criteria (18 AAC 70) for arsenic in fresh water used for recreation or growth and propagation of fish reference the EPA Quality Criteria for Water. The acute criteria for arsenic (III) is 360 ppb and 850 ppb for arsenic (V). The chronic criteria is 190 ppb for arsenic (III). The rill draining from the mine adit and the water in Ferrum Creek is well below all three criteria. The water in Pond D exceeds both the chronic and acute criteria for arsenic.

The Resource Conservation and Recovery Act (RCRA) exempts solid wastes generated during the extraction, beneficiation, and processing of ores and minerals from the definition of a hazardous wastes [40 CFR 261.4(B)]. Thus, the tailings remaining in the ore box (which amount to about ¼ cubic yard) would not be classified as a hazardous waste under RCRA, even though they fail the TCLP criteria for hazardous waste determination.

The tailings pore water would also be exempted from RCRA classification, because it was generated by the commingling of precipitation (rainwater) and an exempt waste [Policy Permit Compendium 9441.1986 (31)]

For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-6} and 10^{-4}, using information on the relationship between dose and response. The 10^{-6} risk level is often used as the point of reference for determining remediation goals for alternatives when cleanup standards are not available, or are not sufficiently protective because of the presence of multiple pathways of exposure. The EPA Region III Risk-Based Concentration (RBC) for arsenic (V) (considered as a noncarcinogen) in soil is 610 ppm for an industrial scenario. The Region III RBC for arsenic (III) (considered as a carcinogen) in soil is 3.3 ppm for the same scenario. Residential scenario RBCs are 23 and 0.37 ppm, respectively.

EPA has recently developed the concept of soil screening levels (SSLs). According to guidance, "these SSLs provide reasonable maximum estimates of transfers of contaminants from soil to other media." The impact on that media is based on a 10^{-6} risk for a residential exposure scenario. The SSL for soil-to-air transfer is 380 ppm, and for soil-to-groundwater transfer is 15 ppm. The soil-to-air SSL may be overly conservative at this site, given the predominant wet and/or frozen conditions. The soil-to-groundwater SSL is difficult to apply without a better understanding of the groundwater regime.

The topic of arsenic toxicity to wildlife is a complex one, dependent on the form of the arsenic, the body weight of the animal, and the amount ingested and over what period of time. Insufficient data is currently available, regarding the nature of the arsenic and the mode of ingestion, to develop a relationship between concentration in the tailings and toxicity.

The naturally-occurring background concentrations of arsenic at the site greatly exceed the levels discussed above.

3.0 IDENTIFICATION OF REMOVAL ACTION OBJECTIVES

The objectives of this removal action are as follows:

- Isolate the potentially hazardous materials at the site from local wildlife and the occasional human visitor. The isolation method should be resistant to degradation from climatic factors and wildlife.

- If possible, prevent infiltration through the tailings ponds.

- If possible, stabilize the material to guard against catastrophic release into Ferrum Creek during periods of high rainfall.

3.1 Determination of Removal Scope

Due to the uncertainty as to the toxicity of the contaminants present at the site, the objective of this removal action is to isolate the tailings piles and area around the ore box from the surrounding wildlife population and the occasional visitor. The logical (although not necessarily conservative) hypothesis is that the greatest risk is posed by the contents of the tailings ponds, their associated white crystals, and attractiveness to wildlife. It is hypothesized that elevated arsenic concentrations in the gravel pad on the site do not pose an imminent risk to wildlife or to humans, if they are adequately warned (by signs or other means) of the dangers associated with the site.

As discussed in Section 2.8, there are no clearly applicable cleanup levels for arsenic in the tailings at the site. Sampling suggests that the mine has not impacted surface water in Ferrum Creek. There is no known groundwater use in the vicinity of the site. Water that has accumulated in Pond D contains a concentration of arsenic which exceeds the MCL. Therefore, the removal action is driven by the potential threat to wildlife which, based on the available evidence, is assumed to be associated with the tailings ponds. It is proposed that the limits of the removal action be determined by visual assessment of the extent of fine tailings in the ponds.

3.2 Determination of Removal Schedule

Ideally the removal action should take place as soon as practical after the snow has melted and the ground has thawed, to take advantage of the warmer and potentially drier, early summer weather.

4.0 IDENTIFICATION AND ANALYSIS OF REMOVAL ACTION ALTERNATIVES

Based on a review of the available information pertaining to the site and a preliminary screening of potentially applicable remediation technologies, the following removal action alternatives are proposed:

- Alternative 1 - **No Action**: (for comparison purposes)

- Alternative 2 - **Site Fencing**: fence either the perimeter of the tailings area or the entire gravel pad area; 10-foot-high chain-link fence will be used to isolate the tailings area from local wildlife and from human contact.

- Alternative 3 - **Cover Affected Area In-Place**: place a relatively impenetrable cover over the tailings area; this cover may consist of dirt fill, geotextile membrane, or urethane spray foam.

- Alternative 4 - **Place Affected Soil in On-Site Containment Cell**: place the arsenic-bearing material on site in a covered and lined containment cell.

- Alternative 5 - **Excavation and Disposal of Contaminated Soil**: remove the arsenic-bearing material and ship to an approved disposal facility.

- Alternative 6 - WITHDRAWN - **On-site Ex-situ Treatment (Cashman Process)**: has been withdrawn as a potential removal action alternative since the preparation of the first draft of the EE/CA.

- Alternative 7 - **Solidification/Stabilization**: on-site in situ isolation using solidification/stabilization technology.

For the purpose of comparison between each of the following seven alternatives, the size of the crew required to implement each alternative has been assumed to be small (generally five people or less, not including NPS oversight personnel). The time required to complete each alternative has been estimated based on the stated crew size. A contractor may decide to use a larger crew to accomplish the same amount of work in less time. The duration of each alternative has been estimated assuming that no days are lost to equipment failure, contractor- or NPS-related administrative or management delays, adverse weather conditions, or other unanticipated occurrences. Each alternative has been described in sufficient detail to allow for a preliminary comparative analysis.

Each alternative, other than Alternative 1, will require that certain health and safety procedures are followed. The level of personal protection (such as protective clothing and respiratory protection) will vary, depending on the type of work required for each alternative. Levels of personal protective equipment (PPE) described in this section are based on the Environmental Protection Agency (EPA) definitions as published in 29 CFR 1910.120, Appendix B. The actual levels of PPE used should be described in the Safety and Health Plan (SHP) developed by the contractor prior to field work.

Inorganic arsenic compounds (as arsenic) have been listed by both the National Institute for Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) as potential or confirmed human carcinogens. The Occupational Safety and Health Act (OSHA) requires exposure monitoring of site workers to determine airborne exposure levels of inorganic arsenic [29 CFR 1910.1018(e)]. Therefore, the contractor must describe in the SHP the proposed methods for conducting such air monitoring, and must conduct the monitoring during performance of the field work. Guidance for conducting air monitoring may be found in the NIOSH/OSHA/U.S. Coast Guard (USCG)/EPA document *Occupational Safety and Health Guidance Manual for Hazardous Waste Activities*.

Other requirements that are common to each alternative but may vary in cost, due to anticipated quantities or duration of field work, are discussed within each alternative. Examples include types of equipment and supplies, methods of transportation to the site (landing craft, helicopter), methods of transportation at the site (such as a Bobcat loader or equivalent, or an all-terrain vehicle [ATV]), and fuel or other power requirements. The contractor must also construct a decontamination station for workers and equipment. Any wastes generated by the decontamination procedures must be collected and disposed in accordance with applicable federal and state laws and regulations. Example decontamination stations are presented in the *Occupational Safety and Health Guidance Manual for Hazardous Waste Activities* document previously cited. The contractor will also be required to demobilize all equipment and unused supplies at the end of the removal action.

Administrative tasks that are also common to each alternative, but may vary in scope between the alternatives, include the development of a site specific SHP, Work Plan (WP), and Quality Assurance Project Plan (QAPP). The costs for developing these plans have not been included in the evaluation of the alternatives presented in this section. No confirmatory sampling has been included to determine the limits of soils to be addressed by these removal action alternatives; it has been assumed that visual examination will be sufficient to identify the suspect soils. No cost has been included for the preparation of an actual removal action design for the purpose of soliciting bids. Additionally, no cost has been included for future monitoring of the site. Monitoring costs would have a greater impact on those alternatives which do not result in permanent disposal or treatment of the arsenic-bearing soils.

The cost estimates presented for each alternative should not be considered firm bids, but rather a reasonable estimate of the anticipated cost developed by applying similar assumptions to each alternative. Estimated costs could be impacted either higher or lower by a contractor selecting different methods for logistics or implementation than were utilized in the development of our estimates. Our estimates do not include any allowance for site reconnaissance work which might be necessary prior to implementing a removal action, such as probing the depth to rock to know whether fence posts would be installed in soil or rock. For these reasons, and because of the items which have not been included in the implementation costs, a generous contingency should be applied to these estimates for the purpose of establishing a budget for accomplishing the work.

Nine criteria were used to analyze each proposed removal action alternative. These criteria incorporate the relevant aspects of the three criteria outlined in EPA EE/CA guidance, which are effectiveness, implementability, and cost. The evaluation criteria used for this EE/CA include:

- Technical feasibility (Is the technology a proven one, and is it suitable for site-specific conditions?)
- Implementability at a remote site
- Ability to meet the removal action objectives
- Compatibility with future remedial actions (Does it meet a long-term remediation goal? Does it hinder future remedial action?)
- Institutional, environmental, and human health concerns (both for workers during the removal action and subsequent site users)
- Environmental impacts (during and after implementation)
- Impact of uncertainty of waste volume (impact on cost and difficulty of job)
- Cost

In this section, each proposed alternative is individually analyzed based on these criteria. In Section 5.0 the alternatives are compared to each other using these same evaluation criteria.

The sections below describe pertinent details of each proposed removal action alternative, and discuss each alternative in terms of the rating criteria described above. Each of the proposed actions meet the statutory limits of $2 million and 12 months for implementation. The uncertain current regulatory status of the site makes it difficult to evaluate permitting requirements for several of the alternatives. For instance, stockpiling the soils from the tailings ponds in a containment cell on site may require permits from ADEC for an extension to long-term stockpiling limitations. The two on-site treatment alternatives could be construed as requiring permitting. No costs for resolution of these issues have been included in our cost estimates. In addition, depending on the depth to water in the tailings at the time the removal action is implemented, the tailings may need to be dewatered. If dewatering is required, the cost of transportation and disposal of a RCRA-exempt arsenic-bearing liquid will need to be added to the cost.

4.1 Alternative 1 - No Action

Alternative 1 would not involve any method of restriction of access to, containment, or treatment of the contaminated soils at the site. Although referred to as no-action, institutional controls, such as posting public notices or signs at the site warning of the potential health risks, would be included in this alternative. We understand that signs have already been posted at the site which warn of the potential health risks associated with the arsenic-bearing soil. Implementation of this alternative would not result in any improvement in the current condition of the arsenic-bearing soils or groundwater. It would, however, facilitate access to the area should future site characterization or remediation activities be conducted. It would not result in any direct cost to the NPS, but may result in adverse public reaction in the event of further impact to wildlife or humans.

4.2 Alternative 2 - Site Fencing

Alternative 2 includes the construction of a 10-foot-high chain-link fence around the portions of the site potentially impacted by arsenic contamination. This alternative is further divided into two fencing options: 2A, wherein only the tailings ponds would be fenced, and 2B, wherein the entire gravel pad portion of the site would be fenced. In each case, the impacted areas would be enclosed within a single fence. The objective of this alternative is to isolate the tailings area from local wildlife, to the extent achievable using this type of fence.

The fence layout would be designed to reduce the potential for large animals to be exposed to arsenic-bearing soils at the site. This alternative would allow access to the site for possible future site activities by including at least one gate.

The thickness of the soil layer within the area to be fenced is currently not known. If the fenceposts must be installed in bedrock, the equipment requirements will be different than if they are installed in soil. For the purpose of this evaluation, it will be assumed that the soil overlying the bedrock is sufficiently thick to support a fence, and the fence will not have to be installed in bedrock. This assumption will have to be verified before mobilizing to the site.

Required supplies for Alternative 2A will include 415 feet of chain-link fence, approximately 52 fenceposts, 1 gate, sacked cement, and a hand-held drill. Required supplies for Alternative 2B will include 880 feet of chain-link fence, approximately 110 fenceposts, 1 gate, sacked cement, and a hand-held drill.

If the fence posts need to be set in bedrock, it will be necessary to mobilize an air compressor and rock drills, although it may be possible to use smaller, gasoline-powered percussion drills. In addition, drilling in rock may increase the time on site required for installation.

A minimum of Level C PPE would be required for this alternative, including protective clothing, gloves, boots, and air-purifying respirators. Either type of drilling equipment could be expected to generate airborne dust, which would increase the risk to workers of exposure to arsenic by inhalation, and Level B PPE may be required, including supplied air respirators, but has not been included in the estimated cost. Air monitoring would be required to determine the airborne exposure levels.

It is estimated that this alternative could be completed using a crew of four people in 4 to 6 days. Equipment and supplies would be transported to Beauty Bay by helicopter from Homer for Alternative 2A. For Alternative 2B, a helicopter would be used to transfer supplies from a ship to the site.

These alternatives involve low technology solutions which should be relatively easy to implement at the site. Both meet the removal action objective (fencing the entire site achieves the objective to a greater extent), but neither are compatible with long-term remedial action goals. Both should be generally compatible with park policies, and have minimal environmental impact. Environmental and health concerns are not necessarily as well addressed by fencing only the ponds, and both solutions may pose risks during implementation due to the drilling which is required.

The costs of implementation are estimated at $45,000 and $63,000 for alternatives 2A and 2B, respectively.

4.3 Alternative 3 - Cover Affected Area In-Place

In this alternative, the affected area would be covered by a material that would eliminate exposure of the arsenic-bearing soils to wildlife and precipitation. Possible cover materials include dirt fill, impermeable synthetic geomembrane, or urethane spray foam. Although the objective of this alternative would be the same regardless of the cover material, the effectiveness, implementability, and costs vary enough to warrant individual evaluations of these three materials within this alternative.

Each of the cover types would restrict access to the contaminated soil to some extent. This may make future site activities more difficult. The soil and urethane spray foam materials could be applied to the precise outline of the tailings pond areas, amounting to a total of approximately

1,225 square feet; whereas, the geomembrane liner would be placed in larger, rectangular sections, amounting to a total of approximately 3,000 square feet.

Soil Cover (3A)

A soil cover would be constructed using materials available at or in the immediate vicinity of the site. The primary requirement of the material is that it can be sufficiently compacted to withstand wildlife walking over it without stepping through the cover, and to shed precipitation to some extent rather than allowing infiltration. The implementability of this alternative is based on the availability of a borrow source of material that meets this requirement. Although such material may be present near the site, it may not be available to the contractor, based on NPS policy. For the purpose of this EE/CA it will be assumed that a suitable borrow source is available for use by the contractor within 100 yards of the site. Applying a soil cover 6 to 8 inches thick would require about 30 cubic yards of borrow material.

Required supplies for this alternative include a piece of excavation equipment such as a Bobcat loader, one or more gasoline-powered compactors, and decontamination equipment. In addition, some sort of trailer attachment for transporting soil from the borrow source to the site would be required if the borrow source was further from the mine site.

A minimum of Level C PPE would be required for this alternative, due to the proximity of the workers to the contaminated soil. The work described in this alternative may, however, be conducted in a manner that precludes contact by the field crew with the contaminated soil. The contractor should describe in the SHP the methods to be used to determine the appropriate level of respiratory protection, whether the level may be downgraded under certain conditions, and if so, what those conditions are. Air monitoring would be required to determine airborne exposure levels.

It is estimated that this alternative could be completed using a crew of four people in 4 days. Equipment and supplies would be transported to Beauty Bay by landing craft, with the crew transported to the site by helicopter.

Geomembrane Cover (3B)

A geomembrane cover would be constructed using a liner material that would be impermeable to water (to prevent infiltration from precipitation or surface runoff) and could withstand wildlife walking over it. A soil cover would be placed over the edge of the liner for additional protection from weather and wildlife.

Required supplies for this alternative include approximately 3,000 square feet of synthetic liner. Excavation and placement of the soil cover over the edges would be performed by hand.

A minimum of Level C PPE would be required for most of this alternative, since liner installation would require field personnel to work in the contaminated area. Once the liner is installed, the level of respiratory protection could possibly be reduced.

It is estimated that this alternative could be completed using a crew of four people in 3 days. Equipment and supplies would be transported to Beauty Bay by helicopter from Homer.

Urethane Spray Foam (3C)

This cover material would consist of urethane spray foam, similar to that used as spray-on insulation. The mixture of foam components could be designed to result in a dense, solid layer, that is desirable for its rigidity and resistance to rain and sunlight rather than its insulating properties. A layer approximately 4 inches thick, with an ultraviolet (UV)-resistant coating on top, should be sufficient to achieve these properties.

Required supplies for this alternative include the spraying equipment, a large generator to power of the equipment, and about 6,000 pounds of foam reagents and coating.

The contractor would need to determine the appropriate level of PPE and respiratory protection for this alternative, and describe those levels in the SHP. PPE normally worn for foaming may be adequate. Air monitoring would be required to determine airborne exposure levels. Foaming cannot be performed in rainy weather.

It is estimated that this alternative could be completed using a crew of three people in 5 days. Equipment and supplies would be transported to Beauty Bay by landing craft, then to the site using a Bobcat loader and trailer. The crew would be transported by helicopter from Homer.

The soil and geomembrane covers are relatively low technology solutions, while the foam cover involves moderate technology. The soil cover will be difficult to implement, and the foaming operation would be rendered impossible by rain; the geomembrane installation would be moderately difficult to implement. All three variants of cover isolate the tailings from humans and wildlife, but the soil cover does not prevent water infiltration, and it is unknown whether it may continue to allow crystals of potentially arsenic-bearing precipitate to form in the ponds. Neither the soil or foam are viewed as being compatible with potential long term remedial goals, but the geomembrane is slightly more so (although its long term durability is uncertain). Obtaining materials for the soil cover is viewed as incompatible with park policies; installation of the foam or geomembrane are relatively compatible. All three options are reasonably protective of human health and the environment both during and after implementation. Placement of the soil cover would have a large environmental impact because of the need for borrow material; the foaming would have a slight impact related to traversing the road to the site, while the geomembrane installation should have little impact.

The cost of covering the tailings is estimated at $32,000 for a soil cover, $29,000 for a geomembrane cover, and $41,000 for a foam cover.

4.4 Alternative 4 - Place Affected Soil in On-Site Containment Cell

Alternative 4 includes the construction of a geomembrane-lined containment cell into which the arsenic-bearing soil would be placed. An impermeable geomembrane cover would be placed over the cell to protect the soil from precipitation. This containment cell would be located in the immediate vicinity of the tailings ponds, possibly within one of the ponds after excavating the tailings from it, or possibly adjacent to the mill building. The cell would be designed to hold the contaminated soil for an indefinite period, and would protect the soil from surface water run-on and precipitation runoff. The cell would be constructed with a shape and size such that large animals would not be likely to walk across it. For the purpose of this evaluation, a pyramidal cell shape will be assumed, about 25 feet by 25 feet at the base by 8 feet high.

The containment cell should be constructed prior to excavation of the affected soil. One potential concern is that the actual amount of soil requiring excavation may be either much greater or much less than estimated. In these cases, the containment cell may be either too small or too large, respectively. The cover liner must be of a material that is resistant to degradation by sunlight. As with any stockpile of contaminated soil, periodic monitoring of the integrity of this containment cell would be required.

If properly implemented, this alternative would result in the removal of all contaminated soil from the ponds, and no future characterization of the pond areas would be required. The stockpiled soils may need to be treated or disposed at some future time. Additional characterization of these soils may be required prior to treatment or disposal.

Required supplies for this alternative include approximately 2,500 square feet of synthetic liner, materials to cut and field seam the liner, limited borrow materials for the soil component of the containment cell, equipment such as two Bobcats or equivalent to handle the geomembrane and soil, and decontamination equipment.

A minimum of Level C PPE would be required for this alternative, since it involves the excavation and handling of contaminated soil. Level B respiratory protection may be warranted under certain conditions, such as dry, windy weather, but has not been used in cost estimating. Air monitoring is required to determine the airborne exposure levels and, therefore, the appropriate level of respiratory protection.

It is estimated that this alternative could be completed using a crew of four people in 6 days. Equipment and supplies would be transported to Beauty Bay by landing craft, then to the site by Bobcat and trailer. The crew would be mobilized from Homer by helicopter.

Construction of a containment cell is a relatively low technology solution, although implementing it at this site will involve a moderate level of difficulty. The solution meets the removal objective of isolating the tailings from the environment, and partially fulfills potential future remedial goals by having the materials stockpiled for further treatment. Cell construction should be moderately compatible with park policies and have a relatively low environmental impact. Significant environmental and human health concerns should only be present during construction; the soils are thereafter isolated from the environment. This solution is somewhat susceptible to cost escalation, due to the uncertainty of the volume of soils to be stockpiled.

The cost of implementing this alternative is estimated at $44,000.

4.5 Alternative 5 - Excavation and Disposal of Contaminated Soil

This alternative consists of the excavation of contaminated soil at the site, and transportation of the soil for disposal in a RCRA-permitted landfill. Although the material is a RCRA exempt waste, this conservative disposal approach was taken for costing purposes. A less costly disposal method may be available. Due to the remote location of the site, and resulting difficulty in transporting soil in bulk containers, the soil would be packaged in 55-gallon drums for off-site transportation and disposal. Based on an assumed 0.25-yard capacity, approximately 250 drums would be required for this alternative.

If properly implemented, this alternative would eliminate the need for future characterization of the tailings ponds. All arsenic-bearing soil in that area with concentrations above potential action levels should be removed. For this and other alternatives that result in complete removal of the contaminated soil, the NPS should require any future mine plans to address the proper handling of arsenic-rich byproducts.

The drums may be filled either by hand or using a piece of equipment such as a Bobcat loader. Each filled drum would weigh an estimated 500 to 800 pounds. Full drums could be moved either by a helicopter to a barge, or by a Bobcat with a trailer to the beach via the access road. To avoid additional exposure to airborne contaminants which might result from helicopter propwash, the Bobcat option has been costed.

Required supplies for this alternative include three loaders and a trailer, drums, and decontamination equipment.

Level C PPE would be required at a minimum. The work described in this alternative would cause the field crew come into contact with contaminated soil, and would likely generate airborne particulate matter. Level B respiratory protection may be warranted under certain conditions, such as dry, windy weather, but has not been costed. Air monitoring is required to determine the airborne exposure levels and, therefore, the appropriate level of respiratory protection.

It is estimated that this alternative could be completed using a crew of six people in 10 days. Equipment and supplies would be transported to Beauty Bay by landing craft, with the crew mobilized to the site by helicopter from Homer. The drums full of soil would be returned to Homer by the landing craft and then shipped to a RCRA landfill, such as the Chemical Waste Management facility in Arlington, Oregon.

Soil excavation and disposal is a relatively low technology solution, but the amount of effort involved makes it relatively difficult to implement at this location. The solution meets the removal action objective by removing the tailings from the environment, and also meets potential final remediation goals by eliminating, rather than just isolating, the contaminants from the site. However, it is not consistent with the CERCLA preference for treatment over disposal. The duration of the effort, and the number of trips required on the road from the beach to the site, probably makes this solution one of the least compatible with park policy. Although environmental and health concerns are relatively serious during implementation, they are eliminated at the site (at least with respect to the tailings) following completion. The anticipated environmental impact is moderately severe, based on traffic and duration. This solution is quite susceptible to cost escalation, due to uncertainty in the volume of tailings to be excavated and disposed.

The estimated cost of this removal alternative is $186,000, including transportation and disposal at a RCRA landfill.

4.6 Alternative 6 - WITHDRAWN - On-Site Ex-Situ Treatment (Cashman Process)

Alternative 6 originally included the excavation and on-site treatment of the contaminated soil using the Cashman Process. This process involves leaching the soils with an acid solution which leaves the toxic elements, such as arsenic, in a less-toxic form (ferric arsenate). Following treatment, the leach solution would be treated to precipitate the metal oxides and carbonates contained therein. The Cashman Process is designed to be zero discharge and has no water effluent.

The Cashman Process would require that the soils be excavated and stored in a temporary stockpile prior to treatment. The stockpile would need only a bottom liner and should only be used to store limited amounts of soil immediately prior to its treatment.

If properly implemented, this alternative would eliminate the need for future characterization of the contents of the tailings ponds. The treated soils would remain on site, and contaminated residuals would be shipped off site for disposal.

Required supplies would include a Bobcat loader or equivalent and a trailer, holding tanks for makeup water and leach solutions, the process equipment, and decontamination equipment.

Level C PPE would be required for this alternative, since excavation and handling of contaminated soil may expose site workers to contaminated airborne particulate matter. Level B respiratory protection may be warranted under certain conditions, such as dry, windy weather, but has not been costed. Air monitoring is required to determine the airborne exposure levels and, therefore, the appropriate level of respiratory protection.

It was estimated that this alternative could be completed using a crew of five people in 28 days. Equipment and supplies would be transported to Beauty Bay by landing craft, then to the site by Bobcat and trailer.

Treating of the tailings by this process is a relatively high technology process, the success of which is considered somewhat uncertain without having performed treatability testing. In addition, implementation at a remote site is considered difficult because of the equipment involved. This solution fully meets both the removal action objectives and any potential remedial objective involving treating of the tailings. In addition, it complies with the CERCLA preference for treatment over disposal. The amount of required equipment and duration of the work are assumed to be relatively incompatible with park goals. The environmental impact should only be moderate, however, since the equipment will only need to traverse the road once to the site and once back to the beach. The long term mitigation of environmental and human health concerns offsets the potential concerns during implementation. This alternative is moderately susceptible to cost escalation due to uncertainty in tailings volume.

The cost originally estimated for this removal alternative was $167,000. Subsequent to the issuance of the draft EE/CA, we were notified by Mr. Cashman that he felt that it would be too difficult to implement the process at the mine site, but that he would accept the tailings for treatment at his site in Baring, Washington. Since the cost for shipping the tailings to Washington for treatment would be similar to the cost of off-site disposal in Alternative 5, Alternative 6 has been withdrawn from consideration. The description of Alternative 6 has been retained for reference only.

4.7 Alternative 7 - Solidification/Stabilization

Alternative 7 includes in situ capping of the contaminated soil, and encapsulation of a significant percentage of the total volume of the soil, using solidification/stabilization (S/S) methods. S/S is a low technology procedure commonly used for the treatment of wastes containing metals, wherein the soil is mixed with cement or other additives. Soils and the associated metals are encapsulated within the resulting mass, which may be designed to have a high structural strength and high resistance to penetration, infiltration, and erosion by water. While S/S has been successfully used to treat a variety of metal wastes, unfortunately there is no demonstrated history of a commercial scale remediation of soils with arsenic concentrations as high as are found at this site (Reference 12). In addition, available information suggests that arsenic may adversely impact the long term performance of a stabilized mixture. However, this impact is primarily seen as an increase in the leachability of the arsenic from the solidified mass with time. However, at this site the leaching of arsenic from the tailings has not been identified as a contaminant migration pathway of concern. Since reduction of infiltration was a supplemental removal action objective rather than the primary objective, the questions regarding the performance of a solidified mass are not considered a fatal flaw in the process.

As originally conceived in the draft EE/CA, S/S would be used to solidify the entire volume of tailings. The objective of the solidification was to prevent the tailings from being loose enough to be ingested by wildlife, and to reduce the permeability of the tailings sufficiently to prevent the growth of precipitate crystals at the surface (if that in fact was the mechanism for the origin of the white compound, which has never been analyzed). Subsequent consideration of this alternative resulted in the conclusion that the removal action objective could be achieved by using S/S to merely create a solidified "cap" about 6-inches thick over the surface of each pond. Since the mixing process to blend the tailings and cement is limited to a practical depth of about 6 inches with the small equipment which can be mobilized to a remote site such as this, and some of the tailings are up to 36 inches thick, the concept of capping results in a reasonable reduction in the overall amount of work involved in this alternative. In addition, by reducing the depth to which mixing and solidification is performed, it is hoped that the water table noted at a depth of about 10 inches within the tailings at the time of our site visit will not adversely impact the planned solidification activities. If the water in the tailings is present at shallower depth during the implementation of the removal action, the tailings will need to be dewatered.

Since the test pits dug during the August 29, 1995, site visit revealed that the tailings in ponds other than Pond D are relatively thin (2 to 14 inches), the current conceptual design for this alternative involves the solidification of the existing surface of Pond D, followed by the placement of the tailings from the other ponds on the resulting surface and solidifying them as well. This process would result in the solidification of about 45 percent of the total volume of tailings.

This alternative may be implemented by applying an appropriate amount of cement or other additive to the surface of the contaminated area, then mixing the near-surface tailings and cement with a tractor-mounted rototiller. A sufficient amount of moisture should be present in the soil to hydrate the mixture, and minor additional water from precipitation would not be expected to adversely affect the mixture (a downpour might halt the work). The mixture would be compacted using hand-operated, gasoline-powered compactors to increase its density. Shannon & Wilson is in the process of conducting mix design testing to determine the amount of cement required to prepare a durable cap. Since reduction of leaching of arsenic from the solidified tailings is not a primary removal action objective, this testing has not included TCLP analyses.

An initial trial mix design with samples of the tailings from the site resulted in the creation of soil cement with a relatively low compressive strength. Subsequent testing suggests that this is due to the silt which is present in the ponds with the tailings, and not the result of the chemistry of the tailings or the presence of arsenic. At this point it appears that it will be possible to create a soil cement with a compressive strength of about 1,000 psi, and then to use admixtures to increase the compressive strength of the surface of the soil cement for increased abrasion resistance and freeze-thaw durability.

As with Alternative 6, this alternative is intended to be a final treatment, at least for the portion of the tailings which are solidified. S/S does not reduce the volume or toxicity of the contaminants, but reduces their mobility and availability for leaching. If properly implemented, this alternative would eliminate the need for future characterization of the treated soil.

Required supplies for this alternative include about 250 sacks of cement, one tractor-mounted rototiller, one or more gasoline-powered compactors, and decontamination equipment.

Level C PPE would be required, due to the potential for this process to produce airborne particulate matter containing both contaminated soil particles and cement or other additive dusts.

Level B respiratory protection may be warranted under certain conditions, such as dry, windy weather, but has not been costed. Air monitoring is required to determine the airborne exposure levels and, therefore, the appropriate level of respiratory protection.

It is estimated that this alternative could be completed using a crew of four people in 5 days. Equipment and supplies would be transported to Beauty Bay by landing craft, then to the site by Bobcat.

In situ solidification/stabilization is a relatively low technology process. Implementation is anticipated to be moderately difficult at this site. This solution meets both the removal objectives and the CERCLA preference for treatment over disposal as an ultimate remedial measure (for the portion of the tailings which are solidified). Transporting the required amount of cement over the road from the beach is anticipated to have a relatively severe environmental impact. The long term reduction in environmental and human health concerns offsets the moderate risk during implementation. This solution is relatively insensitive to the uncertainty in the volume of tailings.

The estimated cost for this removal alternative is $38,000.

5.0 COMPARATIVE ANALYSIS OF REMOVAL ACTION ALTERNATIVES

In this section, the nine evaluation criteria defined in Section 4.0 are used to compare the proposed removal action alternatives with each other. Each alternative is given a numeric score from 1 to 5 for each of the evaluation criteria (with 1 being least desirable and 5 being most desirable), based on the analysis of each alternative presented in Section 4.0. A final score is assigned to each alternative that is the sum of the individual criteria scores, and should reflect the overall desirability of the alternative. A score of 0 has been assigned to an evaluation criteria if it appears that it may represent a "fatal flaw," which would eliminate an otherwise apparently desirable alternative from further consideration.

The general range of scoring is defined below for each criteria:

► Technical feasibility:	5 = low technology, proven method
	3 = more complicated technology, uncertainty as to applicability
	1 = high technology, uncertainty as to applicability
► Implementability	5 = easy to implement
	1 = difficult to implement
► Meets removal objectives	5 = fully meets objectives
	1 = does not meet objectives
► Compatibility with future remediation	5 = achieves long term goal, with CERCLA preference for treatment
	3 = achieves long term goal, does not meet CERCLA preference
	1 = no benefit to long term remediation

▸ Compatibility with park goals	5 = no activities incompatible with park policies 1 = many activities incompatible with park policies
▸ Environmental and human health concerns	5 = most protective both during implementation and thereafter 3 = significant impact only during implementation 1 = may not be protective in long term
▸ Environment impacts	5 = least impact 1 = greatest impact
▸ Uncertainty	5 = most certain 1 = greatest susceptibility to escalation
▸ Cost	not rated on a 1 to 5 scale

The evaluation criteria presented here have not been weighted to reflect the importance of one over another.

Table 1 summarizes the score assigned to each alternative for each evaluation criteria. The sum of the evaluation criteria scores is presented for each alternative, as is the estimated cost. The sum of the evaluation for a given alternative is then divided by the estimated cost (in thousands of dollars) to arrive at a unitless number, which is an indication of the cost effectiveness of the alternative; the higher the number, the greater the implied cost effectiveness.

Table 1

Comparative Analysis of Removal Action Alternatives

Alternative Number	Alternative	Technical Feasibility	Implementability	Meets Removal Objectives	Compatibility with Future Remediation	Compatibility with Park Goals	Environmental and Health Concerns	Environmental Impacts	Uncertainty	Sum of Evaluaton Criteria	Estimated Cost ($1,000's)	Effectiveness/Cost Ratio
1	No Action	5	5	0	0	5	0	5	5	For Comparison Only		
2A	Fence Ponds Only	5	4	4	1	5	2	5	5	31	45	0.69
2B	Fence Entire Pad	5	4	5	1	5	3	5	5	33	63	0.52
3A	Soil Cover	4	1	3	1	1	4	1	5	20	32	0.63
3B	Geomembrane Cover	4	3	3	2	4	4	5	5	30	29	1.03
3C	Foam Cover	3	2	4	1	4	4	4	5	27	41	0.66
4	Containment Cell	4	3	5	2	3	3	4	4	28	44	0.64
5	Off-Site Disposal	4	2	5	3	1	4	1	2	22	186	0.12
6	Ex Situ Treatment	1	0	5	5	2	4	3	3	0	NA	
7	Solidification/ Stabilization	4	3	5	4	2	4	2	4	28	38	0.74

Referring to Table 1, it can be seen that Alternative 3B (the geomembrane cover) has an effectiveness/cost ratio of 1.03; Alternative 7 (solidification/stabilization) has an effectiveness/cost ratio of 0.74; five of the alternatives are clustered in the range of 0.52 to 0.69; and the off-site disposal alternative has an effectiveness/cost ratio of 0.12, primarily due to the much higher cost. The ex situ treatment alternative has been withdrawn; therefore inclusion in this evaluation is not applicable.

The alternative with the highest ratio, the geomembrane cover, coincidentally also has the lowest estimated cost, $29,000. Reexamining the individual criteria scores for this option, the primary shortcoming for this option is that while it meets the removal action objective, it does not achieve a more permanent remedial solution. The NPS and the EPA concur that the long-term durability of the cover is somewhat uncertain with animal traffic on the membrane.

The alternative with the next lowest estimated cost, Alternative 3A (soil cover, with a cost of $32,000), achieves an effectiveness/cost ratio of only 0.63. This is primarily due to the difficulty and impact of developing a nearby borrow source for the soil (if in fact the park will allow borrow source development). In addition, there is some uncertainty whether a 6- to 8-inch-thick soil cover might not continue to allow development of crystals of potentially arsenic-bearing precipitate in the ponds.

The second highest effectiveness/cost ratio (0.74), and the third lowest estimated cost ($38,000), is associated with Alternative 7, formation of a cap using solidification/stabilization. This alternative achieves a durable, low permeability cover which isolates the tailings while minimizing the potential for catastrophic release of the tailings. This reduction in mobility meets the CERCLA preference for remediation over disposal. This alternative is relatively insensitive to the uncertainty of the volume of tailings.

6.0 RECOMMENDED REMOVAL ACTION ALTERNATIVE

Based on the comparative analysis, solidifying/stabilizing the surface of the tailings ponds with a concrete mixture is the recommended removal action alternative. This alternative has a low estimated cost, but a relatively severe impact on the park and the environment. It meets the removal action objective of isolating the tailings from humans and wildlife, while also limiting infiltration and reducing the potential for surface water transport of the tailings. The primary drawback of this solution is that the long-term affect of the arsenic on the durability of the concrete mixture is not known. This alternative may interfere with future operations at the mine and could hamper any required future site investigations or remedial actions.

The placement of the tailings in a containment cell appears to be an attractive alternative which should meet remedial goals at a moderate cost. However, the long-term durability of the containment cell is questionable. This alternative would not adversely affect future operations at the mine. Since the alternative does not involve treatment, but rather storage, it is not consistent with the CERCLA-preferred treatment alternative.

Sincerely,

SHANNON & WILSON, INC.

Mark S. Lockwood
Geologist

John E. Cronin
Vice President
Environmental Services/Hydrogeology

RPT/#178.4/26/95.jec/laf

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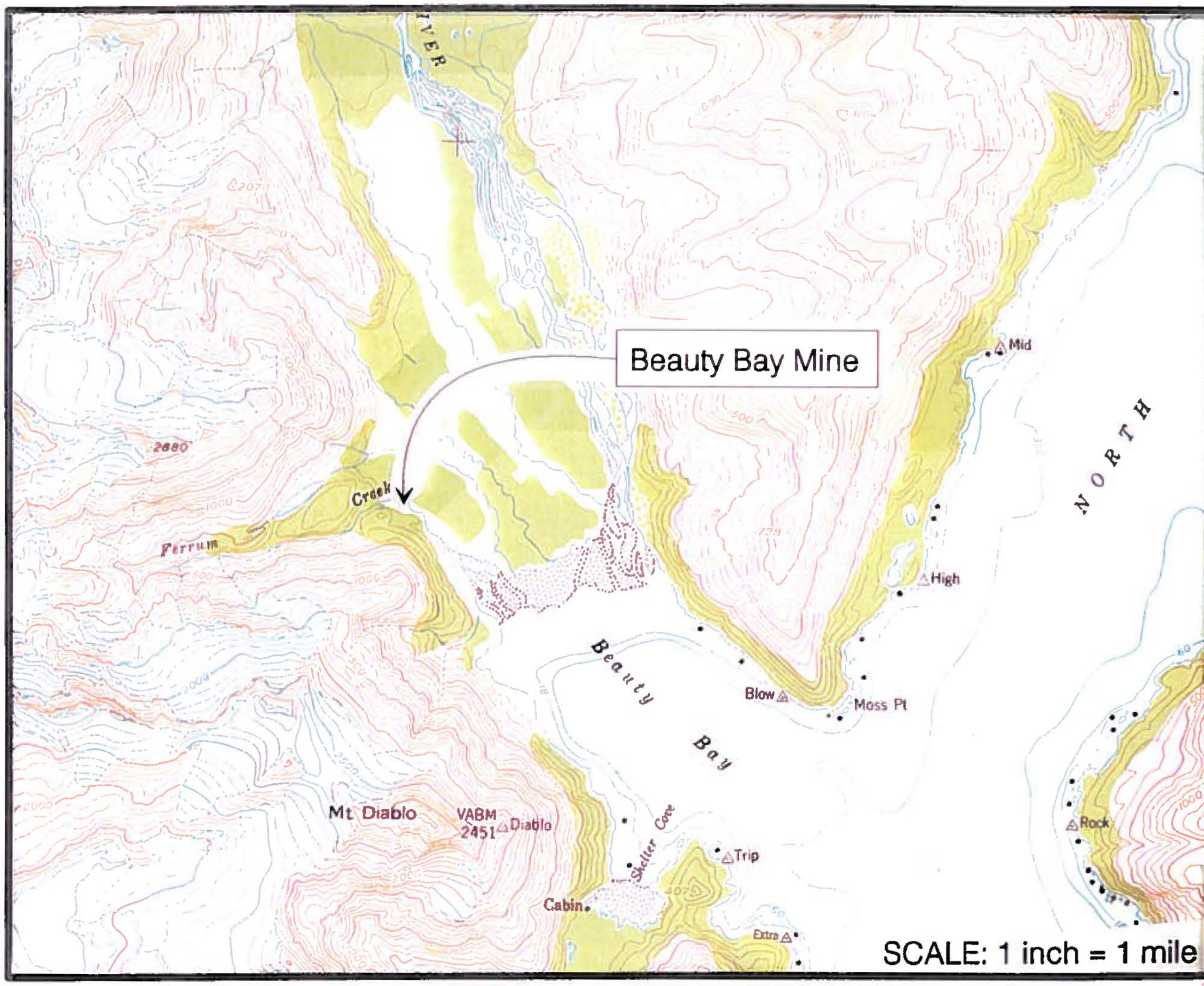
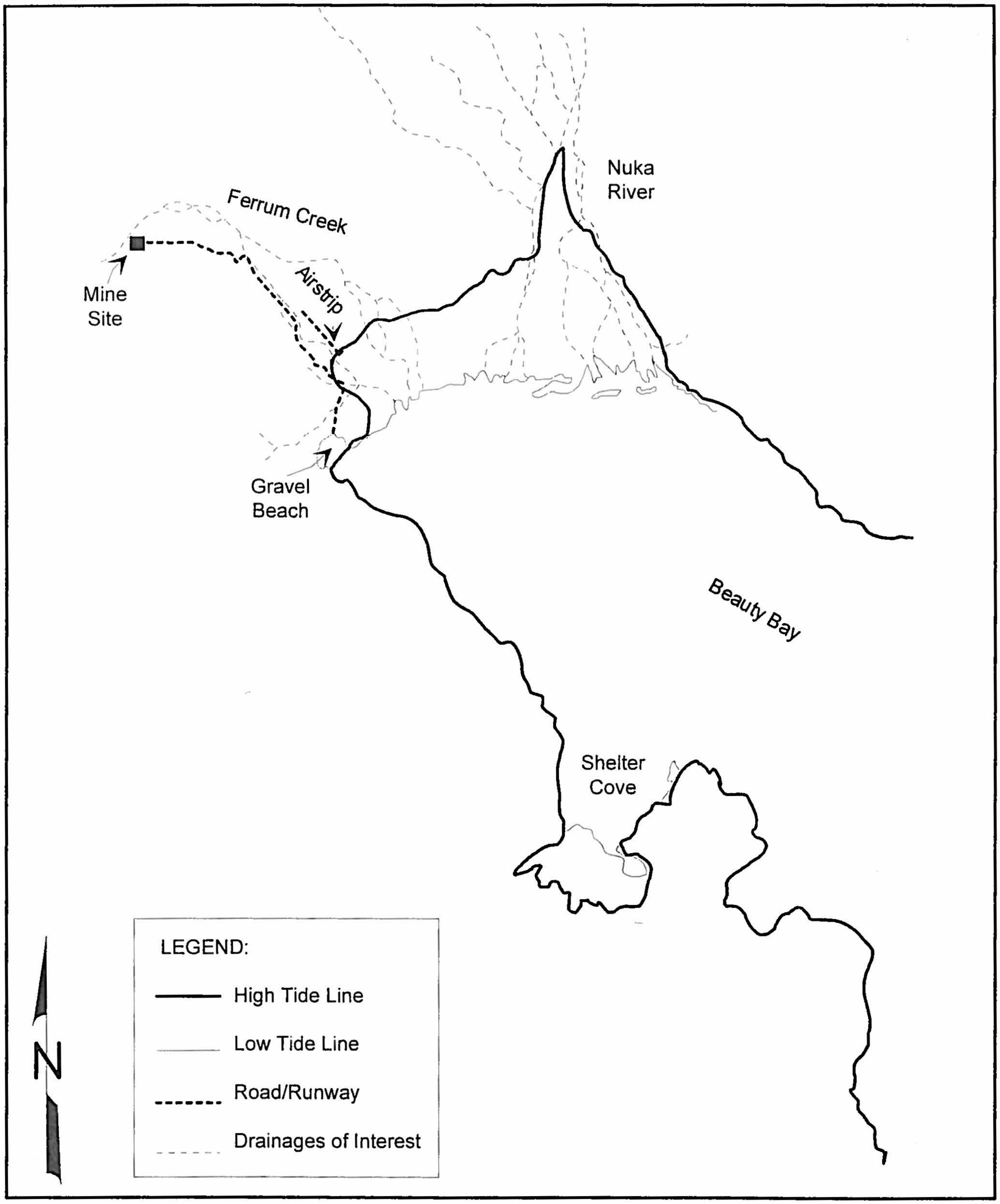


Base Map: USGS Seldovia (C-2), 1953

N

Beauty Bay Mine EE/CA Kenai Fjords National Park, Alaska	
SITE LOCATION MAP January 1996 X-0715-2	
SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS	Figure 1



APPROXIMATE SCALE: 1 inch = 2500 feet

0 1250 2500 5000 7500
(feet)

Beauty Bay Mine EE/CA
Kenai Fjords National Park, Alaska

SITE VICINITY MAP

January 1996 X-0715-2

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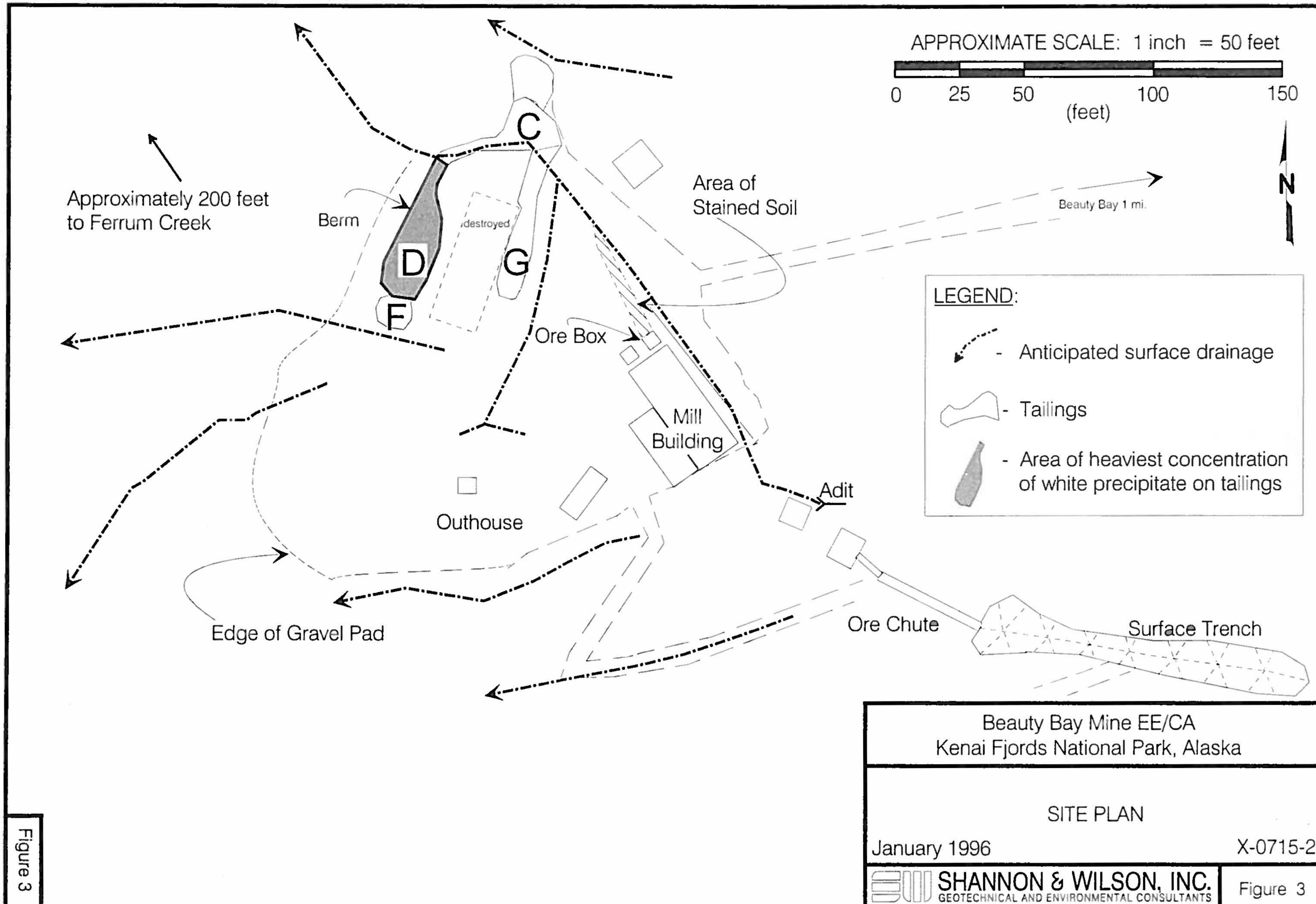
Figure 2



Beauty Bay Mine EE/CA
Kenai Fjords National Park, Alaska

SITE PLAN

January 1996

X-0715-2

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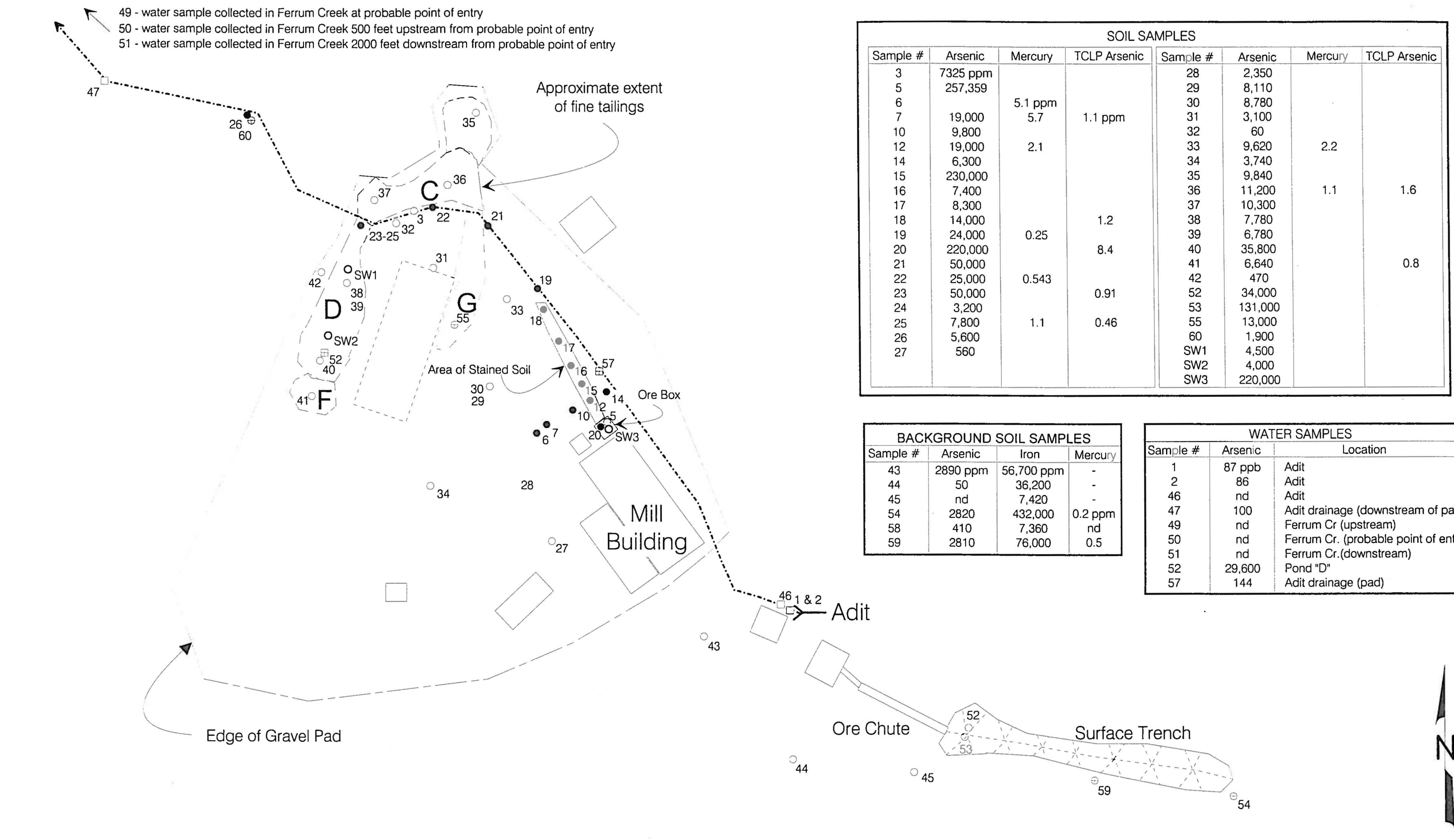
Figure 3



SOIL SAMPLES							
Sample #	Arsenic	Mercury	TCLP Arsenic	Sample #	Arsenic	Mercury	TCLP Arsenic
3	7325 ppm			28	2,350		
5	257,359			29	8,110		
6		5.1 ppm		30	8,780		
7	19,000	5.7	1.1 ppm	31	3,100		
10	9,800			32	60		
12	19,000	2.1		33	9,620	2.2	
14	6,300			34	3,740		
15	230,000			35	9,840		
16	7,400			36	11,200	1.1	1.6
17	8,300			37	10,300		
18	14,000		1.2	38	7,780		
19	24,000	0.25		39	6,780		
20	220,000		8.4	40	35,800		
21	50,000			41	6,640		0.8
22	25,000	0.543		42	470		
23	50,000		0.91	52	34,000		
24	3,200			53	131,000		
25	7,800	1.1	0.46	55	13,000		
26	5,600			60	1,900		
27	560			SW1	4,500		
				SW2	4,000		
				SW3	220,000		

BACKGROUND SOIL SAMPLES			
Sample #	Arsenic	Iron	Mercury
43	2890 ppm	56,700 ppm	-
44	50	36,200	-
45	nd	7,420	-
54	2820	432,000	0.2 ppm
58	410	7,360	nd
59	2810	76,000	0.5

WATER SAMPLES		
Sample #	Arsenic	Location
1	87 ppb	Adit
2	86	Adit
46	nd	Adit
47	100	Adit drainage (downstream of pad)
49	nd	Ferrum Cr (upstream)
50	nd	Ferrum Cr. (probable point of entry)
51	nd	Ferrum Cr.(downstream)
52	29,600	Pond "D"
57	144	Adit drainage (pad)

Water Soil
□ ○ - Samples 1, 2, 3 and 5 collected by the NPS on July 7, 1994;
■ ● - Samples 6 through 25 collected by the NPS on August 24, 1994;
□ ○ - Samples 27 through 53 collected by the NPS on May 31, 1995;
⊞ ⊕ - Samples 54 through 60 collected by the NPS on August 29, 1995 (Water sample 52 also collected on this date);
○ - Samples SW1, SW2, and SW3 collected by Shannon & Wilson on August 29, 1995.

Approximate Scale: 1 inch = 40 feet

Beauty Bay Mine EE/CA
Kenai Fjords National Park, Alaska

SAMPLE LOCATION MAP

January 1996 X-0715-2

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Figure 4