Pebble Project

NORTHERN DYNASTY MINES INC.

DRAFT ENVIRONMENTAL BASELINE STUDIES
2004 PROGRESS REPORTS

CHAPTER 7. NATURALLY OCCURRING CONSTITUENTS IN SOIL, SEDIMENT, VEGETATION, AND FISH

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ACRONYMS

AASHTO	American Association of State and Highway Transportation Officials
ABA	acid-base accounting
ac-ft	acre-feet
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ADOT/PF	Alaska Department of Transportation and Public Facilities
agl	above ground level
AHRS	Alaska Heritage Resource Survey
ALS	ALS Environmental Laboratory
ANCSA	Alaska Native Claims Settlement Act
AP	acid potential
APE	area of potential effect
ASCI	Alaska Stream Condition Index
ASTM	American Society for Testing and Materials
ASTt	Arctic Small Tool tradition
BBNA	Bristol Bay Native Association
BEESC	Bristol Environmental & Engineering Services Corporation
bgs	below ground surface
BLM	Bureau of Land Management
BP	before present
ºC	degrees Celsius
^{14}C	Carbon 14
CEMI	Canadian Environmental and Metallurgical Laboratory
cfs	cubic feet per second
cm	centimeter(s)
CQ	continuous flow
CRM	cultural resources management
CUEQ%	copper equivalent grade
DEM	digital elevation model
DI	deionized
DRO	diesel-range organics
EBD	environmental baseline document
EIS	environmental impact statement
EPT	Ephemeroptera, Plecoptera, or Trichoptera
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FL	fork length

fps	feet per second
FR	Federal Register
ft	foot (feet)
ft^2	square foot (feet)
GIS	geographic information system
GLM	general linear model
GMU	Game Management Unit
GPS	global positioning system
GS	gauging station
HC-3	high-gradient, contained channel
HDR	HDR Alaska, Inc.
HWM	high-water mark
ICP	inductively coupled plasma
IQ	instantaneous flow
KC	Kaskanak Creek
KR	Koktuli River Main Stem
L	liter(s)
LC-1	low-gradient, contained channel
LIDAR	light detection and ranging
m	meter(s)
m^2	square meter(s)
M.A.	Master of Arts
MC-1	moderate-gradient, narrow, shallow, contained channel
MCHTWG	Mulchatna Caribou Herd Technical Working Group
MDC	mine development concept
me-Hg	methyl-mercury
MEND	mine environment neutral drainage
mg	milligram(s)
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
mi^2	square mile(s)
ml	milliliter(s)
ML/ARD	metal leaching/acid rock drainage
mm	millimeter(s)
MM-1	moderate-gradient, mixed-control channel
MMS	Minerals Management Service
MODIS	moderate resolution imaging spectroradiometer
mph	miles per hour
µL	microliter(s)
NASA	National Aeronautics and Space Administration
ND	non-detect
NDM	Northern Dynasty Mines Inc.
NEPA	National Environmental Policy Act

NK	North Fork Koktuli River
NMFS	National Marine Fisheries Service
NP	neutralization potential
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
Nv	calculated variance
NWR	National Wildlife Refuge
OHMP	Office of Habitat Management and Permitting
OHW	ordinary high water
PA-1	narrow, placid-flow habitat
PA-3	shallow-ground, water-fed slough
PA-5	palustrine beaver habitat
PAG	potentially acid-generating
PSD	Prevention of Significant Deterioration
PVC	polyvinyl chloride
Q	discharge
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RBP	Rapid Bioassessment Protocols
RRO	residual-range organics
SHPO	State Historic Preservation Officer
SK	South Fork Koktuli River
SRB&A	Stephen R. Braund & Associates
SRK	SRK Consulting (Canada) Inc.
SWE	snow/water equivalent
TOC	total organic carbon
USC	United States Code
USDA	United States Department of Agriculture
USDI	United States Department of Interior
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UT	Upper Talarik Creek
VHF	very high frequency
WRIR	water-resources investigations report

7. NATURALLY OCCURRING CONSTITUENTS IN SOIL, SEDIMENT, VEGETATION, AND FISH

7.1 Introduction

This chapter presents the findings of the 2004 study of naturally occurring constituents for the Pebble Project mine area and the road/port area. Soil, vegetation, sediment, and fish were sampled in 2004 to assess the presence and concentrations of naturally occurring constituents.

The data summarized here are preliminary because not all data have been compiled and validated. Therefore, this discussion and any interpretations herein should also be considered preliminary.

7.2 Study Objectives

The primary objective of these studies is to collect baseline data to provide defensible documentation of the natural levels of trace elements in soil, vegetation, fish tissue, and sediment in the mine area, along the road corridor, and at the proposed port facility prior to mining operations. A second objective was to establish the biogenic fingerprint associated with petroleum hydrocarbons in soil prior to mining operations.

In the mine study area, chemical characteristics of soil, vegetation, sediment, and fish established in the baseline study will be used in evaluating the potential effects of mining development and operations on human and ecological health. Along the road corridor and at the port facility, the data will be used to evaluate the potential ecological effects of fugitive dust over the life of the project, once the facilities are constructed and in use. Information generated in this baseline study will also be used in evaluating potential environmental impacts associated with project alternatives. In all areas, the information may also be used in any risk assessments to evaluate impacts relative to background levels.

7.3 Study Area

The study area is divided into the mine study area and the road/port study area. For the mine area, the study area includes 160 square miles identified by Northern Dynasty Mines Inc. (NDM). Within that overall area, media samples were randomly collected (as described in Section 7.4 below). For the road/port area, the study area includes a one-mile-wide corridor centered on the preferred road corridor, as identified by the Alaska Department of Transportation and Public Facilities (ADOT&PF), between the mine site and Cook Inlet, and the area surrounding the proposed port site. At the time the 2004 field studies were conducted, the port location and the configuration of upland facilities had not been determined. Sampling during this event focused on ADOT&PF Port Site 1 and an upland area to the west where flat land suitable for upland development could be reasonably expected. The study areas for the mine and the road/port are separately delineated in Figures 7-1 and 7-2, respectively. For fish tissue at the mine site, the study area also included the full length of the North Fork of Koktuli River, South Fork of Koktuli River, and Upper Talarik Creek (UT).

Two predominant soil types have been identified in the study area, from literature. From the mine site to the east side of Pile Bay, unconsolidated materials consist of outwash plains, terraces, and moraines. The soil is reported to be composed of predominately well-drained, gravelly material with interbedded coarse volcanic ash. Poorly drained, fibrous peat locally caps the sequence. From Pile Bay to Iniskin Bay, exposed bedrock predominates. This material is talus and locally derived glacial till in mountain foot-slopes and moraine hills. Soils consist of shallow silt-loam over gravelly loam or sandy loam with local, poorly drained, fibrous peat cover (Selkregg, 1976).

In the mine area, future operations will cut across soil types, habitats, and terrains (also referred to as "landforms") common to the study area. Therefore, the rationale for defining the study area to encompass the entire mine site is to ensure that sufficient samples are collected from each medium to provide statistically valid estimates for the entire area.

Along the road/port site corridor, landforms primarily consist of unconsolidated materials of outwash plains, terraces, moraines, and exposed bedrock. The rationale for defining the study area to encompass the entire road corridor is to ensure that sufficient samples are collected from each landform to provide statistically valid estimates for the entire site.

7.4 Summary of Sample Analyses

A summary of laboratory analyses by media for both the mine study area and the road/port study area is provided in Table 7-1.

TABLE 7-1
Summary of Laboratory Analyses of Soil, Sediment, Vegetation, and Fish

		Media			
Parameter	**Methods**	**Soil**	**Sediment**	**Vegetation**	**Fish**
		Inorganics			
Ammonia as N	E350.3	x	x	x	
Chloride	E300.0	x	x	x	
Cyanide-total	E335.2	x	x	x	
Fluoride	SW4500FC	x	x	x	
Sulfate	E300.0	x	x	x	
		Metals			
Mercury[1]	SW7471A	x	x	x	x
Metals[2]	SW6010B/6020	x	x	x	x[3]
		Organics			
Total Organic Carbon	ASTM D4129-82M	x			
Diesel Range Organics[4]	AK102	x			
Residual Range Organics[4]	AK103	x			

1. A subset of fish tissues was also analyzed for methyl-mercury, as well as for low-level mercury analysis (E1631).
2. Al, Sb, As, Ba, Be, Bi, B, Ca, Cd, Co, Cr, Cu, Fe, Pb, Mg, Mn, Mo, Ni, K, Se, Ag, Na, Tl, Sn, V, Zn.
3. Sb, As, Cd, Cu, Pb, Ni, Se, Ag.
4. For biogenic fingerprinting.

7.5 Mine Area

7.5.1 Scope of Work

The research and field work for this study were conducted during the second half of 2004. For the mine area, the study was conducted by CH2M Hill. Soil and vegetation field work in the mine study area was conducted between August 25 and September 4, 2004. The field work for sediments in the mine study area was conducted July 13-16, August 13-17, August 25, and September 1-4. The study was conducted according to the approach described in the *Draft Environmental Baseline Studies, Proposed 2004 Study Plan (*NDM, 2004a).

The following work was conducted for the mine study area in 2004:

- Preparation of the work plan for the 2004 trace elements study and of the 2004 quality assurance project plan (NDM, 2004b).
- Collection of 83 soil samples from the upper 6 inches of the soil profile, and analysis of the samples for metals, anions and cations, biogenic petroleum hydrocarbons, and physical properties (analyses included 9 duplicate and 7 triplicate samples).
- Collection of 10 soil samples from a depth of 18 inches below ground surface, and analysis of the samples for metals, anions and cations, biogenic petroleum hydrocarbons, and physical properties (analyses included 1 duplicate and 1 triplicate sample).
- Collection of 84 vegetation samples from a variety of species, and analysis of the samples for metals, anions and cations, and physical properties (analyses included 9 duplicate and 9 triplicate samples).
- Collection of 60 sediment samples from tundra ponds, lakes, and streams and analysis of the samples for metals, anions, and cations (analyses included 8 duplicate samples).
- Collection of whole-body samples of juvenile salmonids from 16 streams, and 10 muscle and liver fish-tissue samples of northern pike from 2 lakes, and analysis of the samples for metals.

Mine development and operations will include open pit mining, impoundment dams, tailing ponds, mill/plant site, gravel roads, and pads. These features will cut across landforms common to the study area. Therefore, to adequately characterize background levels of target analytes in soil, sediment, vegetation, and fish, a sampling strategy was developed to ensure sufficient numbers of samples to be statistically meaningful in each type of landform that might be impacted through mine development and operation in the future. In the mine area, 10 landforms were identified. The landforms included categories based on geology (i.e., organic rich soils, fine sands with silts and clays, poorly graded gravel with sand and silts, and glacial till), habitat type (i.e., high brush shrubs, high brush sedges, arctic tundra shrubs, and alpine sedges), and media (e.g., sediment from streams, lakes, and ponds), and 21 samples were targeted in each landform to be spatially representative.

A systematic random sampling program was developed and employed in the mine study area to ensure that sampling locations provide a representation of study area conditions and also to allow rigorous statistical analyses of the data. This systematic random sampling program is based on the Bureau of Land Management's township/range/section cadastral survey system, which allowed for sampling locations to be re-established in the field using a global positioning system (GPS). A grid using 160 existing cadastral survey sections as separate cells was laid out over the study area. Each grid cell was assigned a sequential number, and a random-number generator was used to select 50 cells, referred to as sections. Each selected section was then observed to identify landform types.

Of the 50 sections, 16 contained tundra lakes and ponds suitable for sediment sampling. A statistically random subset of these lakes and ponds was sampled. Stream-sediment sampling locations and frequencies were based on the surface-water-quality sampling program, which also is ongoing at the mine area as part of environmental baseline studies. Stream sediments were sampled at nineteen surface-water stations twice during 2004, with the exception of location UT100A (Figure 4-5 in Chapter 4, Surface-Water Hydrology), which was not sampled during the July 2004 field trip.

7.5.2 Sampling Methods

In general, methods for sample collection were consistent with those outlined in the 2004 study plan (NDM, 2004a). Since the field efforts were conducted by CH2M Hill, who is no longer on the project team, modifications to field methods were identified based solely on the field notes prepared by CH2M Hill in 2004.

7.5.2.1 Soil

Before soil and vegetation sampling began, general sample locations in sections selected from the random grid system were translated into longitude/latitude coordinates and transferred to navigational GPS on the helicopter used during field work. The GPS data were recorded in a format compatible with the existing graphical information system (GIS) for Pebble Project.

The field team used the helicopter and its navigational systems to locate each section, where generally up to three sample locations were staked, flagged, and marked with the sample location number. Information taken from the field notes prepared by CH2M Hill in August and September 2004 suggests that more than three locations were sampled in several sections, while only a single location, with only a single soil sample, was sampled in other sections. Although supporting documentation is not available, we assume this was because apparently not all soil types were adequately present in each landform.

Surface-soil samples were collected to a depth of 6 inches using hand tools, such as stainless steel or disposable polyethylene shovels and trowels. The bowl, trowel, and other tools used were washed with an Alconox detergent and water solution and rinsed with deionized water between samples. Quality assurance (QA)/quality control (QC) protocols followed procedures outlined in the 2004 quality assurance project plan (NDM, 2004b). Subsurface-soil samples were collected at a depth of 18 inches using similar methods. If an organic mat was present at the ground surface, the mat was removed before the soil sample was collected. Sampling followed state and federal guidelines for analytical requirements.

Soil sampling occurred in August and September 2004, concurrent with soil and vegetation sampling for the road/port study area. In many cases, soil and vegetation samples were collected from the same 1-mile-square section, but not from the exact same location within that section. In a few rare cases, the exact same sample location appears to have been used for both soil and vegetation sampling. Based on CH2M Hill's field notes, it appears that soil and vegetation samples were not generally co-located.

7.5.2.2 Vegetation

One of the primary pathways of interest in this program is settling of dust on vegetation and subsequent plant uptake of trace elements. To consider dust on plant surfaces, vegetation sampling was conducted a minimum of four days after a rain event. Samples of both non-woody vegetation and berries were collected, where appropriate. Non-woody material was collected from the plants using clippers and placed into sealed plastic bags to ensure that edible portions of the plant species were analyzed. The non-woody material included leaves and browsable twigs and shoots. Where possible, each sample represented a composite within a taxonomic group (genus or species) from at least three plants listed in the 2004 study plan (NDM, 2004a). All non–disposable sampling equipment was decontaminated prior to and between sampling sites.

As stated by CH2M Hill in development of the 2004 study plan, selection of the particular species for sampling was based on overall dominance, bio-uptake potential, use as wildlife forage, and/or subsistence use, including traditional medicines. However, once in the field, species selection was largely influenced by what was available at the randomly selected locations. Sampling for vegetation occurred in August-September 2004, concurrent with sampling for the road/port study area. Some, but not most, vegetation samples were collected from the same sampling location as the soil samples. Not all sampling locations had sufficient vegetation for each landform. This represents a deviation from the 2004 study plan that was realized in the field.

7.5.2.3 Sediment

Lake and tundra-pond sediment samples were collected from the top 6 inches of sediment below the water line with a hand trowel. All samples and sampling equipment were handled with gloved hands. All non-disposable sampling equipment was decontaminated prior to sampling and between sampling sites. Grab samples were collected near the water's edge along a transect perpendicular to surface-water flow at each location. Grab samples were thoroughly mixed in a large stainless-steel bowl using gloved hands prior to filling the sample bottle to form a composite sample. Large debris (e.g. rocks, gravels, and sticks) were removed in the field during homogenization of the samples. Field forms documenting sampling-location description and coordinates, time, sampling device(s) used, and other pertinent information were completed at the site before leaving.

Stream-sediment samples were collected from beneath the water line at eighteen of the nineteen predetermined sites twice during 2004 (July and September). Sampling was not conducted at site UT100A in July, 2004, although that site was sampled in September. Sediment samples were collected by hand as the small shallow sediment deposits and fast-moving water were not conducive to the use of polyvinyl chloride (PVC) suction tubes, hand trowels, or small mechanical dredges. Sediment deposits were cupped and enclosed by gloved hands, using new gloves for each sample, were quickly lifted out of the water, and were put into a mixing bowl lined with a clean plastic bag. Sediment samples were collected at various locations in the stream bottom and near the water's edge on each side of the stream to obtain a representative sample of the sediment throughout the cross-sections. Gravel was removed by hand. Sediment samples were thoroughly mixed before being placed into the sample bottles.

All sediment samples from lakes, ponds, and streams were screened at the analytical laboratory. Analyses were conducted on the fraction less than 2 millimeters in diameter in each sample.

7.5.2.4 Fish Tissue

Sixteen stream and two lake monitoring sites were selected to provide a basis for detecting potential changes within the primary drainages over time. In general, sites are distributed so that some are upstream of mineralized areas and/or zones of potential man-made influence (potential reference sites), some are within zones that might be affected by mine development, and some are downstream from the study area. Methods for fish-tissue sampling were generally consistent with those outlined in the 2004 study plan (Northern Dynasty Mines, 2004a). See Chapter 11, Fish and Aquatic Resources, of this progress report for further discussion of fish-tissue sampling methods.

7.5.3 Results and Discussion

The following sections present the results for soil (Section 7.5.3.1), vegetation (Section 7.5.3.2), sediment (Section 7.5.3.3), and fish tissue (Section 7.5.3.4).

7.5.3.1 Soil

Eighty-three soil samples from the upper six inches of the soil profile and 10 samples from a depth of 18 inches were collected and analyzed. The data represent a compendium across 83 separate locations within the mine study area. A total of 18 duplicate and triplicate samples also were analyzed, for an overall total of 111 analytical samples. By design, not all test methods were conducted on all samples. Total solids were analyzed in all 111 samples. All metals (plus cyanide and sodium) were analyzed in 105 samples, and anions and cations were analyzed in 103 samples. Petroleum hydrocarbons and organic carbon were analyzed in only 17 samples. In general, except for petroleum hydrocarbons and organic carbon, analytes were measured at all 83 locations. Table 7-2 presents the soil analysis results, inclusive of both sampling depths, as well as duplicate and triplicate data.

TABLE 7-2
Preliminary Results for Naturally Occurring Constituents in Soil, Mine Study Area

Analyte	Detection Frequency (%)	Range[1]	Arithmetic Mean[1]
		Metals (Total)	
Aluminum	100	1,730-109,000	19,000
Antimony	94	0.0397-1.5	0.22
Arsenic	95	0.6-73.8	9.7
Barium	100	22.1-263	71
Beryllium	98	0.0514-0.762	0.34
Bismuth	44	0.027-0.798	0.097
Boron	36	2.3-17.9	3.7
Cadmium	48	0.04-0.879	0.11
Calcium	100	340-7,180	1,900
Chromium	100	2.71-63.2	16
Cobalt	98	0.38-21.9	6.7
Copper	100	4.93-192	26
Iron	100	613-103,000	22,000

Analyte	Detection Frequency (%)	Range[1]	Arithmetic Mean[1]
Lead	100	1.36-78.4	8.4
Magnesium	100	93.4-10,400	3,200
Manganese	100	5.43-1,840	370
Mercury	90	0.012-0.201	0.047
Molybdenum	88	0.146-13.6	1.3
Nickel	98	0.59-33.3	8.7
Potassium	95	151-5,510	560
Selenium	92	0.181-2.71	0.74
Silver	49	0.023-0.927	0.082
Thallium	65	0.0099-0.35	0.067
Tin	92	0.489-8.9	1.3
Vanadium	100	3.2-139	52
Zinc	99	2.77-227	41
Anions/Cations			
Chloride	75	0.409-33.8	3
Cyanide	91	0.041-0.75	0.21
Fluoride	36	0.334-39.3	1.2
Nitrogen, Ammonia (as N)	95	2.7-2,200	158
Sodium	96	50.9-512	160
Sulfate	91	0.657-1,820	38
Petroleum Hydrocarbons			
Diesel-range Organics	94	3.93-302	49
Residual-range Organics	100	31.4-3,620	470
Total Organic Carbon/Total Solids (%)			
Total Organic Carbon	100	0.31-65.1	5.9
Total Solids	100	16.4-95.1	74

1. All concentrations in milligrams per kilogram (mg/kg) dry weight except where noted

Statistical distribution tests have not yet been performed on the data, but arithmetic means are provided for preliminary discussion purposes. These mean concentrations were calculated using a surrogate value of one-half the detection for non-detect sample results. The individual means also include both duplicate and triplicate sample results for this preliminary discussion, which may skew the data if these QA samples represent outliers. Statistical analyses will be conducted once the data have been fully validated. At this point, trends in the data can be evaluated using means. However, for future risk assessment purposes, it may be more relevant to use statistically-based concentrations.

Relative concentrations at different sampling depths across the entire mine site are summarized in Table 7-3. Note that not all means in Table 7-3 will be consistent with those provided in Table 7-2 because non-detect samples were excluded from the additional data manipulations based on depth. Therefore arithmetic means in Table 7-3 may appear slightly higher than would be implied from close inspection of Table 7-2. Once the data set has been finalized, Table 7-3 will be updated.

TABLE 7-3
Preliminary Results for Naturally Occurring Constituents in Soil
Based on Sampling Depth, Mine Study Area

Analyte	Mean[1] of Samples from 6 Inches	Mean[1] of Samples from 18 Inches
Metals (Total)	**n = 80**	**n = 9**
Aluminum	19,000	16,600
Antimony	0.23	0.21
Arsenic	10.0	11.3
Barium	70.1	79.4
Beryllium	0.35	0.39
Bismuth	0.15	0.12
Boron	5.97	5.76
Cadmium	0.19	0.09
Calcium	1,930	1,650
Chromium	15.9	14.3
Cobalt	6.66	8.19
Copper	26.3	20.1
Iron	22,300	21,200
Lead	8.58	6.31
Magnesium	3,240	3,340
Manganese	361	407
Mercury	0.05	0.05
Molybdenum	1.43	1.76
Nickel	8.83	8.88
Potassium	581	642
Selenium	0.81	0.60
Silver	0.14	0.08
Thallium	0.10	0.09
Tin	1.19	1.07
Vanadium	51.7	49.7
Zinc	41.0	43.2
Anions/Cations		
Chloride	3.14	6.21
Cyanide	0.23	0.13
Fluoride	2.14	0.84
Nitrogen, Ammonia (as N)	274	196
Sodium	160	173
Sulfate	40.3	43.8
Petroleum Hydrocarbons		
Diesel-range Organics	66.4	37.7
Residual-range Organics	710	262

Analyte	Mean[1] of Samples from 6 Inches	Mean[1] of Samples from 18 Inches
Total Organic Carbon/Total Solids (%)		
Total Organic Carbon	9.17	2.13
Total Solids	73.0	83.4

1. All concentrations in mg/kg dry weight except where noted

The soil data were also categorized by landform in an effort to discern patterns or differences among elemental concentrations in different geological units. The four landforms represent all of those sampled in the mine site, consistent with the 2004 study plan (NDM, 2004a). Preliminary results by landform are summarized in Table 7-4.

TABLE 7-4
Preliminary Results for Naturally Occurring Constituents in Soil by Landform—Average Concentrations, Mine Study Area

Analyte	Flood Plain[1]	Moraine[1]	Outwash Plain[1]	Talus Slope[1]
Metals (Total)	**n = 8**	**n = 38**	**n = 23**	**n = 11**
Aluminum	15,000	20,200	16,500	24,100
Antimony	0.21	0.22	0.18	0.33
Arsenic	8.1	9.6	7.6	21.3
Barium	49	73	71	95
Beryllium	0.32	0.34	0.35	0.44
Bismuth	0.11	0.09	0.09	0.15
Boron	3.2	3.9	4.3	2.5
Cadmium	0.10	0.13	0.09	0.15
Calcium	1,520	2,040	1,820	2,330
Chromium	14	15	14	29
Cobalt	4.3	6.8	5.4	13
Copper	22	29	16	53
Iron	16,900	24,500	17,500	31,900
Lead	6.5	9.7	6.2	12.5
Magnesium	2,440	3,640	2,690	4,490
Manganese	223	399	284	603
Mercury	0.04	0.04	0.06	0.05
Molybdenum	1.8	1.5	0.92	1.5
Nickel	6.6	8.2	7.4	20
Potassium	481	673	485	577
Selenium	0.78	0.72	0.77	0.99
Silver	0.06	0.08	0.05	0.25
Thallium	0.09	0.06	0.06	0.12
Tin	1.2	1.3	1.3	0.96
Vanadium	44	57	41	70

Analyte	Flood Plain[1]	Moraine[1]	Outwash Plain[1]	Talus Slope[1]
Zinc	40	45	31	64
Anions/Cations				
Chloride	5.3	2.7	3.6	2.2
Cyanide	0.19	0.22	0.20	0.28
Fluoride	1.9	0.76	2.3	0.35
Nitrogen, Ammonia (as N)	297	257	303	173
Sodium	201	159	157	164
Sulfate	281	14	29	4.9
Petroleum Hydrocarbons				
Diesel-range Organics (DRO)	15	89	22	N/A
Residual-range Organics (RRO)	106	932	151	N/A

1. All concentrations in mg/kg dry weight except where noted

N/A = no sample collected

Metals

As shown in Table 7-2, 26 total metals were detected in soil samples. Ten metals were present above detection limits in all samples, with another nine metals detected in at least 90 percent of all samples. Only four metals (bismuth, boron, cadmium, and silver) were detected in less than one-half the samples. Boron was detected with the lowest frequency (36 percent) of all the metals. Aluminum and iron were generally present at the highest concentrations (mean concentrations near 20,000 mg/kg), with levels of calcium and magnesium an order of magnitude lower (mean concentrations of 2,000 to 3,000 mg/kg). All other metals present were at substantially lower concentrations. Arithmetic means for aluminum and iron were rounded to the nearest thousand for presentation. Elements vary greatly in concentration across sampling locations, and also differ widely in their relative abundance within a given location.

Table 7-3 indicates that average concentrations of the metals are similar at both depths. Exceptions are noted for cadmium and silver, both of which are present in surface samples at approximately twice the concentration in the deeper samples.

Table 7-4 shows that concentrations of most metals were consistent across landforms. However, marked differences are apparent for some metals. Arsenic, chromium, cobalt, copper, and nickel were present at substantially higher average concentrations in talus-slope samples than in other landforms. Outwash plains and flood plains generally had the lowest concentrations of metals, likely due to the scouring effects of water over time on these soils.

Anions and Cations

Anions and cations were grouped together for this preliminary evaluation. Anions included chloride, cyanide, fluoride, and sulfate, and cations included ammonia (as nitrogen) and sodium. As shown in Table 7-2, the frequency of detection across these analytes ranged from 96 percent for sodium to 36 percent for fluoride. Sodium and ammonia (as nitrogen) were generally present at the highest concentrations across these analytes, and sulfate was the next most abundant analyte. Cyanide was present at the lowest concentration, with an arithmetic mean of 0.21 mg/kg.

Concentrations of several analytes were noticeably different at the two depth intervals (Table 7-3). Chloride is present at twice the concentration in samples from 18 inches than in those collected from the upper 6 inches. The situation is reversed for cyanide and fluoride, with concentrations two to three times greater in the shallow interval than in the deeper samples.

The preliminary data summary provided in Table 7-4 indicates that concentrations of anions and cations also differ by landform. Sulfate was detected at much higher average concentration in flood-plain samples than in samples from other landforms, and fluoride was higher in flood-plain and outwash-plain samples than in samples from moraines or talus slopes. This is consistent with the relatively high solubility of anions and cations in water. The two landforms characterized by historic or seasonal surface-water flow are relatively enriched in these analytes.

Petroleum Hydrocarbons

As shown in Table 7-2, both diesel-range organics (DRO) and residual-range organics (RRO) were detected in soil samples. DRO was detected in all but one sample, and RRO was detected in all 17 samples. Concentrations were higher than expected for background soils; the arithmetic average concentrations were 49 mg/kg and 470 mg/kg for DRO and RRO, respectively. These data indicate that hydrocarbons in the size and weight range of petroleum products (e.g., DRO and RRO) occur naturally in soil at concentrations above detection limits. The range of concentrations varies widely across locations, with the minimum RRO concentration being 31.4 mg/kg.

A difference in concentration relative to the depth profile is apparent for petroleum hydrocarbons (Table 7-3). RRO concentrations were about three times greater in shallow samples than in those collected from 18 inches. DRO concentrations were higher in shallow samples, but less notably so than for RRO. An explanation for the difference in concentrations is that the biogenic petroleum likely originates from plant material growing and dying on the soil surface. This information suggests that the upper six inches may be critical to appropriately identify naturally occurring levels of biogenic petroleum hydrocarbons. This has ramifications for risk-assessment exposure scenarios, where the shallow soil samples are often a mixture across the upper two feet of soil. For this reason, it is important that any future soil sampling include the upper six inches as a discrete sampling interval.

Petroleum-hydrocarbon concentrations from moraine samples were substantially higher than those from flood plains or outwash plains (Table 7-4). This may be due to the differences in vegetation density in the latter two landforms, in part due to historical water flow through these plains.

Total Organic Carbon

As shown in Table 7-2, total organic carbon (TOC) averaged 5.9 percent across 17 samples, but also exhibited a wide variability across locations (range of 0.31 to 65.1 percent). This could have an impact on bioavailability and toxicity of some metals, due to the tendency of some metals to form complexes with organic materials.

TOC was present at a higher average concentration in samples from the upper six inches of soil than in samples collected from 18 inches below the ground surface (Table 7-3). This is consistent with expectations, since TOC concentrations are largely a function of the amount of plant material decaying in the soil, which is typically higher at shallow depths.

Total Solids

As shown in Table 7-2, the range of total solids across all soil samples varied from 16.4 percent to 95.1 percent, indicating that the variability of water content in the samples collected was quite high. Across all samples the arithmetic mean was 74 percent. Given the wide variability of these values, dry-weight-based concentrations could be substantially different than the wet-weight-based concentrations provided above. Many ecological risk models are based on dry-weight concentrations, which could lead to different results than using wet-weight concentrations. This issue will be further addressed once the data are finalized.

Due to the lack of sufficient samples across landforms, variability in physical properties across landforms was not evaluated. Additional sample collection in 2005 should lead to a sufficient number of samples for further analysis.

7.5.3.2 Vegetation

Vegetation samples were divided by taxonomic category and species in an effort to evaluate the success of the program thus far. Table 7-5 summarizes the number of samples collected and analyzed by type of plant (and species, where appropriate).

TABLE 7-5
Summary of Vegetation Samples Collected by Category and Species, Mine Study Area

Category/Species	No. Samples	Notes
Trees	**3**	
White Spruce (*Picea glauca*)	2	
Balsam Poplar (*Populus balsamifera*)	1	
Shrubs	**38**	
Willow (*Salix* sp.)	9	
Bog Blueberry (*Vaccinium uliginosum*)	9/9	Leaf samples/berry samples
Dogwood (*Cornus canadensis*)	3	
Lingonberry (*Vaccinium vitis-idaea*)	2/2	Leaf samples/berry samples
Labrador Tea (*Ledum palustre*)	2	
Crowberry (*Empetrum nigrum*)	1/1	Leaf samples/berry samples
Grasses	**12**	
Short stalk sedge (*Carex microchaeta*)	12	
Forbs	**9**	
Fireweed (*Epilobium angustifolium*)	8	
Sourdock (*Rumex areticus*)	1	
Mosses	**10**	
Green terrestrial moss (*Ptelium crista casttensis*)	10	

Category/Species	No. Samples	Notes
Lichens	**12**	
Reindeer lichen (caribou moss; *Cladina rangiferina*)	12	

As is evident from the table, the majority of sampled plants were shrubs. Only a single species each of grasses, mosses, and lichens were collected for analysis, and only three tree samples were collected. While this is not consistent with the 2004 study plan (NDM, 2004a), the samples were collected based on available vegetation across the randomly selected sample locations. Except for sourdock and balsam poplar, these same species also were collected and analyzed in the road/port study area (Section 7.6), providing for species comparison in these different areas once data validation is complete. Table 7-6 shows preliminary results for all vegetation samples from the mine study area.

TABLE 7-6
Preliminary Results for Naturally Occurring Constituents in Vegetation, Mine Study Area

Analyte	Detection Frequency (%)	Range[1]	Arithmetic Mean[1]
Metals			
Aluminum	100	10.3-9,730	530
Antimony	97	0.02-0.66	0.11
Arsenic	28	0.07-6.2	0.16
Barium	100	1.8-167	32
Beryllium	43	0.003-1.18	0.025
Bismuth	49	0.008-0.14	0.012
Boron	98	0.1-34.6	8.4
Cadmium	100	0.009-0.79	0.12
Calcium	100	524-34,400	5,900
Chromium	77	0.3-14.6	0.78
Cobalt	100	0.02-4.86	0.42
Copper	100	0.82-39.9	4.3
Iron	100	13.6-9,670	520
Lead	100	0.03-6.75	0.61
Magnesium	100	183-6,540	1,500
Manganese	100	28.4-2,450	330
Mercury	91	0.01-0.156	0.042
Molybdenum	100	0.008-3.5	0.3
Nickel	100	1.51-244	8.1
Potassium	100	586-23,500	6,000
Selenium	22	0.1-0.6	0.08
Silver	61	0.003-0.163	0.011
Thallium	90	0.002-0.094	0.013
Tin	100	1.9-4	2.8
Vanadium	100	0.03-26.4	0.84

Analyte	Detection Frequency (%)	Range[1]	Arithmetic Mean[1]
Zinc	100	5.4-155	29
Anions/Cations			
Chloride	97	9.1-16,100	1,300
Cyanide	17	0.2-0.9	0.17
Fluoride	80	0.22-1,510	39
Nitrogen, Ammonia (as N)	89	1.18-1,770	140
Sodium	100	7.1-607	77
Sulfate	100	6.88-10,700	1,500
Physical Properties (%)			
Total Solids	100	12.1-94.1	39

1. All concentrations in mg/kg dry weight except where noted

Statistical distribution tests have not yet been performed on the data, but arithmetic means are provided for preliminary discussion purposes. These mean concentrations were calculated using a surrogate value of one-half the detection for non-detect sample results. The individual means also include both duplicate and triplicate sample results for this preliminary discussion, which may skew the data if these QA samples represent outliers. Statistical analyses will be conducted once the data have been fully validated.

Metals

As shown in Table 7-6, 26 metals were detected in plant samples. Sixteen metals were present above detection limits in all samples, with another four metals detected in at least 90 percent of all samples. Only four metals (arsenic, beryllium, bismuth, and selenium) were detected in less than one-half the samples. Selenium was detected with the lowest frequency (22 percent) of all the metals. The essential nutrients calcium, potassium, and magnesium were present at the highest concentrations (mean concentrations over 1,000 mg/kg), with levels of aluminum, iron, and manganese a bit lower (mean concentrations of 300 to 530 mg/kg). All other metals present were at substantially lower concentrations.

Elements vary greatly in concentration across samples and also differ widely in their relative abundance in plants within a given location. Once data have been validated, a comparison of concentrations in soil and plant samples collected from the same area will be conducted. The preliminary data sets discussed here provide the information to suggest that the elemental profile in plants is different than that in soil, indicating that differential chemical uptake is occurring. This will have ramifications for any risk assessment conducted, since background elemental concentrations in soil may not be predictive of tissue concentrations using simple uptake factors.

To assess this issue in more detail, vegetation data were summarized by plant species, as shown in Table 7-7. This table excludes those metals that were not detected in the majority of species (arsenic, beryllium, bismuth, and selenium) and those species with only one or two data points (white spruce, balsam poplar, lingonberry, Labrador tea, crowberry, and sourdock).

It is evident from Table 7-7 that metal concentrations are quite different among species, which indicates the importance of species-specific measurements with regard to background concentrations. This has further ramifications for any risk assessment since possible exposure concentrations will vary widely depending on the plant species being evaluated. Several examples are discussed below to illustrate this point. It should be noted that some of the variability across species may be due to different levels of these elements in soil; this variable will be addressed once the data have been finalized.

Green moss had substantially higher mean concentrations of several metals (aluminum, chromium, iron, lead, nickel, silver, thallium, and vanadium) than other species. This was most dramatic for nickel, where the average concentration of 35 mg/kg is almost six times higher than in any other species. Reindeer lichen also had relatively high concentrations of all these metals except nickel.

Concentrations of some elements in blueberry differed markedly between edible browse and berries. While concentrations of most elements were lower in the berries, the opposite was the case for others, particularly copper. Copper concentrations were higher in blueberries than in any other species and were more than twice as high in the berries than in the rest of the browse material.

Willow had the highest concentrations of cadmium, cobalt, and zinc, while dogwood had the highest concentrations of barium, calcium, magnesium, mercury, and molybdenum. Dogwood had the lowest concentration of manganese among all analyzed species.

This discussion demonstrates the complexity and variability of naturally occurring elemental concentrations in plants. This issue will be further evaluated once data validation is complete.

Anions and Cations

As shown in Table 7-6, all analytes, except cyanide, were detected in at least 80 percent of vegetation samples. Cyanide was detected in only 17 percent of plant samples. Sulfate and chloride were present at the highest concentrations (average concentrations of 1,500 and 1,300 mg/kg, respectively), with nitrogen present at an average concentration an order of magnitude lower.

Analysis of concentrations by plant species is provided in Table 7-7. This table shows that there is wide variability of concentrations across species. Concentrations of chloride were much greater in dogwood, sedge, and fireweed than in other species. Concentrations of fluoride were highest in blueberry leaves, while sodium and sulfate were highest in dogwood.

As discussed above for metals, these differences will be more fully evaluated once data validation has been completed.

TABLE 7-7
Preliminary Results for Naturally Occurring Constituents by Plant Species—Average Concentrations[1], Mine Study Area

Analyte	Willow	Blueberry (leaves)	Blueberry (berries)	Dogwood	Short-Stalk Sedge	Fireweed	Green Moss	Reindeer Lichen
Metals	n = 10	n = 10	n = 11	n = 3	n = 12	n = 10	n = 11	n = 13
Aluminum	76	81	113	607	29	64	3,030	618
Antimony	0.06	0.12	0.12	0.06	0.06	0.04	0.17	0.21
Barium	12	66	12	121	25	33	49	13
Boron	12	14	6.8	15	7.9	13	1.9	0.76
Cadmium	0.42	0.22	0.08	0.06	0.03	0.02	0.14	0.07
Calcium	6,390	6,510	1,200	30,700	5,180	11,500	4,710	1,230
Chromium	0.20	0.22	0.46	0.32	0.43	0.23	3.1	1.5
Cobalt	1.5	0.11	0.04	0.28	0.09	0.12	1.3	0.22
Copper	3.4	4.1	10	1.9	2.7	4.2	3.7	1.6
Iron	60	30	19	51	109	54	3,180	708
Lead	0.07	0.05	0.46	0.18	0.14	0.05	2.4	1.2
Magnesium	1,590	2,070	535	5,240	1,000	3,670	1,170	263
Manganese	590	787	107	69	318	204	252	84
Mercury	0.03	0.03	0.02	0.09	0.03	0.07	0.06	0.05
Molybdenum	0.26	0.10	0.13	1.3	0.79	0.28	0.43	0.10
Nickel	2.5	3.5	6.0	3.9	3.7	2.2	35	6.5
Potassium	6,770	4,750	5,420	9,250	11,200	7,860	3,250	954
Silver	0.014	0.004	0.015	<0.003	0.007	0.004	0.047	0.017
Thallium	0.011	0.003	0.006	0.011	0.003	0.010	0.051	0.021
Tin	2.4	2.9	3.4	2.6	2.9	2.5	2.7	3.0
Vanadium	0.11	0.10	0.07	0.15	0.11	0.12	4.9	1.3
Zinc	85	27	18	14	20	26	28	16

Analyte	Willow	Blueberry (leaves)	Blueberry (berries)	Dogwood	Short-Stalk Sedge	Fireweed	Green Moss	Reindeer Lichen
Anions/Cations								
Chloride	944	282	50	6,520	3,870	2,040	476	120
Fluoride	15	138	95	2.5	1.0	28	2.4	0.82
Nitrogen, ammonia (as N)	21	130	18	175	362	435	17	6.3
Sodium	70	11	22	353	68	41	191	80
Sulfate	1,160	586	2,600	7,880	2,120	2,240	399	789

1. All concentrations in mg/kg dry weight except where noted

7.5.3.3 Sediment

Preliminary data for a portion of the analytical the parameters are shown in Table 7-8. Final data and evaluation of the data will be presented at a later time. Preliminary data suggest that the mine study area and the sampling that occurred in 2004 were consistent with the 2004 study plan (NDM, 2004a).

Table 7-8 presents a review of the 2004 spring and fall sediment sampling events for select analytes.

TABLE 7-8
Preliminary Results for Sediment Samples, Mine Study Area

Analyte	Frequency of Detection[1]	Percent Detected (%)	Range of Detects[2] (Min.-Max.)	Average[2]
Metals				
Mercury (total)	47 / 68	69	12.7-128	37.02
Anions and Cations				
Nitrogen, Ammonia	64 / 68	94	3.9-1,730	233
Chloride	60 / 68	88	0.327-80.8	7.24
Cyanide	64 / 68	98	0.032-1.9	0.338
Fluoride	42 / 68	62	0.287-118	6.64
Sulfate	68 / 68	100	0.648-2,600	101

1. Frequency of detection = Number of samples with detectable concentrations / total number of samples in assessment data set
2. All concentrations in mg/kg dry weight

7.5.3.4 Fish Tissue

Northern pike was the only species analyzed from tundra lakes, while salmon were analyzed from streams. See Chapter 11, Fish and Aquatic Resources, for a discussion of the fish-tissue analyses.

7.5.4 Summary

Samples of soil, vegetation, fish tissue, and sediments were collected between late August and early September 2004. Preliminary data evaluation revealed some interesting patterns and relationships of naturally occurring constituents across different soil types and plant species. Final analytical data for soil, vegetation, and sediment and evaluation of the data will be presented at a later time. Fish-tissue analyses are discussed in Chapter 11.

7.6 Road/Port Area

7.6.1 Scope of Work

The 2004 field study for the road/port area was conducted by Bristol Environmental & Engineering Services Corporation (BEESC) according to the approach described in the *Draft Environmental Baseline Studies, Proposed 2004 Study Plan* (NDM, 2004a). The following work was conducted for the road/port study area in 2004:

- Collection of 22 soil samples from the upper 6 inches of the soil profile, and analysis of samples for metals, anions and cations, biogenic petroleum hydrocarbons, and physical properties.
- Collection of 157 vegetation samples from 22 locations along an 85-mile-long corridor in August. Berries were collected in the same sample locations where leaves and shoots were sampled.
- Collection of 20 berry samples in September at five locations. The locations with the most berries observed during August were chosen for resampling. The berries were collected separately from leaves and shoots (berry and leaves/shoots from two species at each site).
- Collection of stream-sediment samples from 12 locations in July.
- Collection of stream-sediment samples from 16 locations in October.
- Collection of sediment samples from five tundra ponds in July and October.

7.6.2 Methods

In general, methods for sample collection were consistent with those outlined in the 2004 study plan (NDM, 2004a). The procedures were the same as those used for the sample collection at the mine study area, unless documented below. QA/QC protocols followed procedures outlined in the *Draft Environmental Baseline Studies, Proposed 2004 Quality Assurance Project Plan* (NDM, 2004b).

7.6.2.1 Soil

The soil-sampling effort was designed to collect samples that are representative of the predominant soil types encountered and to establish spatial distribution of trace elements along the road corridor and at the port. In 2004, soil samples were collected at regular intervals along the 85-mile-long road corridor—one sample for every 4 miles—and at an upland area near Port Site 1 (Figure 7-2). Sampling was accomplished in August and consisted of the collection of soil samples from 22 locations.

Soil samples were collected as a composite sample from the upper 6 inches below the soil surface. Similar amounts of soil were collected from four random locations within a 3-foot square adjacent to the vegetation sample area. The soil was collected with a gloved hand (gloves were changed between samples) or a trowel and was placed into a stainless steel bowl. The soil was mixed, and rocks were removed by hand, after which the soil was placed into the sample container. The bowl, trowel, and other tools used were washed with an Alconox detergent and water solution and were rinsed with deionized water between samples. General soil type and color were documented. The laboratory analyses for the soil samples are listed in Table 7-1.

7.6.2.2 Vegetation

Three predominant vegetation types have been identified in the study area, from literature: high brush, upland spruce/hardwood forest, and alpine tundra/barren ground. The dominant species in high brush habitats range from dense willows along streams to dense alder above the timber line. Trees such as quaking aspen, Alaskan paper birch, and white spruce may be present but widely scattered. Upland spruce/hardwood forests are dense mixed forests composed of white spruce, Alaska paper birch, quaking aspen, black cottonwood, and balsam poplar.

Vegetation sampling is intended to define the species present and the baseline concentrations of trace elements, particularly in and on vegetation that may be a food source for upland mammals, birds, or humans. In addition, vegetation used traditionally for medicinal purposes was sampled. The study included samples of trees, shrubs, grasses, forbs, mosses, and lichens. In 2004, vegetation samples were collected at regular intervals along the road corridor and at the port site (Figure 7-2).

A list of typical vegetation-species types expected to be found along the road corridor was developed from observations in the field and from literature and is shown in Table 7-9 (following Section 7.7). Each vegetation-sample area encompassed a 10-foot radius of vegetation typical for the area. Within each sample area, all vegetation species that were observed were documented. Four to eight species were sampled at each location, depending on the type and density present. Species included moss, lichen, grass, shrubs, and berry-producing plants. Plants used specifically for subsistence purposes—food or traditional medicine—or as game forage were collected. Approximately 50 grams (weighed on a portable scale) of leaves, berries, shoots, and other edible/browsable portions of the plant were collected and placed into a resealable plastic bag. Gloves were worn and were changed between samples. If scissors or shears were used, they were washed with an Alconox detergent and water solution and rinsed with deionized water between samples.

The initial procedure was to collect all edible/browsable portions (leaves, shoots, and berries) as a single sample. However, due to large quantities of berries at the mine study area, berries were segregated from leaves and shoots at five of the sample sites along the road corridor in order to maintain consistency in sampling procedures between the mine study area and the road study area.

7.6.2.3 Sediments

Stream sediments were collected at the same locations as surface-water samples, which coincide with monitoring stations used for the hydrology study and with fish-sampling areas. Stream-sediment samples were collected at the same time as surface-water samples. Few stations were sampled in July because only a portion of the water-quality-sampling/hydrology-monitoring stations had been established at that time.

Stream-sediment samples were composited from three locations across the channel at each sample location. Sediment from the middle of the channel and from the stream bottom adjacent to each bank was placed into a stainless steel bowl, mixed, and then placed into the sample container, following the same procedures used for sample collection at the mine study area.

Five tundra ponds along the road corridor were sampled to provide baseline characteristics of pond sediments. A predominant wind direction and resulting sediment deposition were observed at the tundra ponds sampled along the road. Samples were collected from the leeward side of the ponds in the upper five inches of sediment, within approximately 10 feet of the edge of the pond. Sediment from three locations was collected, placed into a stainless steel bowl, mixed, and then placed into the sample container.

7.6.3 Results and Discussion

Validated analytical data from the July 2004 sampling event for sediment are presented in Table 7-10 (following Table 7-9). Remaining data for sediments and data for soil and vegetation, as well as evaluation of the data, will be presented at a later date.

7.6.4 Summary

Soil, vegetation, and sediment samples were collected along the 85-mile-long road corridor and at the port site during July through September 2004. Table 7-9 summarizes the vegetation species identified and sampled at each site. Partial sediment-analysis results are presented in Table 7-10. Final analytical results and evaluation of the data will be presented at a future date.

7.7 References

Northern Dynasty Mines Inc. (NDM). 2004a. Draft Environmental Baseline Studies, Proposed 2004 Study Plan.

———. 2004b. Draft Environmental Baseline Studies, Proposed 2004 Quality Assurance Project Plan.

Selkregg, Lidia. 1976. Alaska Regional Profiles, Volume I, Southcentral Region. University of Alaska, Arctic Environmental and Information Data Center.

TABLES 7-9 and 7-10

TABLE 7-9.
Vegetation Species Identified and Sampled—Road/Port Study Area

Sample Acronym	Species Scientific Name	Species Common Name	TE 01	TE 02	TE 03	TE 04	TE 05	TE 06	TE 07	TE 08	TE 09	TE 10	TE 11	TE 12	TE 13	TE 14	TE 15	TE 16	TE 17	TE 18	TE 19	TE 20	TE 21	TE 22
TREES																								
Bp	*Betula papyrifera*	Kenai birch						S					S	S										
Bg	*Betula glandulosa*	shrub birch			S	S				S														
Pm	*Picea mariana*	black spruce	S	S	S	S			S	S		I	I	I		S	S	S						
Pg	*Picea glauca*	white spruce					S	I				S			S				S					I
SHRUBS																								
Ac	*Alnus crispa*	mountain alder									S				I		I			S	S	S	S	S
Ap	*Andromeda polifolia*	bog rosemary		I			I		I			I												
Ar	*Arctostaphylos rubra*	red-fruit bearberry		I		I	I																	I
Bn	*Betula nana*	dwarf birch	S	I	I	S	I		I	S		I	I	S	S	I	S	S	I			I	I	I
Cc	*Cornus canadensis*	dogwood													I								S[1]	
En	*Empetrum nigrum*	crowberry	S[1]	S	S	S	S	I	I	S[1]		S	S	S[1]	S	S	S		S[1]	S		S	S[1]	S[1]
Lp	*Ledum palustre*	narrow leaf labrador tea	I	S	S	S	S	I	S	S		S	S	I		S	I			S		S		
Mf	*Menziesia ferruginea*	rusty menzisii (sitka burnett)						I						I				I						
Mg	*Myrica gale*	sweet gale							S															
Pf	*Potentilla fruticosa*	shrubby cinquefoil (tundra rose)							I					I										
Rg	*Ribes glandulosum*	skunk currant																			I			
Rs	*Rubus spectabilis*	salmonberry																			S	S		
Sa	*Salix alaxensis*	feltleaf willow									S													
Sb	*Salix brachycarpa*	barren-ground willow	S		S	I								I		I	I	I				I		
Sp	*Salix planifolia*	diamond-leaf willow					I					I							S					
Sr	*Sambucus racemosa*	elderberry																			S			
Ssp	*Salix sp.*	willow								I										I				I
Ssti	*Sanguisorba stipulata*	false huckleberry						I																
Vu	*Vaccinium uliginosum*	bog blueberry	S[1]	S	S		S[1]	I	S	S		I	S	S	S	S	S		S[1]	I		S		
Vv	*Vaccinium vitis-idaea*	lingonberry (low bush cranberry)	I	I	I	I	S[1]	S	I	S[1]		S	S	S[1]	I		I		I	I			S[1]	S[1]
GRASSES																								
Ca	*Carex aquatilis*	northern water sedge														S				I		S		
Cm	*Carex microchaeta*	short stalk sedge												I										
Cs	*Calamagrostis sp.*	blue joint grass						S			S		I		S	I	I	S		S		I		
Ear	*Elymus arenarius*	beach rye																			S			
Ss	*Carex sp.*	sedge	I	I			S	I	I			I					I		I					I
FORBS																								
Ab	*Achillea borealis*	northern yarrow																I						
Ag	*Angelica genuflexa*	wild celery (putchkie)																			S			
At	*Artemisia tilesii*	worm wood									S													

Sample Acronym	Species Scientific Name	Species Common Name	TE 01	TE 02	TE 03	TE 04	TE 05	TE 06	TE 07	TE 08	TE 09	TE 10	TE 11	TE 12	TE 13	TE 14	TE 15	TE 16	TE 17	TE 18	TE 19	TE 20	TE 21	TE 22
Ea	*Epilobium angustifolium*	fireweed						S		I	S			S	S			S	S					
Ep	*Equisetum pratense*	horse tail					I	S	S	S		S		I		I	S	I				S		
Ln	*Lupinus nootkatensis*	lupine		S																				
Lpe	*Leutkea pectinata*	alpine spirea				I			I			I								I				
Ls	*Ligusticum scoticum*	beach loveage																			I			
Oh	*Ochinopanax horridum*	devil's club																			S			
Pp	*Potentilla palustris*	marsh five finger						I								I								
Rc	*Rubus chamaemorus*	cloudberry					I	S	I	I						S								
Rp	*Rubus pedatus*	trailing raspberry													I			I						
Sd	*Solidago decumbens*	golden rod																I						
Sro	*Sedum rosea*	rose root																		I				
Sst	*Spiraea stevenii*	alaska spirea						I		I			I		I	I	I	I	I	I				
Te	*Trientalis europea*	star flower																I						
FERNS AND FERN ALLIES																								
Af	*Athyrium filix-femina*	lady fern																		S				
Dd	*Dryopteris dilatata*	spreading wood fern													S			S						
MOSSES																								
La	*Lycopodium annotinum*	club moss																I						
Pcc	*Ptelium crista casttensis*	green terrestrial moss	I	S	S			I	S	S	S		I	S	S	S	S	S	S	S		S	S	I
LICHENS																								
Ccu	*Cetraria cucullata*	white shagnum																						S
Cr	*Cladina rangiferina*	reindeer lichen or "caribou moss"	S	S		S	S		I	I		S	S						S				S	

I = Species identified in sample area, however not collected for laboratory analysis.

S = Species identified and collected for laboratory analysis.

1. Leaves, twigs, and shoots submitted separately from the berries for laboratory analysis.

TABLE 7-10
Stream Sediments and Tundra Pond Sediments--July 2004
Road/Port

		SAMPLE ID:	072204NHRIVSD001	072204NHRIVSD201	072204NHRIVSD301	072204GS20SD001	072204GS20SD201	072204GS20SD301
		LOCATION:	NHRIV	NHRIV	NHRIV	GS20	GS20	GS20
Parameter	**Method**	**Units**		Duplicate	Triplicate		Duplicate	Triplicate
Metals								
Aluminum	SW6020	mg/kg	6050	5780	6570	7200	7270	7720
Antimony	SW6020	mg/kg	0.126	0.137	0.28	0.0814 J	ND (0.15)	0.2
Arsenic	SW6020	mg/kg	3.87	3.56	3.2	13.7	13.5	10.7
Barium	SW6020	mg/kg	33.5	32	32.9	48.6	54	52.3
Beryllium	SW6020	mg/kg	0.184	0.181	0.146	0.147	0.149	0.122
Bismuth	SW6020	mg/kg	ND (0.0595)	ND (0.0608)	ND (0.1)	ND (0.0603)	ND(0.0599)	ND (0.1)
Boron	SW6010B	mg/kg	ND (2.97)	ND (3.04)	2.7 J	ND (3.02)	ND (2.99)	2.4 J
Cadmium	SW6020	mg/kg	0.0957 J	0.0803 J	0.07	ND (0.0603)	ND(0.0599)	0.04 J
Calcium	SW6020	mg/kg	2160	2160	2450	2770	2870	3120
Chromium	SW6020	mg/kg	9.56	8.11	6.24	6.73	7.59	5.25
Cobalt	SW6020	mg/kg	3.28	3.17	2.79	3.71	4.17	3.2
Copper	SW6020	mg/kg	9.29	9.56	9.04	4.47	4	3.69
Iron	SW6020	mg/kg	12500	12400	13300	15500	14900	15300
Lead	SW6020	mg/kg	7.9	9.16	8.93	2.48	2.72	2.36
Magnesium	SW6020	mg/kg	3180	3100	3260	3510	3270	3400
Manganese	SW6020	mg/kg	217	199	228	402	396	405
Mercury	SW7471A	µg/kg	ND (11.8)	ND(11.9)	ND (10)	ND (12)	ND (11.8)	ND (10)
Molybdenum	SW6020	mg/kg	0.363 J	0.376 J	0.35	0.519 J	0.374 J	0.42
Nickel	SW6020	mg/kg	5.52	5.22	4.98	4.43	3.68	3.4
Potassium	SW6020	mg/kg	480	414	536	344	358	357 J
Selenium	SW6020	mg/kg	ND (0.144)	0.178 J,BQ	0.2 J	ND (0.146)	ND (0.145)	0.2 J
Silver	SW6020	mg/kg	0.0313 J	0.0336 J	0.039	0.0362 J	ND (0.0299)	0.026
Sodium	SW6020	mg/kg	140 J+	133 J+	180	189 J+	208	202
Thallium	SW6020	mg/kg	0.0094 J,BQ	ND (0.0061)	0.026	ND (0.006)	ND (0.006)	0.026
Tin	SW6020	mg/kg	0.792 J,BQ	0.825 J,BQ	0.6	0.746 J,BQ	0.625 J,BQ	0.5
Vanadium	SW6020	mg/kg	28.2	27.2	15.3	33.2	33.2	21.9
Zinc	SW6020	mg/kg	40.2	40.1	35	38.8	38.7	31.3
Other Parameters								
Chloride	E300.0	mg/kg	1.97	0.94 J	***ND (0.8)R***	0.805 J	0.969 J	***ND (0.8) R***
Cyanide	A4500CN	mg/kg	0.047 J	0.035 J	ND (0.03)	0.31	0.055	ND (0.03)
Fluoride	E300.0	mg/kg	ND (0.31)	ND (0.3)	ND (0.8)	0.307 J	0.366 J	***ND (0.8) R***
Nitrogen, Ammonia (as N)	A4500NH	mg/kg	21.4	21.3	2.2	33.5	31.8	1.7
Sulfates	E300.0	mg/kg	68.4	62.8	7.3	74.8	78.6	ND (2.4)

BQ = The result is associated with inorganic method-blank contamination. Results should be considered not detected at the concentration of the MRL or as biased high for those reported above the MRL.

J = The result is an estimated quantity.

J+ = the result is an estimated quantity, but the result may be biased high.

mg/kg = milligrams per kilogram.

µg/kg = micrograms per kilogram.

ND (xx) = not detected at listed detection limit.

R = The data are unusable.

TABLE 7-10
Stream Sediments and Tundra Pond Sediments--July 2004
Road/Port

		SAMPLE ID:	072004GS20ASD001	072004GS18ASD001	072004GS17ASD001	072004GS14ASD001	072304GS14BSD001	080104GS12ASD001
		LOCATION:	GS20A	GS18	GS17A	GS14A	GS14B	GS12A
Parameter	**Method**	**Units**						
Metals								
Aluminum	SW6020	mg/kg	8270	9400	12200	7120	10600	7190
Antimony	SW6020	mg/kg	0.0998	0.101	0.274	0.121	0.109	0.155 J
Arsenic	SW6020	mg/kg	13.4	17	14.7	12.90	5.89	3.17
Barium	SW6020	mg/kg	32.6	57.2	33.9	39	35.5	20.3
Beryllium	SW6020	mg/kg	0.132	0.3	0.274	0.223	0.249	0.162
Bismuth	SW6020	mg/kg	ND (0.061)	0.155 J	0.113 J	0.0617 J	ND (0.0599)	0.0649 J
Boron	SW6010B	mg/kg	ND (3.05)	ND (2.99)	ND (3.05)	ND (2.97)	ND (2.99)	8.23
Cadmium	SW6020	mg/kg	0.11 J	0.263	0.16 J	0.0769 J	0.0838 J	0.0992 J
Calcium	SW6020	mg/kg	3370	3240	3320	2680	5480	3040
Chromium	SW6020	mg/kg	4.86	8.38	15.20	8.47	7.34	5.03
Cobalt	SW6020	mg/kg	2.99	4.15	7.35	3.6	3.47	4
Copper	SW6020	mg/kg	5.75	9.46	14.50	6.65	6.62	7.51
Iron	SW6020	mg/kg	9110	17800	24200	14300	15700	12600
Lead	SW6020	mg/kg	2.22	10.6	9.09	3.69	4.09	3.56
Magnesium	SW6020	mg/kg	2360	3840	7330	3420	3730	3710
Manganese	SW6020	mg/kg	164	258	526	419	443	298
Mercury	SW7471A	µg/kg	15.5 J	ND (11.9)	ND (11.9)	ND (12)	ND (11.9)	ND (11.8)
Molybdenum	SW6020	mg/kg	3.22	1.74	0.899 J	0.831 J	0.717 J	0.512 J
Nickel	SW6020	mg/kg	2.81	4.86	9.39	4.85	3.89	3.01
Potassium	SW6020	mg/kg	194	381	528	331	490	418
Selenium	SW6020	mg/kg	0.556 BQ	0.391 J,BQ	0.448 J,BQ	0.34 J,BQ	0.33 J,BQ	0.326 J,BQ
Silver	SW6020	mg/kg	ND (0.0305)	0.0679 J	0.0681 J	0.0464 J	0.0799 J	0.0479 J
Sodium	SW6020	mg/kg	398 J+	178 J+	196 J+	124	232 J+	133 J+
Thallium	SW6020	mg/kg	0.0347 BQ	0.0549 BQ	0.041 BQ	0.0143 J,BQ	ND (0.006)	0.0161 J
Tin	SW6020	mg/kg	0.651 J,BQ	0.653 J,BQ	0.696 J,BQ	0.732 J,BQ	0.849 J,BQ	0.698 J,BQ
Vanadium	SW6020	mg/kg	24.1	31.3	55.1	31	33.5	30.2
Zinc	SW6020	mg/kg	28.1	65.1	67.3	41	46.3	43.3
Other Parameters								
Chloride	E300.0	mg/kg	3.46	2.6	1.2	1.33	2.03	0.443 J
Cyanide	A4500CN	mg/kg	0.11	0.2	0.067	0.049 J	0.12	ND (0.03)
Fluoride	E300.0	mg/kg	0.719 J	0.827 J	0.42 J	0.429 J	0.504 J	ND (0.269)
Nitrogen, Ammonia (as N)	A4500NH	mg/kg	184	111	23.8	35	76.3	13.8
Sulfates	E300.0	mg/kg	153	245	20.4	36.1	63.1	4.36

BQ = The result is associated with inorganic method-blank contamination. Results should be considered not detected at the concentration of the MRL or as biased high for those reported above the MRL.

J = The result is an estimated quantity.

J+ = the result is an estimated quantity, but the result may be biased high.

mg/kg = milligrams per kilogram.

µg/kg = micrograms per kilogram.

ND (xx) = not detected at listed detection limit.

R = The data are unusable.

TABLE 7-10
Stream Sediments and Tundra Pond Sediments--July 2004
Road/Port

		SAMPLE ID:	072304GS11ASD001	072104GS8ASD001	072104GS6ASD001	073104GS4ASD001	080204POND1SD001	080204POND2SD001
		LOCATION:	GS11A	GS8A	GS6A	GS4A	POND1	POND2
Parameter	Method	Units					Tundra Pond	Tundra Pond
Metals								
Aluminum	SW6020	mg/kg	9340	3020	7360	4800	7310	7660
Antimony	SW6020	mg/kg	0.0878 J	ND (0.0297)	0.0622 J	0.0917 J	0.162	0.0764 J
Arsenic	SW6020	mg/kg	1.78	ND (0.546)	7.06	0.787 J	13.60	4.28
Barium	SW6020	mg/kg	34.3	19.3	27.6	59.7	31.3	25.2
Beryllium	SW6020	mg/kg	0.181	0.113	0.134	0.0592 J	0.193	0.209
Bismuth	SW6020	mg/kg	ND (0.0611)	ND (0.0594)	ND (0.0606)	0.0756 J	ND (0.0593)	ND (0.0604)
Boron	SW6010B	mg/kg	ND (3.06)	ND (2.97)	ND (3.03)	ND (2.99)	ND (2.96)	ND (3.02)
Cadmium	SW6020	mg/kg	ND (0.0611)	ND (0.0594)	0.276	0.0621 J	ND (0.0593)	ND (0.0604)
Calcium	SW6020	mg/kg	5630	1590	2250	2420	1810	1610
Chromium	SW6020	mg/kg	3.15	2.75	3.38	9.7	10.9	6.53
Cobalt	SW6020	mg/kg	3.48	1.48	7.63	4.21	2.84	3.2
Copper	SW6020	mg/kg	8.64	4.29	4.21	40.7	4.4	6.8
Iron	SW6020	mg/kg	15700	12800	11300	18700	12500	11300
Lead	SW6020	mg/kg	2.65	3.11	5.89	2.74	4.26	5.13
Magnesium	SW6020	mg/kg	3530	1010	1370	2750	2920	3130
Manganese	SW6020	mg/kg	368	263	695	219	141	232
Mercury	SW7471A	µg/kg	ND (11.9)	ND (12)	ND (11.9)	ND (12)	ND (11.8)	ND (11.9)
Molybdenum	SW6020	mg/kg	ND (0.306)	0.353 J	1.17	0.822 J	ND (0.296)	0.404 J
Nickel	SW6020	mg/kg	1.82	1.41	1.64	3.4	3.59	3.43
Potassium	SW6020	mg/kg	595	232	189	956	500	348
Selenium	SW6020	mg/kg	ND (0.148)	0.15 J,BQ	0.324 J,BQ	0.368 J,BQ	0.206 J,BQ	0.439 J,BQ
Silver	SW6020	mg/kg	0.0581 J	ND (0.0297)	0.104	ND (0.0299)	ND (0.0296)	ND (0.0302)
Sodium	SW6020	mg/kg	196 J+	81.9 J	281 J+	226	129	151
Thallium	SW6020	mg/kg	ND (0.0061)	ND (0.0059)	0.0271 BQ	0.0127 J	ND (0.0059)	ND (0.006)
Tin	SW6020	mg/kg	0.66 J,BQ	0.575 J,BQ	0.525 J,BQ	0.518 J,BQ	0.615 J,BQ	0.598 J,BQ
Vanadium	SW6020	mg/kg	39.8	31.1	33	51.5	20.3	21.9
Zinc	SW6020	mg/kg	34.1	26.6	66.6	28	33.8	32.9
Other Parameters								
Chloride	E300.0	mg/kg	0.749 J	0.544 J	2.47	0.634 J	0.544 J	1.64
Cyanide	A4500CN	mg/kg	ND (0.028)	ND (0.027)	0.16	ND (0.028)	0.035 J	ND (0.028)
Fluoride	E300.0	mg/kg	0.394 J	0.363 J	0.662 J	ND (0.293)	ND (0.268)	ND (0.282)
Nitrogen, Ammonia (as N)	A4500NH	mg/kg	ND (3.11)	8.11 J	87.8	13.5	57.7	69.4
Sulfates	E300.0	mg/kg	6.47	2.41	64.1	6.9	15.7	16.2

BQ = The result is associated with inorganic method-blank contamination. Results should be considered not detected at the concentration of the MRL or as biased high for those reported above the MRL.

J = The result is an estimated quantity.

J+ = the result is an estimated quantity, but the result may be biased high.

mg/kg = milligrams per kilogram.

µg/kg = micrograms per kilogram.

ND (xx) = not detected at listed detection limit.

R = The data are unusable.

TABLE 7-10
Stream Sediments and Tundra Pond Sediments--July 2004
Road/Port

		SAMPLE ID:	080204POND3SD001	080204POND4SD001	080304POND5SD001
		LOCATION:	POND3	POND4	POND5
Parameter	**Method**	**Units**	Tundra Pond	Tundra Pond	Tundra Pond
Metals					
Aluminum	SW6020	mg/kg	8750	8380	3230
Antimony	SW6020	mg/kg	0.0528 J	0.052 J	ND (0.0297)
Arsenic	SW6020	mg/kg	4.1	0.973 J	0.917 J
Barium	SW6020	mg/kg	53.3	32.8	11.2
Beryllium	SW6020	mg/kg	0.188	0.178	0.0395 J
Bismuth	SW6020	mg/kg	ND (0.0599)	ND (0.0608)	ND (0.0593)
Boron	SW6010B	mg/kg	ND (2.99)	ND (3.04)	ND (2.97)
Cadmium	SW6020	mg/kg	0.21	0.188 J	ND (0.0593)
Calcium	SW6020	mg/kg	3770	3380	1070
Chromium	SW6020	mg/kg	6.7	5.71	1.66
Cobalt	SW6020	mg/kg	3.45	1.93	1.45
Copper	SW6020	mg/kg	5	5.76	1.99
Iron	SW6020	mg/kg	8470	6350	5440
Lead	SW6020	mg/kg	4.47	1.96	1.29
Magnesium	SW6020	mg/kg	2960.00	1250	988
Manganese	SW6020	mg/kg	151.00	79.3	146
Mercury	SW7471A	µg/kg	ND (11.9)	18 J	ND (12)
Molybdenum	SW6020	mg/kg	0.467 J	0.63 J	ND (0.297)
Nickel	SW6020	mg/kg	3.76	2.04	0.389
Potassium	SW6020	mg/kg	277	169	125
Selenium	SW6020	mg/kg	0.505 BQ	0.949 BQ	0.153 J,BQ
Silver	SW6020	mg/kg	ND (0.0299)	ND (0.0304)	ND (0.0297)
Sodium	SW6020	mg/kg	307	360	194
Thallium	SW6020	mg/kg	ND (0.006)	ND (0.0061)	ND (0.0059)
Tin	SW6020	mg/kg	0.516 J,BQ	0.504 J,BQ	0.492 J,BQ
Vanadium	SW6020	mg/kg	19.8	19.7	14.7
Zinc	SW6020	mg/kg	37.1	28.8	21.8
Other Parameters					
Chloride	E300.0	mg/kg	1.67	12.8	0.576 J
Cyanide	A4500CN	mg/kg	0.23 J	ND (0.29)	ND (0.027)
Fluoride	E300.0	mg/kg	3.63	2.84	ND (0.303)
Nitrogen, Ammonia (as N)	A4500NH	mg/kg	216	672	12
Sulfates	E300.0	mg/kg	256	201	6.82

BQ = The result is associated with inorganic method-blank contamination. Results should be considered not detected at the concentration of the MRL or as biased high for those reported above the MRL.

J = The result is an estimated quantity.

J+ = the result is an estimated quantity, but the result may be biased high.

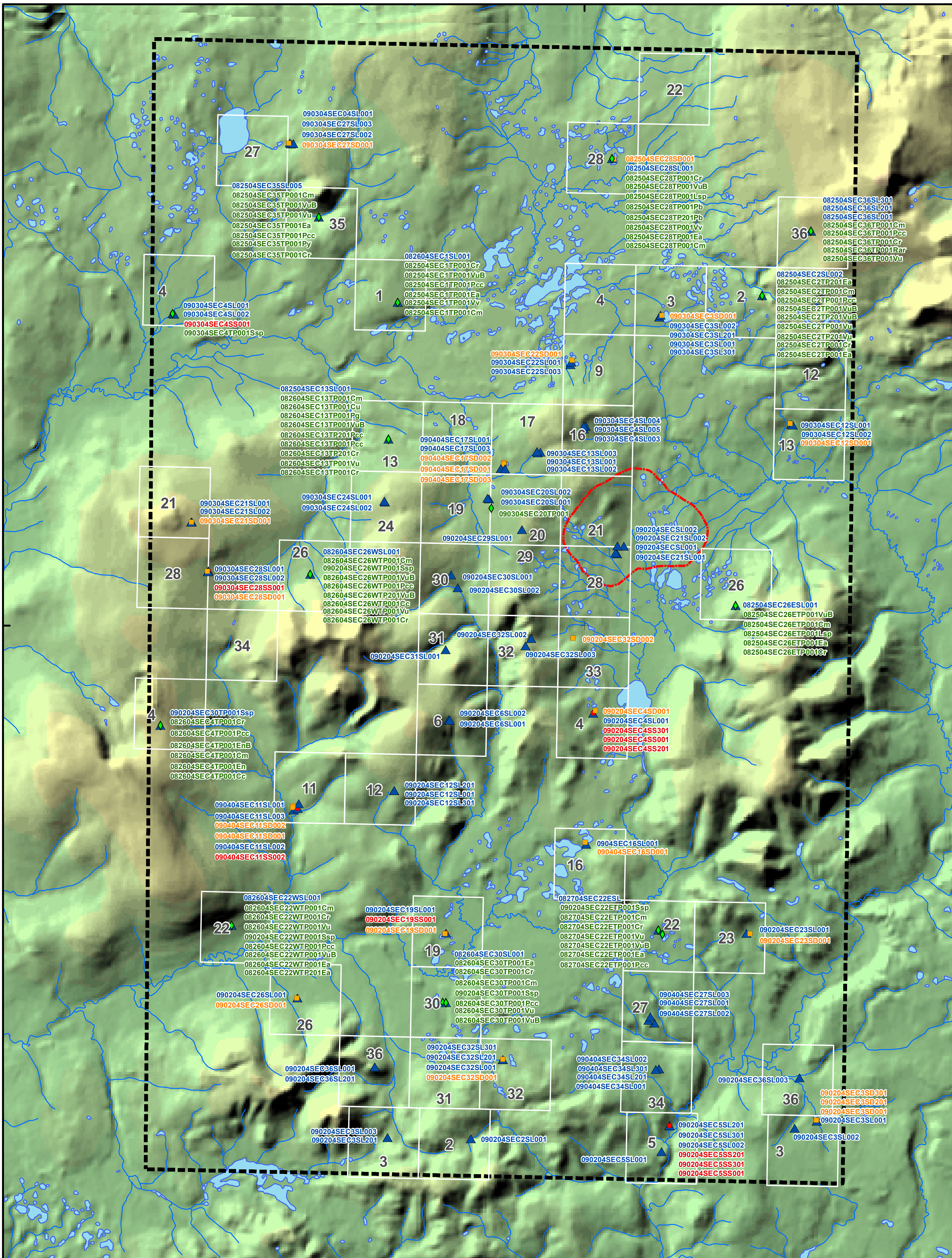
mg/kg = milligrams per kilogram.

µg/kg = micrograms per kilogram.

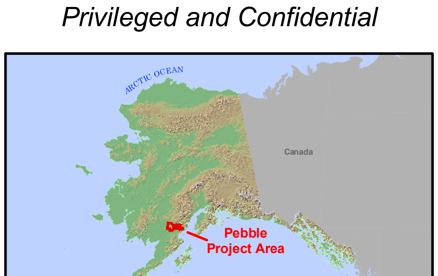
ND (xx) = not detected at listed detection limit.

R = The data are unusable.

FIGURES



Privileged and Confidential



N

Miles: 0 0.5 1 1.5 2

Kilometers: 0 0.5 1 1.5 2

Scale 1:86,000

Alaska State Plane Zone 5 (units feet)

1983 North American Datum

Legend

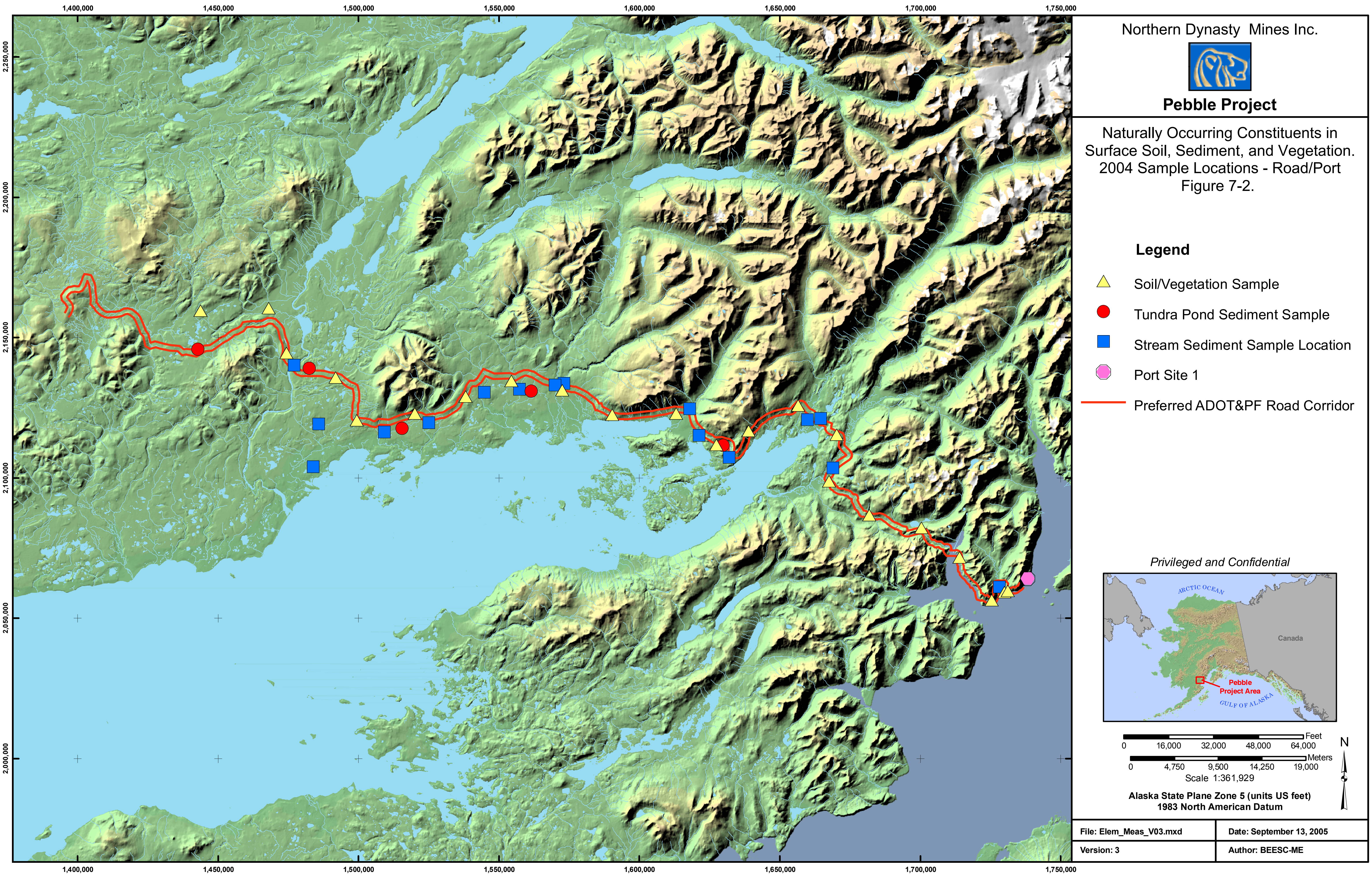
- ▲ Soil
- ■ Sediment
- ◆ Vegetation
- ● Subsurface Soil
- Proposed Mine Site
- Mine Area Study Boundary

Pebble Project

NORTHERN DYNASTY MINES INC.

Pebble Project
Natural Occuring Constituents
2004 Progress Report
Soil, Sediment, and Vegetation Sample Locations
Figure 7-1

RDI_SLR_2004_trace7_1_11x17P_v3.mxd	**Date: Sept. 22, 2005**
Version: 1	**Author: RDI**



Northern Dynasty Mines Inc.
Pebble Project
Naturally Occurring Constituents in Surface Soil, Sediment, and Vegetation.
2004 Sample Locations - Road/Port
Figure 7-2.
Legend
Soil/Vegetation Sample
Tundra Pond Sediment Sample
Stream Sediment Sample Location
Port Site 1
Preferred ADOT&PF Road Corridor
Privileged and Confidential
ARCTIC OCEAN
Canada
Pebble Project Area
GULF OF ALASKA
Feet
0 16,000 32,000 48,000 64,000
Meters
0 4,750 9,500 14,250 19,000
Scale 1:361,929
N
Alaska State Plane Zone 5 (units US feet)
1983 North American Datum
File: Elem_Meas_V03.mxd
Date: September 13, 2005
Version: 3
Author: BEESC-ME
1,400,000
1,450,000
1,500,000
1,550,000
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